Managing Fresh Air Effectively with Dedicated Outside Air Systems

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The Green Building movement is driving the heating, ventilation and air conditioning (HVAC) community to look at innovative solutions for reducing energy costs and better Indoor Environment Quality. The ventilation and air conditioning system which is a key component in Green Building design is on the verge of a paradigm shift.

This shift is providing designers opportunities to explore energy efficient designs. The new initiatives are aimed at improving health, comfort and productivity.

Integration of Dedicated Outdoor Air System or DOAS/Treated Fresh Air Units (TFAs), with a parallel terminal system offers a migratory path from the single all-air variable air volume systems.

As an example, Active Chilled Beams combined with a system design suitable for tropical climate, the DOAS system becomes an excellent choice to address Indoor Air Quality (IAQ), Humidity Control and help buildings become green.

Green buildings could be defined as the practice of 1) increasing the efficiency with which buildings and their sites use energy, water, and materials, and 2) reducing the building’s impact on human health by providing better indoor environment quality (IEQ).

With a progressive economy, new building technologies began to transform the urban landscape. The advent of air conditioning, low-wattage fluorescent lighting, structural steel, and reflective glass made possible enclosed glass-and-steel structures that could be heated and cooled with massive HVAC systems, thanks to the availability of cheap fossil fuels. The economic boom accelerated the pace of this phenomenon, to the point where the International Style “glass box” became the design icon of cities and rapidly growing suburbs. However, a small group of forward-thinking architects, environmentalists, and ecologists, began to question the advisability of building in this manner.

Global warming and the growing awareness of its consequences led to the nascent “environmental movement” capturing the attention of the public at large. As fossil fuel prices...
spiked upward, everyone started to wonder about the wisdom of relying so heavily on fossil fuels for transportation and buildings.

Besides the media buzz about eco-friendly buildings, builders are becoming more educated on the long-term cost reductions created by more efficient energy usage and the reduction or even outright elimination of toxins in building materials. Up until recently, however, building green usually meant building at a higher cost. But even those premiums are beginning to drop. The US Green Building Council (USGBC) came up with the concept of the Leadership in Energy and Environmental Design (LEED) rating system to establish a method to identify and quantify the green content of the building.

**The Basics of LEED**

The LEED Building Rating Programme is, in the words of the USGBC “a national consensus-based, market-driven building rating system designed to accelerate the development and implementation of green building practices. In short, it is a leading-edge system for designing, constructing, and certifying the world’s greenest and best buildings.” LEED works so well because it is simple to understand. LEED is divided into five categories related to siting, water conservation, energy, materials, and indoor environmental quality, plus an innovation and design category. Each category contains a specific number of credits; each credit carries one or more possible points. A project that earns enough points (26) can become “LEED Certified,” or up the ladder to Silver (33), Gold (39), and Platinum (52 or more points). Some categories have prerequisites that must be met, or points cannot be earned in that category.

About 15% of new building owners of green buildings can state that their properties are, at least in theory, environmentally superior to at least 85% of the contemporary buildings in the market. Of course, Silver, Gold, or Platinum status conveys even more prestige. The LEED brand has already become a marketing distinction for a number of certified projects, especially those with Silver or Gold ratings. Like the catalytic agent that speeds up a chemical reaction without itself being consumed, LEED has precipitated enormous activity in the real estate community without losing any of its potency. LEED has certainly lived up to its goal to “accelerate the development and implementation of green building practices.

**Human and Economic Benefits Of Green Buildings**

Are green buildings healthier for occupants than conventional buildings? If so, does this benefit translate into improved worker productivity, greater creativity in problem solving, more efficient task-handling, perhaps even lower health insurance costs for employers? Are green schools produce better student performance? Do patients in green hospitals recover more quickly? Do green retail stores ring up higher sales than their traditional counterparts? These and related questions were first asked in the 1980s and 1990s when “sick building syndrome” (SBS) in offices and workplaces was brought to the public’s attention. Volatile organic compounds (VOCs) from carpeting and furniture, inadequate air circulation, poor lighting, disgusting mould build-up and disruptive temperature variances—all were contributing to nausea, respiratory problems, skin rashes, lethargy, headaches, and numerous other health concerns. Public outcry over sick building syndrome led to improvement in building design and maintenance, although SBS, as it came to be known, has hardly been conquered (which is why the Green Building Council has launched its LEED pilot programme for existing buildings). For the purposes of this article, however, the discussion necessarily must focus on not worst-case “sick” buildings but on conventional buildings in comparison to high performance buildings. According to the output of a study, productivity in the new building increased by 16%, with the personal controls alone accounting for a 3% gain. In health care, dramatic improvements in patient outcomes have been reported for hospitals participating in sustainable design projects.
Consider The Following Case Study:

In a survey of 100 office buildings, 23% of office workers experienced frequent symptoms of SBS such as respiratory ailments, allergies and asthma.

The impact was usually hidden in sick days, medical costs and lower productivity, but the economic impact is enormous, with an estimated decrease in productivity around 2% nationwide, resulting in an annual cost of approximately USD60 billion.

Source: Emerging Energy-Efficient Technology in Promoting Workplace Productivity and Health, a report by Lawrence Berkeley National Laboratory

Outdoor Air Requirements For Ventilation Of Air Conditioned Spaces

The LEED standard states to “Increase breathing zone outdoor air ventilation rates to all occupied spaces by at least 30% above the minimum rates required by ASHRAE Standard 62.1-2007 as determined by EQ Prerequisite 1.” This increased amount of ventilation has definitely solved IAQ related problems, but the inability to maintain the right humidity using our HVAC systems has led to other problems. Mould and mildew, which are caused by lack of humidity control are a serious dilemma in themselves. The question is: have we traded one problem for another?

IAQ & Relative Humidity (RH) Control

The benefits of increased ventilation have been clearly established and absorbed by the HVAC industry at large. The health of occupants is of great concern and more and more systems are being designed with the right amount of outside air.

The outside air however, while solving this problem, poses a great challenge for the HVAC system. The saviour of IAQ brings along with it a quandary of high latent load, cornering the HVAC equipment and resulting in high levels of RH inside. Let us examine the load profile of outside air in a tropical country like ours.

Figure 1: Outside air load - Mumbai

Figure 1 shows the outside air for the city of Mumbai, which is similar to Kuala Lumpur. The curve defines the load of outside air in terms of the sensible and latent load in tonnes for the entire year. Clearly one can see that latent load of the city is quite high and is around 78% of the cumulative fresh air load.

Similarly, if one studies the profile of the cumulative loads (i.e. cooling and dehumidification only) for major cities in Asia, one can see that the latent load component of fresh air is quite high (ranges between 60% and 85%).

With outside air bringing in high amounts of latent energy, RH management becomes difficult. The HVAC fraternity received a wakeup call for IAQ and RH control when the bacteria spread by a hotel air conditioning system killed 34 people and afflicted more than 200 people at an American Regional Convention in Philadelphia around 20 years ago.

Lack of RH control leads to growth of mould and mildew which leads to various health related issues. Mould releases tiny spores to reproduce. These spores then waft through the indoor air and start developing in damp areas. They can cause several problems like rashes, asthma, runny noses and respiratory problems including serious diseases like hypersensitivity pneumonitis.
Figure 2: Latent Load Characteristics

Comparing the sources of the latent load, it is clear that the largest contribution to the latent component is outside air.

Latent Loads

If RH control is so critical and important, we should examine the latent load profiles in a building. Comparing the sources of the latent load, it is clear that the largest contribution to the latent component is outside air. The chart (Figure 2) clearly shows that the almost 50% - 70% of internal latent load comes from ventilation.

RH Control Challenge

Why is it so difficult to manage RH? The answer lies in the fact that the sensible and latent loads don’t peak at the same time.

Hence in moderate weather the sensible loads are reduced but the latent load remains high.

Experiencing moderate weather over a considerable part of the year in many ASEAN cities, this problem needs some immediate attention. Consider the grains levels in outside temperatures of 75°F (i.e. moderate weather), one can see a considerable number of hours where the grains level is more than 65 gss/lb (moisture level generally maintained inside).
On studying the hourly data of outside air, one can see that RH control definitely is a problem in moderate weather which is present almost 2500 hrs a year for city like Atlanta in the US.

The various DOAS technologies evaluated in this article are shown in Table 1.

**OPTION I: Baseline system with dehumidification coil only (CC)**

This option gives high efficiency heat recovery and reduces the total installed tonnage of the HVAC system. Since the recovery reduces the both latent and sensible load of the outside air (the recoveries can be as high as 85%) and the dehumidification coil reduces the dew point to almost 450F, this approach is most widely used and is highly cost effective and paybacks are often negative.

The benefits of this option are:

i) **Installed tonnage reduction,**

ii) **Lower power consumption** of the installed HVAC system,

iii) **Higher apparatus dew point (ADP)** of sensible cooling devices hence lower row deeps (lower pressure drop) and higher chilled water (CHW) temperature of the main Chiller, and

iv) **Better performance of the chiller in terms of IKW/TR due to higher CHW temperature.**
**OPTION III: Rotary Passive Desiccant Heat Exchanger With Coil And Rotary Sensible Heat Exchanger. (EW+CC+SW)**

This option is designed with the following objectives: Always provide conditioned air that is drier than the air in the space. Deliver cold conditioned air whenever possible, and use recovered energy to reheat during mild weather.

Select equipment to limit indoor relative humidity to 55% in all seasons.

This option has all the features of OPTION II and in addition supplies air at almost room temperature. The advantage here lies in the fact that during moderate weather, i.e. when outside ambient temperature is low but latent loads are high (typically monsoons), the OPTION II too can have difficulty in handling the RH.

This option supplies air at almost room temperature with lower dew point than space, hence it can continue to control the moisture without the risk of lowering the temperature.

The benefits of this option are:

i) Possibility of obtaining substantial LEED points,

ii) Good RH control in all the seasons,

iii) Reduced installed tonnage and lower power consumption of HVAC system, and

iv) Internal sensible cooling devices have higher CHW, lower ADPs resulting in reduced pressure drops and better IKW/TR for chiller.

**OPTION IV: Active Desiccant Dehumidification Wheel (With Condenser Heat Reactivation) Coupled With DX Cooling Coil. (CC+ADESW)**

This option combines the benefits of desiccant dehumidification with cooling of the DX air conditioners. Contrary to the first two options, this approach uses desiccant wheel to remove moisture and lower the dew point of the supply air instead of using a cooling coil.

The reactivation of the desiccant wheel is undertaken by recycled heat from the DX condenser air.

The benefits of this option are:

i) Meets ASHRAE standard 90.1 requirements,

ii) The co-efficient of performance (COP) is 65% more than a conventional DX system with reheat,

iii) Uses recycled heat from DX system for reactivation,

iv) No active reheat required, and

v) Maintains RH control in all the seasons (including for areas having high internal latent loads).
**OPTION V: Rotary Passive desiccant heat exchanger with cooling coil and Passive desiccant dehumidification wheel (EW+CC+PDHC)**

This approach utilises the strengths of passive total energy recovery, conventional cooling and a new type of desiccant rotor, the passive dehumidification wheel. The ability of this system lies in the fact that it optimises the moisture removal between the cooling coil and the desiccant wheel without the need of active reactivation. The passive desiccant wheel removes moisture from saturated air streams in a highly energy efficient manner.

The benefits of this option are:

i) Extremely good RH control in all seasons,
ii) High energy efficiency,
iii) Lower dew point of supply than the other three options,
iv) Versatile and adjusts well to varying climate,
v) Installed tonnage reduction for the HVAC system, and
vi) Substantial LEED points.

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### Table: Schedule of DOAS System with Cooling Coil and Active Dessicant Wheel

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<thead>
<tr>
<th>S. No.</th>
<th>Outdoor Air Conditions</th>
<th>Off Wheel Conditions</th>
<th>Off Coil Conditions</th>
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<td>gsr/lb</td>
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<td>2</td>
<td>1000</td>
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<td>162</td>
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</tbody>
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### Table: Schedule of DOAS with Enthalpy Wheel, Cooling Coil and Passive Dessicant Wheel

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<thead>
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<th>S. No.</th>
<th>Outdoor Air Conditions</th>
<th>Off Wheel Conditions</th>
<th>Off Coil Conditions</th>
<th>Supply Air</th>
<th>Return Air on EN</th>
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DOAS holds a lot of promise with its ability to maintain the right humidity in all weather conditions. The “divide and conquer” approach definitely allows the designer to have better management of the two key elements of air conditioning, i.e. temperature and moisture.

CONCLUSION

The Indoor air quality requirement of higher ventilation rates along with proper RH control and energy management will push the HVAC designer to the use of “Dedicated Outside Air System” in the near future. DOAS holds a lot of promise with its ability to maintain the right humidity in all weather conditions. The “divide and conquer” approach definitely allows the designer to have better management of the two key elements of air conditioning, i.e. temperature and moisture. The original definition of air conditioning can now be met in an energy efficient manner.

The DOAS has already proved itself with high potential of energy savings in nearly all applications and weather profiles. The benefits of Options II, III and V over the first option in terms of energy savings are significant. Otherwise from IAQ, RH and energy points of view, Option V has been proven to be the most cost effective.

However, in RH control the last three options discussed have performed better for a wide variety of applications and weather profiles. To clearly state that a particular option is the best solution would be a meaningless statement as proper simulation exercises need to be conducted on a few key applications for a few weather profiles and a “first cost + operating cost” matrix tabulated, giving due consideration to the importance of RH control. Some studies have indicated that the installed first cost of DOAS is lower than conventional systems for certain applications.

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