Proper Control Key to System Economics

DOAS Misconceptions

By Stanley A. Mumma, Ph.D., P.E., Fellow/Life Member ASHRAE

Dedicated outdoor air systems (DOAS) have many favorable indoor environmental quality (IEQ) attributes such as good ventilation performance and decoupled space humidity control. But, two design/operation misconceptions exist that may be barriers to its adoption. Total energy recovery (TER) control and supply air (SA) thermal conditions waste energy, destroying a DOAS's economics, and preventing its wider application.

DOAS Defined

A DOAS is generally designed to provide at least the minimum 100% outdoor air (OA) to each individual occupied space (as specified by ASHRAE Standard 62.1-2010). In addition, the OA is cooled and dehumidified, generally mechanically with the aid of TER, to accommodate the entire space latent loads. In all but very high occupancy density rooms, space dry-bulb temperature (DBT) control is achieved with parallel terminal equipment selected to meet the design sensible loads not met by the DOAS supply air.

Enhanced IEQ with a DOAS

DOAS can help provide excellent IEQ. Some of the best enhancements to IEQ are discussed briefly here.

Ensured ventilation. A DOAS, by virtue of its 100% OA design (i.e., no recirculated air), can ensure proper space ventilation even in multi-space applications. On the contrary, as a general rule multizone recirculating systems (all-air systems) are challenged in this area, and virtually always require overventilation of some spaces to meet the ventilation requirements of critical spaces. It is recommended that a DOAS be equipped with demand controlled ventilation (DCV) when serving highly variable occupancy situations, which reduces summer cooling energy use and essentially eliminates the use of terminal reheat while still providing the ensured ventilation.

Decoupled humidity control from sensible control. A DOAS, by virtue of its ability to provide latent load control independent of temperature control, can provide excellent energy efficient humidity control—a key part of acceptable IEQ.

Minimize the spread of odors, infections, microbes, and other contaminants between conditioned spaces. Since a DOAS uses no recirculated air, contaminant transfer between conditioned spaces is minimized, which is an especially important advantage in school applications and other public places of assembly. On the contrary, all-air systems, often supplying 80% recirculated air, can unfortunately often be efficient contaminant transport systems, even when fitted with particle filters.

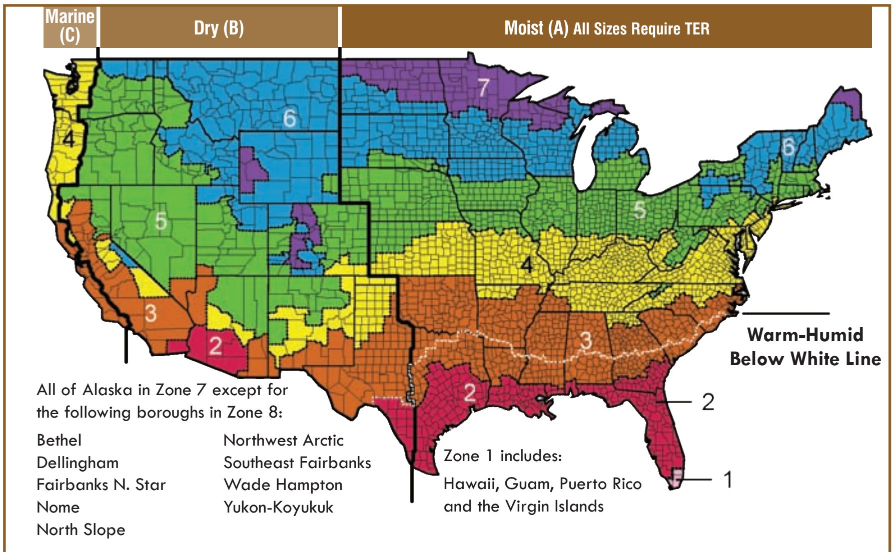
Enhanced isolation from unexpected outdoor events. A DOAS with parallel terminal space heating/cooling equipment has a relatively low air change rate per hour due to low SA flow rates when compared to all-air systems. As a result they have been correctly identified as slow to dilute contaminants that get into a space. However, if unexpected outdoor events are a concern, and the agent of concern is known, a much higher efficiency DOAS filter can be used compared to that for an all-air system, greatly reducing the comparable exposure. This is achieved with a DOAS at lower first and operating cost compared to all-air systems. More on this topic is at http://doas-radiant.psu.edu/Mumma_Filter_Paper_LO_09_032_Summer_Mtg.pdf.

Building pressurization. Pressurization is an important design requirement for enhanced IEQ. With a properly designed DOAS, this requirement can be met cost effectively even when the building is unoccupied. The feature also makes it possible to provide reserve latent capacity very cost effectively. More on this topic is at http://doas-radiant.psu.edu/DOAS_Pressurization_Paper.pdf.

Most terminal equipment choices provide excellent thermal comfort. A wide range of sensible terminal equipment is available to complement a DOAS (fan coil units, ceiling radiant cooling panels, chilled beams, and various types of unitary equipment). Because a DOAS removes both the space and OA latent loads, the terminal equipment need only provide sensible cooling. This avoids standing water in the terminal equipment condensate pans that could otherwise serve as septic amplifiers.

Total Energy Recovery Requirement

A key component in a DOAS is total energy recovery (TER—frequently an enthalpy wheel [EW]), a requirement for even the smallest systems as summarized in *Figure 1*. Since the near universal requirement to use TER with a DOAS is relatively recent, and is not required for most all-air systems, many in the industry have not developed sufficient trust or familiarity with TER to make informed decisions. Many considerations exist; some are addressed at this link http://doas-radiant.psu.edu/DOAS_Enthalpy_Wheel_Issues.pdf. In this column, specific attention is focused on addressing EW control.



Climate Zone (60% TER Required Standard 189.1-2009)	Design Airflow When >80% OA
1A, 2A, 3A, 4A, 5A, 6A, 7, 8 (Moist Eastern U.S. & Alaska)	≥0 cfm (All Sizes Require TER)
6B	≥1,500 cfm
1B, 2B, 5C	≥4,000 cfm
3B, 3C, 4B, 4C, 5B	≥5,000 cfm

Figure 1: U.S. locations and requirements for TER per ASHRAE Standards 90.1 and 189.1.

First Misconception

TER to operate all the time in both analysis software and in real time. Hourly weather data for most geographic locations fall into five regions of the psychrometric chart as illustrated in *Figure 2*. In each region, the appropriate enthalpy based control action is defined in *Table 1*. If the EW is permitted to operate all the time, the consequences for each region are presented in *Table 2*. *Table 2* shows that operating an EW in Kansas City, Mo., (KC) all the time for a 10,000 scfm (4719 L/s) OA system equipped with a balanced flow 70% effective (ε) means that EW will consume 75,060 extra ton hours (TH) (263 908 kWh) of cooling per year. At 1 kW/ton and $0.15/kWh—this represents $11,260 of waste, and takes us far from net zero energy. The difference in energy use for this one example is large. Other errant EW control concepts exists, for example, DBT control, but they are not discussed in this column.

An example of this EW control error during modeling is presented in *Figure 3* for a U.S. Army Brigade Facility (office facility). The error shows up first at energy efficiency measure (EEM) Step 5 where an EW was introduced. The error carries all the way through to Step 13, and would lead one to falsely conclude that a DOAS uses more energy than all-air systems.

Two important items of EW control that were not discussed include:

• Wheel cleaning when the EW is off. One way of cleaning is to energize the wheel once an hour for 1 min., resulting in about 20 airflow reversals in that minute per every hour for wheel cleaning.

• Frost prevention. There are many ways to do this. One method is discussed in the paper at this link: http://doas-radiant.psu.edu/4428.pdf. A real time control is used to temper the OA just sufficient to assure condensation cannot occur in the EW whenever the OA temperature is below freezing. This is accomplished by computing the tangent to the saturation curve containing the exhaust air thermodynamic state point (TSP), and determining if the outdoor TSP is to the right or left of the tangent. If the TSP is to the left, and the OA DBT is below freezing, then the OA is sensibly heated enough to intersect the tangent curve. This control logic has been working superbly for more than 10 years in the field saving much unnecessary preheat energy.

Related to EW control is the issue of airside free cooling (economizer). Of course, a DOAS generally does not supply as much airflow as an all-air system, limiting its ability in that area.

DOAS free cooling can be maximized as follows:

• In the illustration presented previously, it was assumed that the SA DBT could not drop below 48°F (9°C); however, it is not uncommon with just ventilation air that 48°F (9°C) is not cold enough to meet all the space sensible loads. In those cases, allowing colder OA expands the free cooling.

• However, allowing the SA temperature to drop below 48°F (9°C) at the diffusers can be problematic. The OA can be tempered with heat removed from the spaces by the sensible terminal cooling equipment without losing free cooling. Such an example is presented at this link: http://doas.psu.edu/IAQ_summer_05.pdf. Radiant panels are discussed in this article, but any hydronic terminal unit can do the same be it fan coil, chilled beam, fan powered box, etc.

Second Misconception

The DOAS supply air temperature must always be at a neutral temperature. For many, the conventional wisdom is to always cool the supply air to the required dew-point temperature (DPT) necessary to remove the space latent load, approximately 48°F (9°C) or lower for many occupancy densities, then to reheat the air continually to a neutral temperature eliminating the need for terminal reheat. But this is not necessary or useful. By avoiding central SA reheat, the system avoids energy waste. Another benefit is that the terminal equipment can be smaller and less expensive to purchase and operate.

Space in this column is insufficient to discuss this important topic in detail. However, in general, when the DOAS is supplying spaces with highly variable occupancy, such as a classroom, the KISS principle would suggest supplying the air at a DBT equal to the required DPT, and modulate the SA flow based

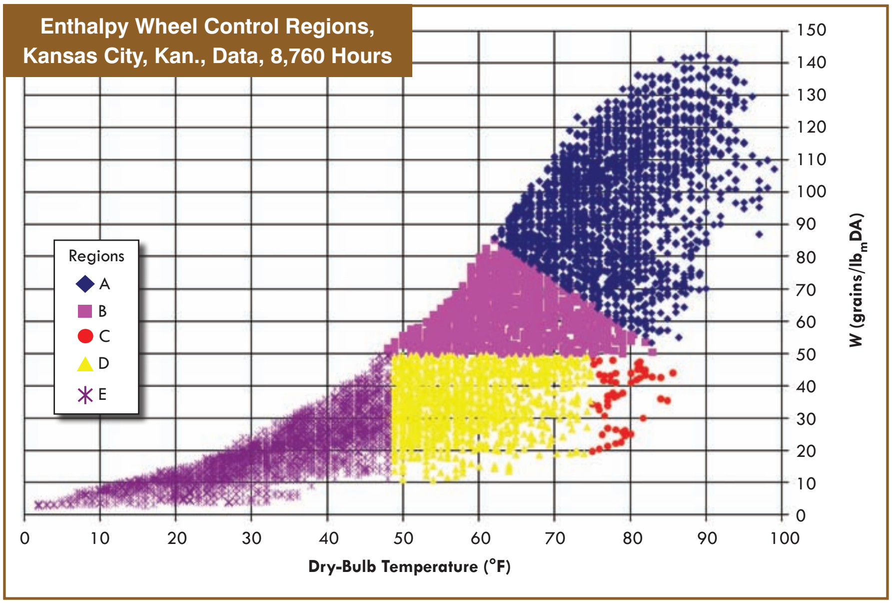


Figure 2: Psychrometric regions related to enthalpy wheel control.

Region ID	Enthalpy Wheel Control Action
A ◆	Hot and humid OA region, the EW should run full speed.
B ■	Humid OA region between the RA enthalpy and the required SA humidity ratio: the EW should be off. Operating the EW in this region elevates the enthalpy of the OA entering the cooling coil (CC) and hence the energy use.
C ●	Warm (hotter than the space) but dry OA region (mechanical dehumidification is not necessary to meet the space latent load using this air directly): the EW should be off. Operating the EW in this region elevates the humidity ratio of the OA entering the CC requiring latent cooling in addition to sensible cooling, increasing the energy use above that needed to sensibly cool the air when the EW is off.
D ▲	Cool (cooler than the space) but dry OA region (mechanical dehumidification is not necessary to meet the space latent load using this air directly): the EW should be off. Operating the EW in this region elevates the humidity ratio of the OA entering the CC, requiring latent cooling in addition to sensible cooling, increasing the energy use above that needed to sensibly cool the air when the EW is off.
E ⚹	Cold (colder than the required SA DPT) and dry OA region (mechanical dehumidification is not necessary to meet the space latent load using this air directly): the EW should modulate as necessary to avoid overcooling or meet the design SA DBT (48°F in this illustration). Modulating the EW in this region to just avoid overcooling enables the system to do most, if not all, of the cooling as an economizer allowing the cooling plant to be off. Mechanical cooling is required when the EW is operating full speed.

Table 1: Appropriate enthalpy wheel control action.

Region ID	Hours in Region	Difference Between Operating the EW Full Time vs. Proper Control
A ◆	2,666	Hot humid OA, EW on either method, no difference.
B ■	1,255	EW should be off. If EW on, cooling use increases by 10,500 ton hours (TH).
C ●	55	EW should be off. If on, cooling use increases 115 TH.
D ▲	1,261	EW should be off. If EW on, cooling use increases 18,690 TH.
E ⚹	3,523	EW speed to modulate holding 48°F SAT. If EW full on, cooling use increases by 45,755 TH.

Table 2: Energy penalty when the enthalpy wheel is on all the time vs. proper control.

upon occupancy (DCV), thereby minimizing or eliminating terminal reheat.

Conclusion

Both misconceptions cause inflated energy use errors, leading to wrong conclusions about the economic viability of a DOAS. As a result, other systems are often selected, which can not deliver the enhanced IEQ that a DOAS actually provides. Analyses based upon one or both misconceptions often falsely make DOAS economics appear non-competitive. As a result, their superior IEQ attributes are lost to "apparently" more cost-effective alternatives.

Stanley A. Mumma, Ph.D., P.E., is professor emeritus, Penn State University, University Park, Pa. ⬢

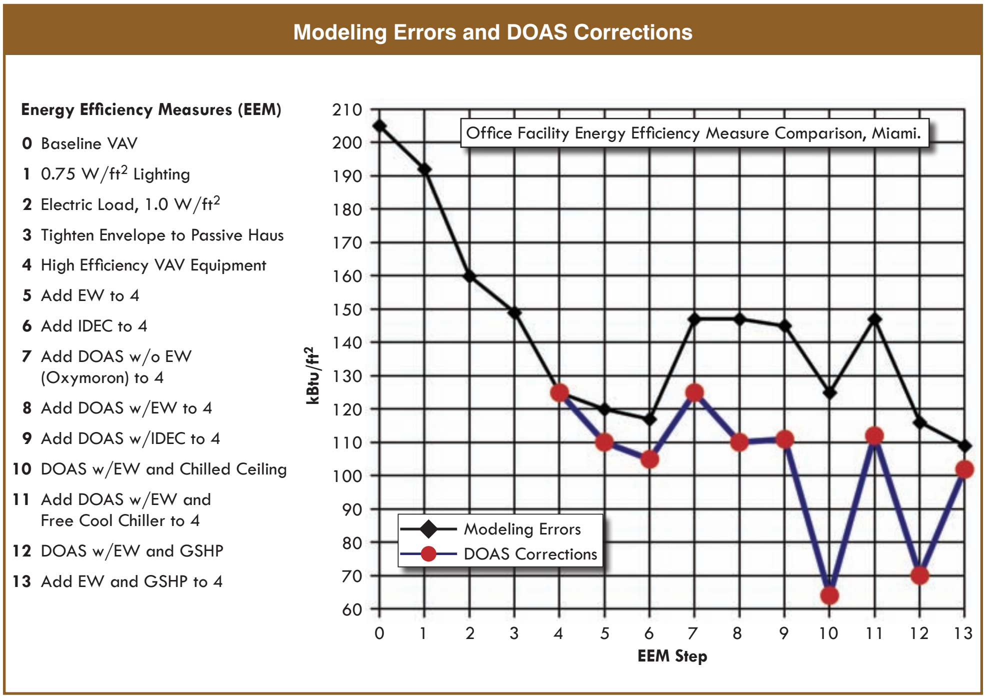


Figure 3: Example of modeling errors involving enthalpy wheel control and the corrections.

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