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## Role of Economizers In DOAS: Part 1

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*Editor's Note: This is the first in a two-part series. Part 2 will be published in a future issue of IAQ Applications.*

A question that frequently arises when a dedicated outdoor air system (DOAS)<sup>1</sup> is discussed, particularly when the parallel sensible cooling system is not an air system, is: "what about the loss of 100% outdoor air (OA) economizers?" Central to this larger question are the following sub-issues:

- Internal zones have a sensible cooling load of 7–10 Btu/h·ft<sup>2</sup> (22.1–31.6 W/m<sup>2</sup>), exceeding the cooling ability of even 45°F (7°C) DOAS supply air at the rate of 0.2 cfm/ft<sup>2</sup> (1 L/s·m<sup>2</sup>) (cooling capacity ~6.5 Btu/h·ft<sup>2</sup> [~20.5 W/m<sup>2</sup>]).
- Some owners are not happy operating mechanical refrigeration during the winter months.
- Therefore, water-side free cooling (WSFC), or economizer, is thought to be required for practical DOAS applications.
- Variable-air-volume (VAV) systems with air-side economizers are considered, by some, to be better at providing satisfactory IAQ than DOAS (with or without WSFC) since, during most of the air-side economizer operation, the building is ventilated beyond the requirements of Standard 62.1-2004.
- What if ASHRAE is wrong again about the quantity of OA required for healthy buildings?

Because of limited space, those economizer issues will be briefly addressed here.

### Economizers

Internal cooling load-dominated buildings, as is the case for most commercial and institutional facilities, require cooling year-round, regardless of geographic location. In the winter months when the outdoor temperatures fall below inside temperatures, some or all of the building cooling can be met by bringing in and circulating the cooler OA, i.e., an air-side economizer. WSFC<sup>2</sup> offers an alternative to the air-side econo-

mizer, and generally is used where space for very large ductwork is scarce, or where floor-by-floor air handlers are used. In this case, heat extracted from the building by the mechanical equipment is transported to the outdoor air via a cooling tower (open or closed). Generally, when an open tower is used, a heat exchanger between the chilled water loop and the tower water minimizes fouling in the chiller and cooling equipment (i.e., cooling coils, fan coils, radiant panels, and chilled beams).

### Air-Side Economizers

An air-side economizer is a collection of dampers (minimum and economizer OA, return, and relief), sensors (e.g., temperature, humidity, flow, pressure, smoke, CO<sub>2</sub>), actuators, and controls working together to determine how much OA to bring in to reduce, or eliminate, the need for mechanical cooling during mild and cold weather. That decision simply is based on either the outdoor air dry-bulb temperature (DBT) or enthalpy. (Further discussions of controls incorporating integrated and fixed vs. differential options are beyond this column. See Standard 90.1-2004, Section 6.5, for details).

This control selection can make a difference in mechanical energy use and peak electrical demand. For the sake of discussion, the psychrometric chart can be broken down into six regions (see *Figure 1*). When the OA temperature is in Region 1, the economizer operates in minimum OA mode. Regions 2a and 2b are the only OA conditions where the control action between DBT vs. enthalpy control differs. In Region 2a—bounded by the room DBT, enthalpy, and the saturation curve—OA is placed in the minimum air mode when using enthalpy control since the OA enthalpy exceeds the room air. With DBT control, when the OA is in Region 2a, 100% OA is used since the OA DBT is less than the room temperature.

Generally, there are few hours in Region 2b, so the difference between the two controls is not significant. The choice of temperature vs. enthalpy control can be significant, as will be discussed more later.

In Regions 3a and 3b, the economizer would bring in 100% OA. Clearly, cooling and dehumidification is required in Region 3a, while sensible-only cooling is required in Region 3b. In Region 4, the OA and return air blend to achieve a desired supply air temperature (SAT) (55°F [13°C] in this example).



**Mumma**

As the OA temperature in Region 4 drops and or the supply air quantity is reduced (VAV at part load), the quantity of OA needed to achieve the 55°F (13°C) SAT also reduces. In view of Standard 62.1-2004, the OA flow has a lower limit and can result in a mixed air temperature colder than 55°F (13°C), which could lead to freeze protection action taking precedence over ventilation.

## Water-Side Free Cooling or Economizers

Here, the supply air of a cooling system is cooled indirectly with water that is itself cooled by heat or mass transfer (evaporative cooling) to the environment without the use of mechanical cooling. Its application largely is reserved for systems that use water-cooled chillers. As such, they use a cooling tower, and the tower leaving water temperature available is a strong function of the ambient wet-bulb temperature. Generally, the OA dry bulb and dew-point temperatures are low enough that dehumidification is no longer a mechanical refrigeration requirement in the wintertime. Often, cooling tower water can be above the summer design chilled-water temperature of 40°F–45°F (4°C–7°C). If ceiling radiant cooling is used with a DOAS, the desired fluid temperature is around 60°F (16°C), easily achievable over many U.S. non-summer hours.

Many possible WSFC arrangements, types of evaporative cooling equipment, and controls exist such as winter freeze protection. However, those discussions are saved for future topics.

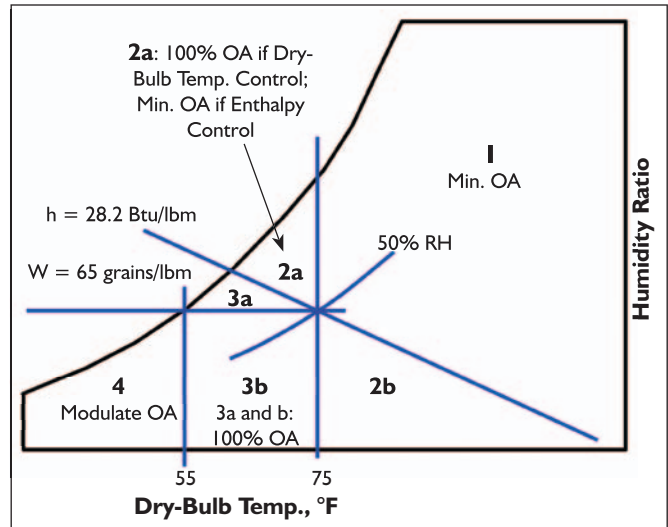
## Standard 90.1-2004 and Economizers

Make no mistake about it, the potential energy saving features of economizers have not been overlooked in ANSI/ASHRAE/IESNA Standard 90.1-2004, *Energy Standard for Buildings Except Low-Rise Residential Buildings*. Mostly, either air- or water-side economizers are required. However, exceptions exist. An important exception is using the Energy Cost Budget Method (Section 11 of the standard), an alternative to the standard's prescriptive provisions (including the economizer provision).

Compliance here requires the use of a simulation program with the ability to explicitly model all of the following (manufacturers load and energy analysis software comply with these points): a minimum of 1,400 hours per year; hourly variations in occupancy, lighting power, miscellaneous equipment power, thermostat setpoints, and HVAC system operation, defined separately for each day of the week and holidays; thermal mass effects; 10 or more thermal zones; part-load performance curves for mechanical equipment; capacity and efficiency correction curves for mechanical heating and cooling equipment; air-side and water-side economizers with integrated control; and the budget building design characteristics.

## Air-Side Economizer Performance Issues

Example: to obtain a rough feel for the performance of an




**Figure 1: Air-side economizer control regions on the psychrometric chart, assuming an inside condition of 75°F DBT and 50% RH.**

air-side economizer, and the associated economics, an oversimplified example will be presented.

Assume that a building is totally internally dominated and fully occupied six days per week 6 a.m.–7 p.m. Assume that the constant 55°F (13°C) supply airflow rate is 100,000 cfm (47 190 L/s), and the minimum ventilation air requirement is 20,000 cfm (9438 L/s). In the economizer mode, the OA flow can modulate between these values. With these assumptions, the only variability in chiller energy consumption/demand is economizer control and geographic location.

Both integrated (meaning the chiller can operate while in the 100% OA economizer mode) DBT and enthalpy controls were analyzed in three climate zones. The illustration cities<sup>3</sup> are Miami (Zone 1), Columbus, Ohio (Zone 5a) and International Falls, Minn. (Zone 7a). Results are in *Table 1*.

## Observations

1. As the cold weather increases, the hours that the economizer is in the minimum mode decreases sharply. Economizers work better the longer the cold weather.
2. During the hours when OA conditions range between 55°F (13°C) and the space enthalpy line (100% OA mode), using an air-side economizer saves ton-hours (TH) of cooling, in the example between 30–75 kTH (106–264 MWh).
3. Time dramatically increases  when an air-side economizer can provide full cooling without the use of mechanical cooling (modulating OA mode) as winters become longer and colder. The system operates in the modulating OA mode less than 2% of the time in Miami, and almost 70% of the time in International Falls. Using only minimum OA in cold climates causes the mechanical cooling to operate substantially more (only 10 kTH [35 MWh] in Miami, but 266 kTH [935 MWh] in International Falls).

# Applications Issues

Region # (Fig. 1)	Region Action	Description	Miami	Columbus, Ohio	International Falls, Minn.
1 & 2b	Min. OA	OA > 75°F, Hours: No Difference in Cooling Ton-Hours, Dry-Bulb Temp., Enthalpy Control, or Using DOAS	2,766	685	206
3a & b		<b>Hours</b>	<b>523</b>	<b>1,058</b>	<b>886</b>
3a & b	100% OA	Thousands of Cooling Ton-Hours, Economizer	59	94	75
3a & b	Min. OA	Thousands of Cooling Ton-Hours, DOAS	88	171	144
4		<b>Hours</b>	<b>76</b>	<b>1,894</b>	<b>2,771</b>
4	Moderate OA	Thousands of Cooling Ton-Hours, Economizer	0	0	0
4	Min. OA	Thousands of Cooling Ton-Hours, DOAS	10	209	266
2a		<b>Hours</b>	<b>691</b>	<b>419</b>	<b>193</b>
2a	Min. OA	Enthalpy Control (also DOAS): Thousands of Cooling Ton-Hours	150	87	40
2a	100% OA	Dry-Bulb Temp. Control: Thousands of Cooling Ton-Hours	234	122	53
2a	100% OA	Dry-Bulb Temp. Control: Peak Load, Tons	560	560	560
		Design Load, Tons: at Highest Enthalpy Hour With Min. OA	311	290	271
		Thousands of Cooling Ton-Hours Difference, Economizer vs. Min. OA (DOAS)	39	286	335
		Enthalpy Economizer Savings Compared To DOAS: Assuming 0.7 kW/ton and \$0.08/kWh	\$2,184	\$16,000	\$18,760
		Dry-Bulb Temp. Economizer Savings Compared to DOAS: Assuming 0.7 kW/ton and \$0.08/kWh	(\$2,520)	\$14,040	\$18,010

**Table 1: Economizer example summary.**

4. The hours of operation in Triangle 2a (*Figure 1*) drop as the winters lengthen, or in hot and dry climates. As a result, enthalpy control is important in a climate like Miami, saving 84 kTH (295 MWh), but less important from an energy-use point of view, as the hours in triangular Region 2a decrease.

5. A striking observation about the impact of the economizer control on peak demand and chiller size (or ability of the system to satisfy the loads): in all three locations, the chiller load to condition 100,000 cfm (47 190 L/s) of OA at 75°F (24°C) and saturated to 55°F (13°C) and saturated was 560 tons (2 MW). When only 20,000 cfm (9438 L/s) of OA (minimum OA mode) was used at the hour with the highest OA enthalpy, the design chiller size was less than half of 560 tons (2 MW). This situation often is overlooked by the design community, resulting in high demand charges and operating cost penalties. It also has resulted in grossly oversized chiller plants and associated operational problems.<sup>4</sup>

6. The optimistic annual cost savings, assuming a 0.7 kW/ton (0.2 kW/kW) chiller and an average \$0.08/kWh energy charge for this 100,000 cfm (47 190 L/s) system ranged \$2,000–\$18,000. The economizer is not very beneficial in Miami, and using DBT controls would wipe out the savings and cost the operator more than \$2,500 annually. A minimum OA-only system (i.e., no economizer) is advised for locations similar to Miami.

7. The relationship between chiller operating costs and fan operating costs in all-air systems is not universally understood. In the example, a 100,000 cfm (47 190 L/s) system operating at constant volume for 4,056 hours annually against an internal pressure drop of 3 in. w.g. (747 Pa) and external drop of 4 in. w.g. (1 kPa). Assuming a fan efficiency of 70%,

motor efficiency of 90% and electricity costing \$0.08/kWh, annual fan energy would be about \$41,500. A DOAS system supplying only 20,000 cfm (9438 L/s) against the same head would cost slightly more than \$8,000 per year to operate.

That difference exceeds the available savings from an economizer, even in International Falls. Granted part of that savings would be consumed by the parallel hydronic system, assuming radiant panels or chilled beams. This is why ASHRAE allows an Energy Cost Budget Method analysis to show compliance with Standard 90.1. It should be done, and the project greatly simplified by using a constant volume DOAS.

*Suffice it to say, not only have studies revealed that many air-economizer cycles are not economically justifiable, but there have been many cases, not only where they added to the investment cost, but they actually consume more total resource energy than the alternatives.<sup>5</sup>*

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