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Select & Control Economizer Dampers in VAV Systems

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Last month's column[1] discussed how to control return fans in VAV systems. This month, we will discuss a closely related subject: how to select and control economizer dampers in VAV systems.

Damper type, sizing, and control strategies vary depending on the type of building pressure control system. The three common types are:

1. Relief Dampers (aka non-powered or barometric relief) as shown in *Figure 1;*[*,2]
2. Relief Fans (aka powered exhaust fans) as shown in *Figure 2;* and
3. Return Fans (aka return/relief fans) as shown with Airflow Tracking in *Figure 3A* and with Direct Pressure Control in *Figure 3B.*

Figures 1 to *3B* also show three common options to control minimum ventilation outdoor air. The advantages and disadvantages of these options, and others, will be the subject of a future Engineer's Notebook column.

Control Logic

Conventional economizer control logic calls for the return air damper to close as the outdoor air damper opens. For systems with return fans, conventional logic calls for the relief air damper to track the outdoor air damper. This is shown in *Figure 4.* But this logic is not optimum for multiple-zone VAV system applications.

For VAV systems using Relief Dampers (*Figure 1*) or Relief Fans (*Figure 2*), pressure drop and supply fan energy can be reduced by sequencing the outdoor air and return air dampers, as shown in *Figure 5.* The pressure drop savings is readily apparent at the 50% outdoor air signal: the two dampers are both wide open rather than both half closed. This substantially reduces pressure drop through the mixing plenum, particularly if the dampers have opposed blade action (discussed further below). The damper sequencing shown in *Figure 5* can be achieved by using separate control system outputs to the two dampers (which may also be needed for minimum outdoor air control, to be discussed in a future column) or by sequencing the active range of the actuators, e.g., 0 to 5 VDC for one and 5 to 10 VDC for the other.

Conventional logic is also not optimum for systems with Return Fans (*Figure 3A* and *Figure 3B*). Not only does it increase pressure drop and supply fan energy, it can cause reverse outdoor airflow through the relief damper when Airflow Tracking control is used.[3] This can result in excess outdoor air intake, depending on minimum ventilation control logic, and also may cause contaminated air to be drawn in through the relief outlet since its location may not meet the code and Standard 62.1 separation distances to pollutant sources required of outdoor air intakes.

A better economizer control sequence for systems with Return Fans and Airflow Tracking control is shown in *Figure 6* and summarized as follows:

- Simply open the outdoor air damper fully. This is true even when the economizer is disabled, i.e., open the outdoor air damper whenever the air handler is on in occupied mode. (It is closed when the air handler is off or when operating in non-occupancy modes such as night setback, warm-up, etc.)
- Modulate the return air damper off the supply air temperature loop in sequence with the mechanical cooling per standard economizer control logic.

*The figure shows direct pressure control with motorized relief dampers. Gravity type barometric dampers are also an option. See Reference 2 for a comparison of these two options.

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- The relief damper modulates as the inverse of the return damper.

For Return Fan systems using Direct Pressure control, the sequence is the same except the relief damper is controlled independently off of building pressure.

It may be counterintuitive, but economizer outdoor air dampers on air handlers with return fans have no impact on the outdoor airflow rate into the mixing plenum. Instead the return fan and return damper controls dictate outdoor airflow. From ASHRAE Guideline 16:[4] "The flow of outdoor air … is always the difference between the supply airflow and the return airflow through path PL-1 to PL-2, and, therefore, the [outdoor air] damper size and type have no effect on the amount of outdoor air." Fully opening the outdoor air damper rather than tracking the other dampers reduces pressure drop and fan energy, and it ensures there is no backflow through the relief damper for systems using Airflow Tracking control (see Reference 3 for more details).

FIGURE 1 Relief damper.

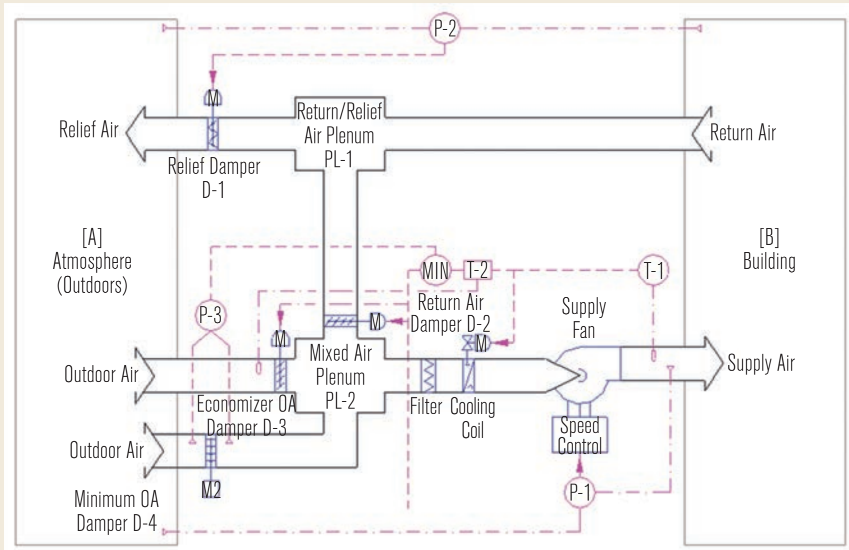
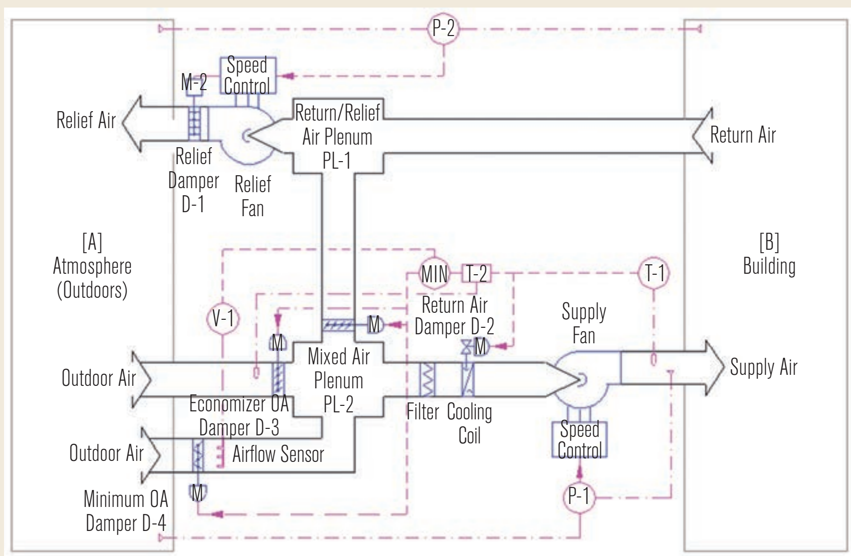


FIGURE 2 Relief fan.



Damper Selection

Table 1 is a summary of recommendations for damper action and sizing, adapted from ASHRAE Guideline 16. Recommended damper action is referred to as either parallel blade damper (PBD) or opposed blade damper (OBD) (*Figure 7*).

One important point in selecting economizer outdoor air and return air dampers is that the concept of "damper authority"[5,6] does not apply. The damper authority concept applies to dampers that throttle airflow but economizer dampers do not; they are mixing dampers and are not intended to vary overall airflow. This fact, and other factors, are considered in Guideline 16 and *Table 1* damper sizing recommendations.

Relief Damper System

For VAV systems using Relief Dampers (*Figure 1*), the most important damper from a sizing perspective is the relief damper (D-1). The relief system relies on building pressurization to cause excess outdoor air to relieve to atmosphere. The relief damper and entire relief path (Path B to A in *Figure 1*) must be sized large enough to prevent overpressurization of the building, i.e., no more than about 0.05 to 0.10 in. w.c. (12 to 25 Pa), when the VAV system is supplying maximum outdoor air. The resulting face velocity will therefore be very low, typically 200 to 500 fpm (1 to 2.5 m/s).

The economizer outdoor air damper (D-3) should be selected for low pressure drop to minimize supply fan energy. Damper face velocities from 400 to 1,500 fpm (2 to 8 m/s) at design flow are typical; the range is a function of space availability and cost. From a functionality standpoint, damper size does not matter. Often, because of space limitations, this damper is the same size as the outdoor intake louver and thus has very low velocity to avoid rain entrainment.

Similarly, the return air damper (D-2) pressure drop should generally be low to minimize supply fan energy. Damper face velocities from 800 to 1,500 fpm (4 to 8 m/s) at design flow are typical. In cold climates where coil freezing is possible and no other mixing device (e.g., air blender) is provided, the design velocity should be on the high end of this range to encourage mixing (see ASHRAE Research Project 1045[7]).

Where outdoor air and return air dampers are controlled so that one opens when the other closes (*Figure 4*), both outdoor air and return air dampers should be PBDs to minimize pressure drop and reduce fan energy. *Figure 8* shows why: the pressure drop across the mixing plenum is almost constant for PBDs and rises significantly when dampers are 50% open for OBDs. The reason is apparent from *Figure 7:* at 50% open, PBDs have a much larger free area than OBDs.

Where outdoor air and return air dampers are sequenced (*Figure 5*) as recommended, either PBDs or OBDs may be used. Many designers (including the author) still prefer parallel blade dampers with the outdoor air and return air damper blades oriented to direct airflow into each other to encourage mixing. RP 1045 found this provided only marginal and statistically insignificant improvement in mixing efficiency vs. dampers that were rotated 90°, but their tests were limited, and earlier research[8] found angled parallel blade dampers did improve mixing.

FIGURE 3A Return fan with airflow tracking control.

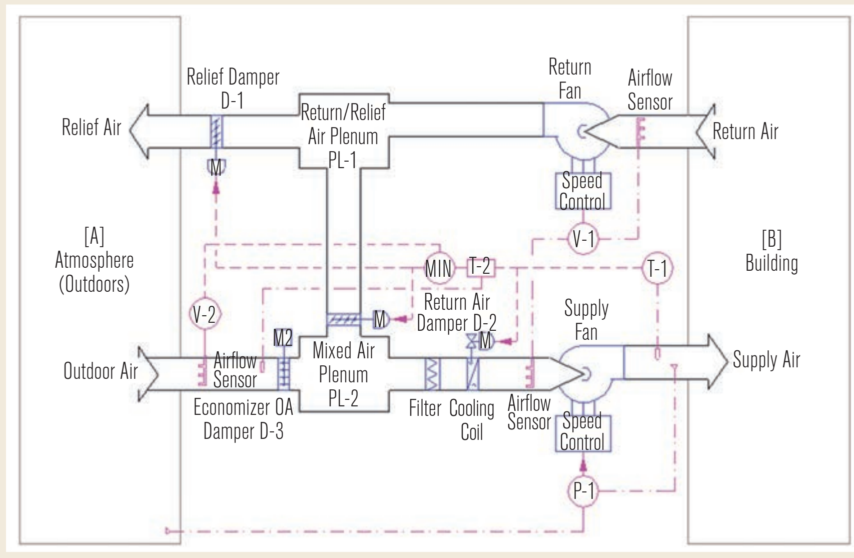
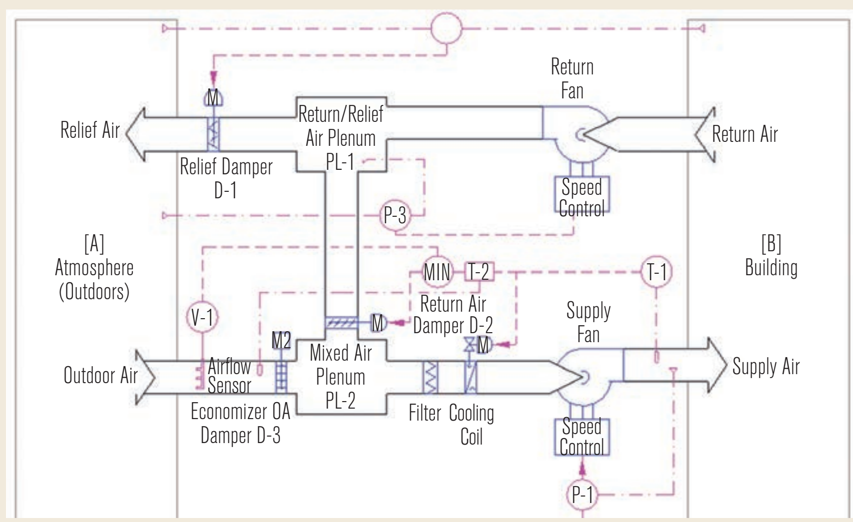


FIGURE 3B Return fan with direct pressure control.



Relief Fan System

Economizer outdoor air and return air damper selections for VAV systems using Relief Fans (*Figure 2*) are the same as those with Relief Dampers described earlier. The one difference is the relief damper (D-1). This damper is typically a two-position damper interlocked to the relief fan. As such, it should be selected for low

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FIGURE 4 Conventional economizer damper control.

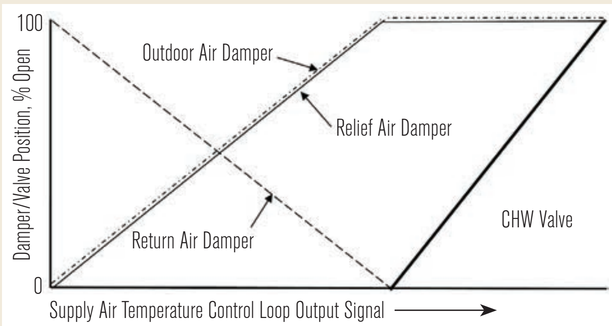

FIGURE 5 Economizer damper control for systems with relief dampers or relief fans.

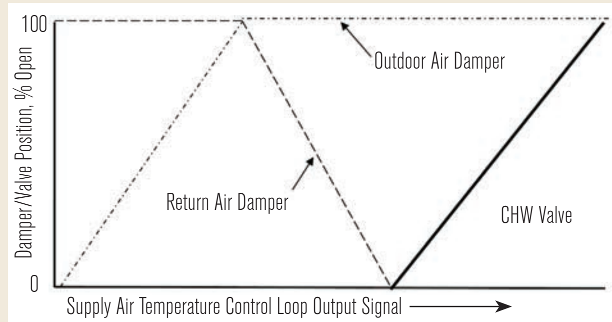

FIGURE 6 Economizer damper control for systems with return fans and airflow tracking control.

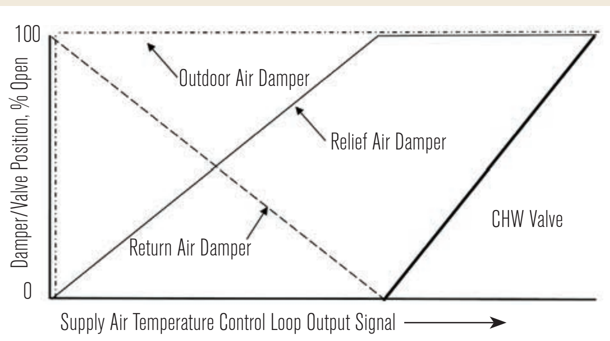

TABLE 1 Economizer damper action and sizing.

RELIEF SYSTEM	DAMPER	ACTION	FACE VELOCITY FPM (M/S)
Relief Dampers	Relief	OBD	Note 1
	Outdoor Air	PBD	400 to 1,500 (2 to 8)
	Return Air	PBD	800 to 1,500 (4 to 8)
Relief Fans	Relief	PBD or OBD	400 to 1,000 (2 to 5)
	Outdoor Air	PBD	400 to 1,500 (2 to 8)
	Return Air	PBD	800 to 1,500 (4 to 8)
Return Fan with Airflow Tracking Control	Relief	PBD	500 to 1,000 (2.5 to 5)
	Outdoor Air	PBD or OBD	400 to 1,000 (2 to 5)
	Return Air	PBD	Note 2
Return Fan with Direct Pressure Control	Relief	OBD	1,000 to 1,500 (5 to 8)
	Outdoor Air	PBD or OBD	400 to 1,000 (2 to 5)
	Return Air	PBD	Note 2

1. Size damper and entire relief path for less than 0.1 in. w.g. (25 Pa) at design return airflow rates, typically 200 to 500 fpm (1 to 2.5 m/s).
2. Size damper so wide open pressure drop uses available pressure drop from PL-1 to PL-2 at design return airflow rates, typically 1,500 to 2,000 fpm (8 to 10 m/s).

pressure drop to minimize relief fan energy and may be either a PBD or OBD.

Costs would be reduced if a gravity backdraft damper were used, but gravity dampers should not be used with variable speed fans because they do not fully open at low speeds, increasing fan energy. They also can be pushed open during off-hours in cold weather due to stack effect, increasing nighttime infiltration and thus increasing morning warmup energy use. Finally, if a motorized damper is used, it may be controlled as the first stage of relief to reduce fan energy; prior to turning on the relief fan, simply open the relief damper to allow air to be relieved using building pressure (similar to *Figure 1*) through the inactive fan. This can be very effective with high free area fans like propeller fans.

Return Fan System

For VAV systems using Return Fans with Airflow Tracking control (*Figure 3A*), the outdoor air damper can be either PBD or OBD since it is simply open or closed. Outdoor air damper size does not affect control performance and sizing is simply a balance of first costs and energy costs. (Design velocity may also be limited by the requirements of the minimum airflow control device, to be discussed in a future column.)

While *Figure 8* was developed for mixing boxes, it should apply as well to diverting assemblies such as

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return/relief plenum PL-1 when using Airflow Tracking control. The relief and return air dampers should therefore be parallel blade dampers to minimize pressure drop through the plenum. This also should provide relatively constant percentage flow either through the return damper or through the relief damper for any given damper position, which can improve the performance of Airflow Tracking control, depending on how return airflow is determined (see last month's column).

When using Direct Pressure control, relief dampers should be OBDs and sized for a pressure drop equal to 7% to 15% of the relief path total pressure drop, per Guideline 16, to provide a fairly linear control response.

With either building pressure control logic, return dampers should be sized to use up the available differential pressure across the damper from the return/relief plenum to the mixed air plenum. In typical air handler applications, this DP will be about 0.25 to 0.75 in. w.g. (63 to 190 Pa) and the damper can be selected for 1500 to 2,000 fpm (8 to 10 m/s) or more depending on damper type. (Be sure to include damper entrance and exit losses when making this selection; these pressure drops will generally far exceed the pressure drop through the damper itself.) Oversizing the return damper has no operational value; the damper will simply throttle to deliver the required return air/outdoor air ratio required by the economizer controls or the minimum outdoor air controls.

Discussion and Conclusions

Conventional economizer damper control logic is seldom optimum for VAV systems. The recommended control logic above reduces fan energy use with little or no increase in first costs. Damper size and control action selections are also commonly non-optimum. Selecting dampers in accordance with ASHRAE Guideline 16, summarized earlier, will improve control and energy performance.

FIGURE 7 Parallel blade and opposed blade dampers at 50% open.

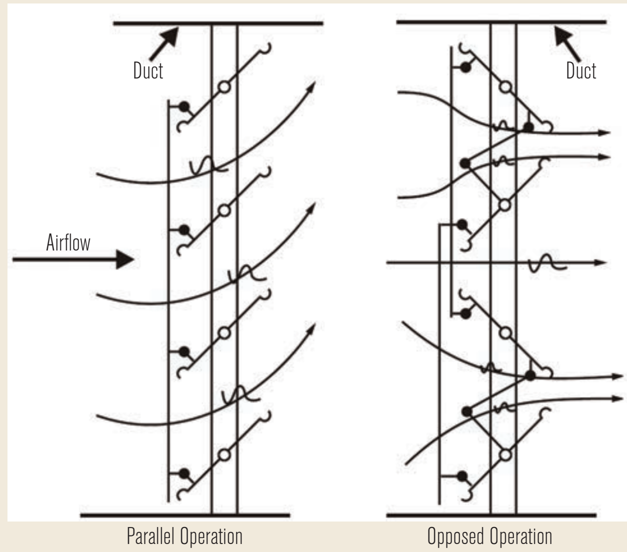
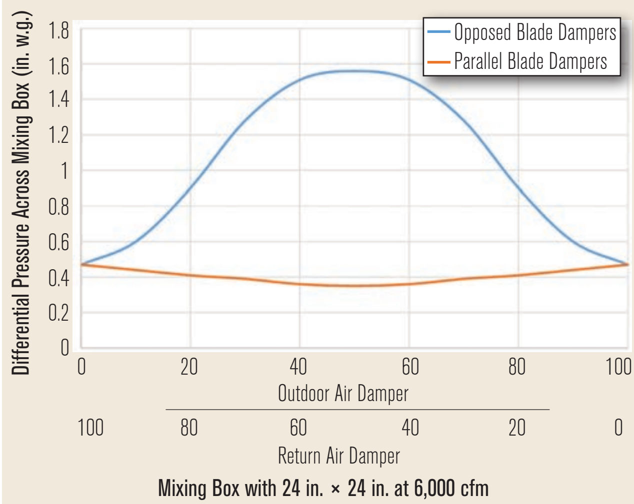


FIGURE 8 Mixing box pressure drop with opposed blade vs. parallel blade mixing dampers. (Adapted from References 9 and 10.)



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