DX - DOAS Control Strategy

INTRODUCTION

As consulting engineers and end users implement ASHRAE 62 or the International Mechanical Code (IMC), they must select the appropriate temperature control method for introducing outdoor air while eliminating humidity within the conditioned space. This bulletin will describe the control options available for maintaining comfortable indoor conditions. Since the control methods described here vary in complexity and cost, the benefits of each will be explained to provide you some guidelines for selecting the most economical system for your application.

This bulletin describes sequences for Direct Expansion Dedicated Outdoor Air Systems (DX-DOAS) and does not cover the sequences of dehumidifiers/air conditioners introducing higher volumes of outdoor air.

SUMMARY OF STRATEGIES

The control strategy of DX-DOAS units is grouped into two major categories. The first is control of the compressor to condition outdoor air (dehumidify, cool, or heat). The second is how the supply air temperature (SAT) is controlled. Since ASHRAE Standard 90.1 generally limits the introduction of new energy (e.g. auxiliary heat) to control SAT in the cooling/dehumidification mode, this bulletin assumes the use of modulating hot gas reheat coils. Liquid sub-cooling coils and on-off hot gas reheat coils cannot properly maintain supply air conditions, thus are excluded in this bulletin.

COMPRESSOR OPERATIONS

By design, a DX-DOAS must handle various entering air conditions that cover a wide range of temperature and humidity conditions. Therefore, at design conditions the system needs to use all of the compressor capacity to achieve the design system supply air dew point or temperature, but on a part load day may only need a portion of the capacity. Desert Aire uses a dual tandem four-compressor set on its 36-ton and larger systems. The controller uses the entering air's enthalpy value to stage the compressors. Figure 1 shows the staging of a dual tandem four-compressor set.

Units between 8- and 30-tons use a single tandem two-compressor set. The two compressors for these systems split the enthalpy range in half with each compressor handling 50% of the load. On the other hand, a dual tandem four-compressor set divides the enthalpy load by 25% per compressor. (See Figure 1.)

A single compressor design is used on our 5-ton systems and smaller because tandem compressors are not available. This example is not shown in any of our figures.

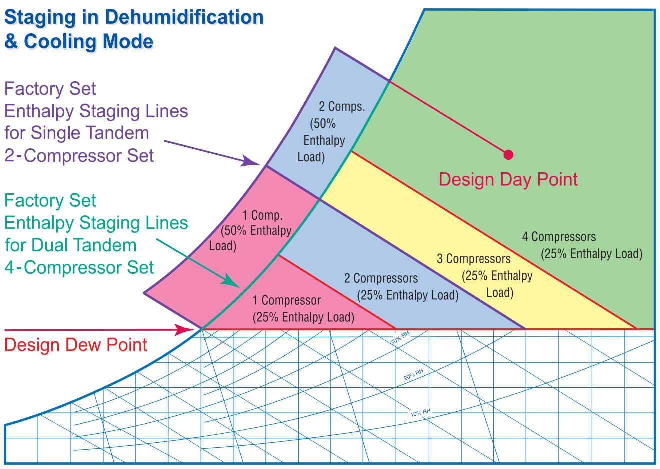

Figure 1 - Compressor Control: Staging Dual & Single Circuits for Enthalpy

A call for cooling occurs when the temperature of the outdoor air, mixed air or the space exceeds the preprogrammed setpoint. Using temperature sensors available on Desert Aire's DOAS units, cooling can be provided even when humidity levels are being met. The need for cooling depends upon the deviation of the temperature from the setpoint. Therefore, the controller calculates the number of compressors needed and their staging sequence to sufficiently cool the air to meet this setpoint. Just like the control of enthalpy, a single tandem two-compressor set will be staged differently than a dual tandem four-compressor set, but each set still provides the same amount of cooling. (See Figure 2.)

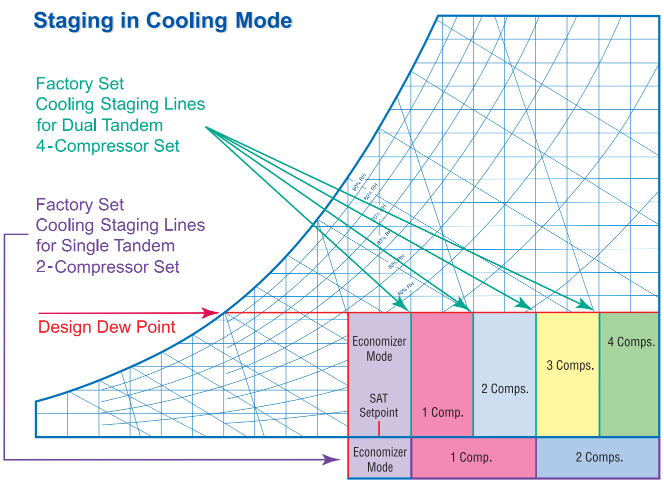

Figure 2 - Compressor Control: Staging Dual Circuit for Cooling

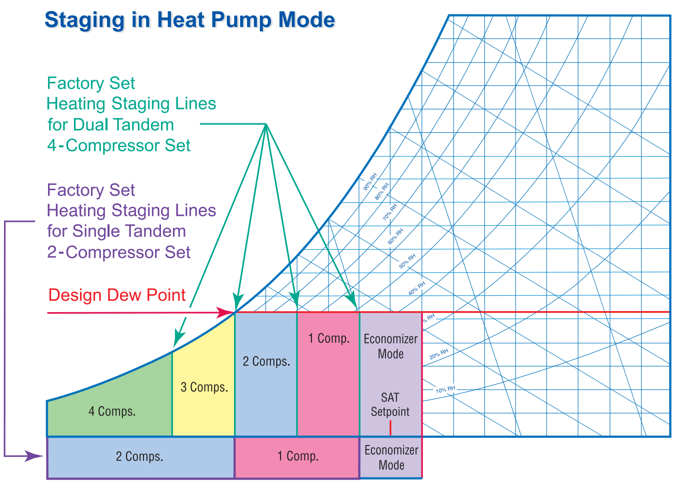

Figure 3 - Compressor Control: Staging Dual Circuit for Heating

If the system is a heat pump unit, the compressor will be energized for the winter heating mode. The controller monitors the outdoor air temperature and calculates the required number of compressors and their staging to extract heat from the loop to maintain the supply air temperature. Again, the staging of a single tandem two-compressor set is different from the staging of a dual tandem four-compressor set, but each set covers the exact same range of heating. (See Figure 3.) In this way the unit matches the variable load as precise as it can without wasting compressor energy. If the unit is not a heat pump, then the auxiliary heater will be energized to maintain the supply air temperature.

Whether providing heating or cooling, the compressor staging offers an economizer mode. The window of temperatures of this mode does not require the compressors to energize because the outdoor air temperature satisfies the required setpoint. (See Figures 2 and 3.) Additionally, the economizer temperature range is field adjustable.

Night Setback Strategy

During the unoccupied mode, the night setback strategy is to close the outdoor air damper and turn off the blower to save energy. However, in some humid environments, there is still a high infiltration rate of moist outdoor air into buildings during unoccupied times creating excessive humidity levels. In these instances, it is desired to add a recirculation damper to the system and turn on the blower and compressors to remove the unwanted moisture during unoccupied times.

Desert Aire has two system configurations that provide night setback. This capability is available on Desert Aire's TotalAire™ series by adding our enthalpy wheel option and an internal mixing damper. (See Figure 4.) Our VerticalAire™ series also offers night setback functionality by adding our mixing box option. (See Figure 5.) For both systems, the Zone Reset of Supply Air Temperature Control package must be ordered to receive the zone sensors. (See next section, *Supply Air Control Strategy.)*

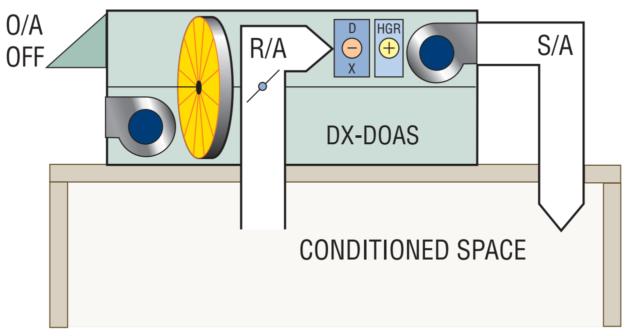

Figure 4 - Diagram of a TotalAire™ Series unit with a wheel in night setback mode.

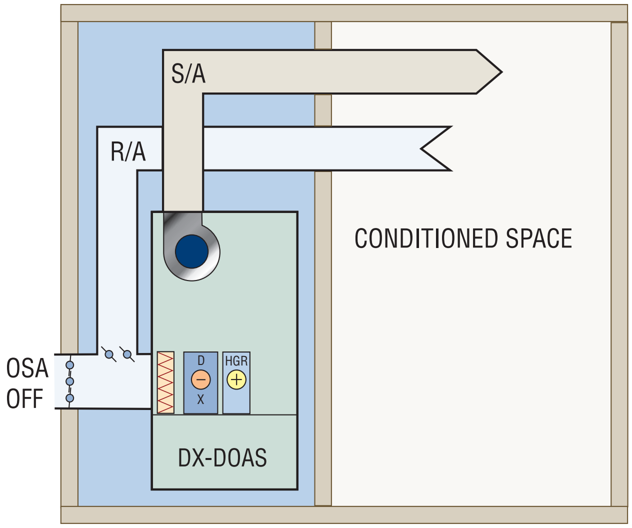

Figure 5 - Diagram of a VerticalAire™ Series unit in night setback mode.

For a night setback mode using an enthalpy wheel, an important assumption is that the return air duct external static pressure will be less than the wheel's pressure drop (approximately 0.3" to 0.6" WC) so that the total pressure drop in both modes of operation remains the same and the supply air volume does not change.

Supply Air Control Strategy

DX-DOAS units can use three unique methods to control supply air temperature.

The first and simplest strategy is referred to as Supply Air Temperature Control. This method maintains a constant supply air temperature (SAT) regardless of the season and space requirements.

However, two other strategies can achieve greater energy efficiency – Zone Reset of Supply Air Temperature Control as well as Outdoor Air Reset of Supply Air Temperature Control. Both of these methods allow the design engineer to integrate the loads of the DX-DOAS and the main air handler. Because supply air temperature control is a byproduct of dehumidification via the DX-DOAS, the main air handler can be downsized to save compressor and fan energy since the latent load is minimized or eliminated for this sensible system.

Supply Air Temperature Control

In this basic mode, the unit always maintains the supply air setpoint value, regardless of the outdoor or inside room temperature. This fundamental control allows the outdoor air to be conditioned to a neutral temperature (e.g. 72° F) in all seasons. The main air handler for the space controls the actual space temperature. This strategy uses a duct-mounted discharge temperature sensor to provide a feedback signal to the PID controller and maintain a precise SAT regardless of the conditions of the entering air. (See Figure 6.) The SAT on the system is maintained at ±0.2° F DB when the compressor is running.

This method enables the DX-DOAS system to deliver neutral air while the main air handler must be sized for the zone's full load.

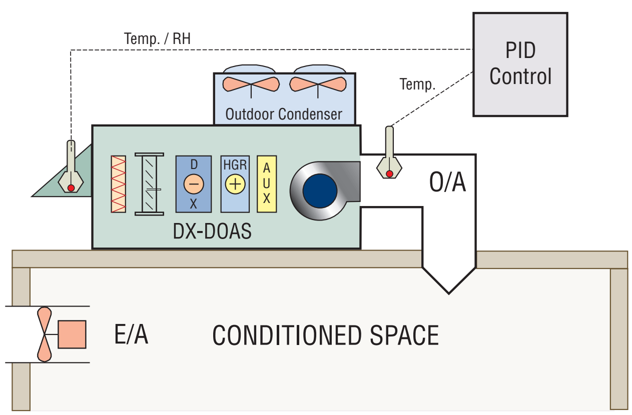

Figure 6 - Supply Air Temperature Control Configuration

Zone Reset of Supply Air Temperature Control

This strategy combines a wall-mounted zone sensor with a duct-mounted sensor to provide supplemental sensible heating or cooling to the conditioned space. (See Figure 7.) The zone sensor completes a feedback loop to the controller such that the supply air temperature setpoint is adjusted to maintain a targeted zone temperature due to changing conditions in the zone. When the system's compressors are energized, the controller will vary the amount of hot gas being rejected to the reheat coil. In the auxiliary heating mode it varies the auxiliary heating output. The controller varies the supply air temperature within a fixed range (e.g., 60° to 95° F) to maintain a room's setpoint (conditional upon system's capacity).

In this strategy, the DX-DOAS unit becomes the first stage cooling or heating system with the main air handler being the second stage. This is best applied if rooms have similar load characteristics.

While a DX-DOAS primarily focuses on dehumidifying and reheating the air, the unit provides a secondary benefit in the cooling mode. Should the space temperature rise above the setpoint, the system can switch to the cooling mode and reject the resulting heat to the condenser. Because the DX-DOAS assumes a large portion of the cooling load, the size of the main air handler can be reduced proportionally to provide second stage cooling.

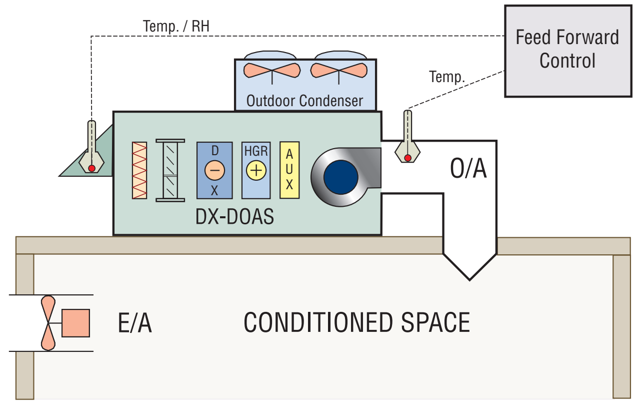

Figure 8 - Outdoor Air Reset Control Configuration

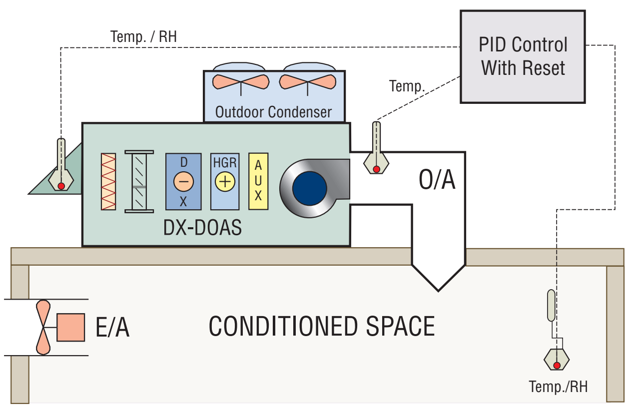

Figure 7 - Zone Reset Control Configuration

Outdoor Air Reset of Supply Air Temperature Control

This strategy uses feed-forward logic in that the controller resets SAT based on the outdoor air temperature. (See Figure 8.) As outdoor air becomes warmer and more humid, the DX-DOAS will identify that the space needs cooling and thus lower the SAT of the system. If the outdoor air turns cooler, it will reset the SAT to a warmer temperature. Four temperature ranges are established. (Refer to Figure 9.) All reset setpoints are adjustable between 60° and 90° F, but cannot overlap.

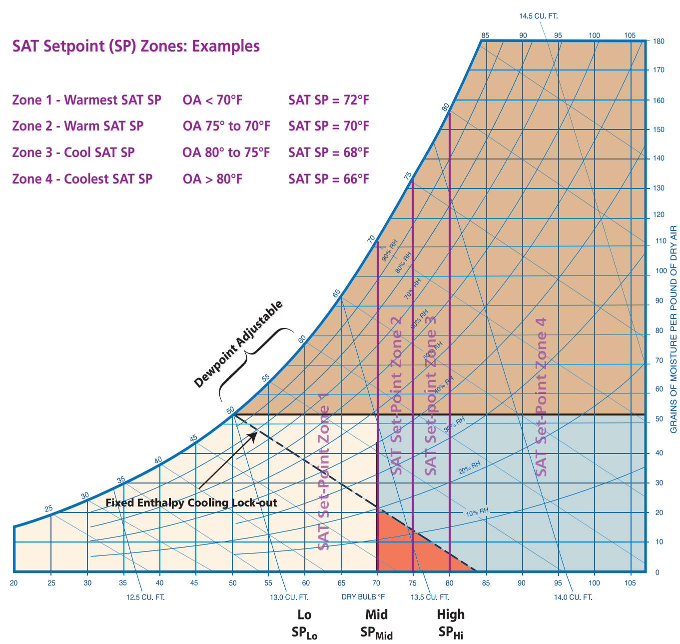

Figure 9 - OSA Reset Mode - Heat Pump Type

Supply Air Control Strategy - Auxiliary Heat Mode

All of these strategies only work when modulating controls are used with the auxiliary heat source. When they are used with gas heating and an energy recovery wheel (ERW), they may not be appropriate with less than an 8:1 turndown ratio. (The gas heater minimum °T must be less than the minimum part load SAT of the ERW and the space setpoint temperature in the heating mode.)

CO_2 Constant Volume (CFM) Control Strategy

As engineers continue to meet ASHRAE 62 ventilation code air flow rates, they also are trying to minimize energy costs where ASHRAE 90.1, LEED programs, GSA P100, or other codes and standards are required. Using additional sophistication in the controls can be an excellent way to minimize energy cost while maintaining proper indoor air quality and building pressurization.

The Ventilation Rate procedure of ASHRAE 62 is a prescriptive procedure that indicates the outdoor air intake flow rate based on the level and type of occupancy as well as the floor area. The Ventilation Rate procedure allows for a dynamic reset of the outdoor air intake flow as operating conditions change. Although the floor area in any building is fixed, the level and type of occupancy may change from day to day or even throughout a single day.

One of the most effective methods of dynamically changing the flow rate based on occupancy is the utilization of CO_2 sensors. Although expected concentrations of CO_2 are not considered a direct contaminant, it is an excellent measurable "tracer gas" that indicates the number of occupants present and their activity level. CO_2 sensors are also relatively inexpensive and durable devices.

Desert Aire TotalAire units can be ordered with a CO_2 control strategy that optimizes the energy efficiency by providing an optimized level of outdoor air at all times. The addition of two CO_2 sensors and variable frequency drives work together to maintain constant total system air flow by recirculating zone air and introducing varying outdoor air flow rates.

Since the zone floor area and the rate required for the floor area are fixed in any one application, the TotalAire unit can be programmed with a minimum outdoor air flow rate to account for this. When a change in CO_2 is sensed due to occupants entering or exiting the breathing zone, the outdoor air dampers account for this change in occupancy. The outdoor air flow rate will vary between the minimum flow rate programmed and 100% outdoor air as needed, always optimizing the indoor air quality and energy use.

The return air is used to maintain the supply air flow rate while the outdoor air flow rate varies. The constant supply air flow rate ensures that the duct system operates as intended. It also ensures that diffusers are able to deliver ventilation air at the correct velocity so that it reaches the breathing zone at all times as required by ASHRAE 62.1.

Desert Aire's basic CO_2 strategy incorporates one indoor CO_2 sensor and one outdoor CO_2 sensor. The controller calculates the differential CO_2 level (ppm) between the indoor and outdoor signals and then uses this value to properly adjust both the outdoor ventilation air and the bypass return air to deliver a constant volume to the space.

For applications that require the same Desert Aire unit to monitor multiple indoor CO_2 sensors, we suggest working with the project's engineer to determine the best method to process these multiple signals into a final, single indoor CO_2 level for the unit to use in the differential calculation. This could be an average of all CO_2 sensors in the space, or using the signal from the one indoor CO_2 sensor detecting the greatest concentration of CO_2.

In any event, the Desert Aire controller will only accept a single input for the indoor CO_2 level and a single input for the outdoor CO_2 level to calculate a final CO_2 differential value. The controller then uses this differential value to modulate the outside air damper and the bypass damper positions in order to provide adequate ventilation and maintain a constant supply air volume to the space.

Furthermore, using a differential calculation eliminates errors in estimating the natural background levels of CO_2 and changes in the levels in urban areas. Also, when sensor drift does occur, the sensors tend to drift in a similar fashion. Calculating a differential helps to ensure accuracy between calibrations.

Desert Aire equipment includes a control loop that further optimizes the outdoor air flow rate by controlling to a specific concentration of CO_2 differential through the use of a PID (proportional/integral/derivative) control loop. In contrast to many other controls for CO_2 which have proportional only control and introduce more air than required during partial occupancy, the TotalAire unit further optimizes energy efficiency by closely maintaining the correct outdoor air flow rate required at any time for any given occupancy.

Since these applications must bring return air back to the unit, it is most beneficial to use an enthalpy wheel to reduce energy consumption. Therefore, Desert Aire does not market a CO_2 controlled unit without an enthalpy wheel. (See Figure 10.)

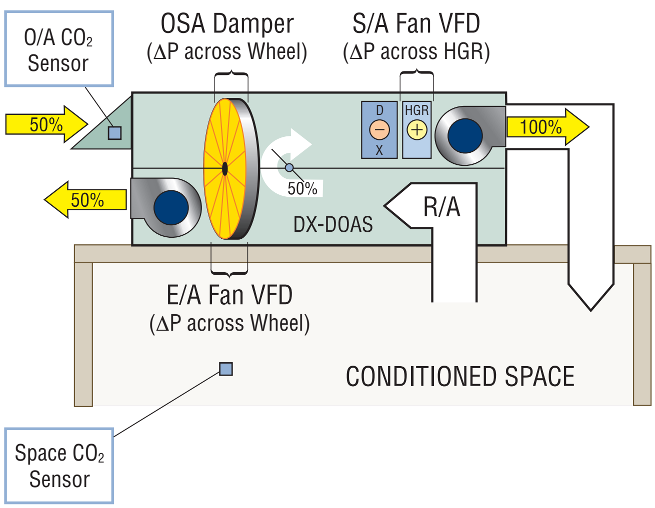

Figure 10 - VFD Control of Fans Using Pressure Sensors

Zone CO_2 > Setpoint (Occupied)

The bypass damper modulates closed and the outdoor air damper modulates open. This continues until the zone CO_2 setpoint is met or 100% outdoor air is introduced. The supply air blower VFD adjusts to an established pressure differential across the hot gas reheat coil. The pressure drop corresponds to the design supply air volume. Also, the exhaust air blower VFD adjusts to an established pressure differential setpoint across the wheel's exhaust air side to maintain design exhaust air volume. Please note that the supply and exhaust air volumes can be different to maintain a design positive pressure in the space.

Zone CO_2 < Setpoint (Occupied)

The bypass damper modulates open and the outdoor air damper modulates closed. This continues until the zone CO_2 setpoint is met or the minimum outdoor air flow rate is sensed. The supply air blower VFD will adjust to maintain the same pressure differential setpoint across the hot gas reheat coil to maintain the specified supply air volume. The exhaust air blower VFD will adjust to a new pressure differential setpoint across the wheel to meet the exhaust air volume.

Unoccupied Time

During unoccupied times, the system can be turned off or enter the night setback mode where the outdoor air is off, the mixing damper opens and the unit controls the humidity within the space based on the standard sequence described in the previous section.

CONCLUSION

Design engineers who implement ASHRAE 62 ventilation requirements are most concerned about occupant comfort and moisture control. Removing moisture from outdoor air provides a cost-effective way to prevent moisture-related IAQ problems. Applying the proper temperature control strategy further enhances the effectiveness of the outdoor air treatment system by precisely controlling the temperature of the air being delivered to the space.

To select the most economical temperature control system, design engineers must take into consideration the size, layout and fresh air requirements of each application. The proper temperature control strategy will offer substantial new energy savings which, in the long run, will ultimately offset the capital cost of installation. With the appropriate dehumidifier and control system in place, a facility can provide its occupants the required level of comfortable, conditioned ventilation air while simultaneously conserving energy.

N120 W18485 Friestadt Road, Germantown, WI 53022 sales@desert-aire.com

Ph: (262) 946-7400 - www.desert-aire.com