PRODUCT APPLICATION

A technical bulletin for engineers, contractors and students in the air movement and control industry

Dedicated Outdoor Air System (DOAS) Fundamentals and Selection Considerations

The need for ventilating sufficient amounts of fresh, conditioned outdoor air into occupied buildings has gained importance as a result of the COVID-19 pandemic that began in 2020.

Filtration and air cleaners do not replace stale, spent recirculated building air with oxygen-rich outdoor air. Indoor air pollutants that need to be exhausted include CO_2 due to building occupants and VOCs (volatile organic compounds) outgassed from synthetic building materials and cleaners. High-occupant building spaces and those with high activity (gymnasiums, exercise rooms, etc.) have higher concentrations of CO_2 that require greater ventilation rates. Significant health benefits of exceeding minimum outside air (CFM/person) defined in industry standards have been identified.[1,2]

Standard rooftop units are not designed (have the capacity) to condition (heat, cool, filter) high quantities of outside air. High-efficiency Variable Refrigerant Flow (VRF) heating and cooling systems do not ventilate buildings and condition outside air. The application of Dedicated Outdoor Air Systems (DOAS) to occupied buildings addresses and solves these issues.

Dedicated Outdoor Air Systems (DOAS)

DOAS units are pre-engineered rooftop ventilators that condition and deliver 100% outside air or mixtures of outdoor air and return air to a building. DOAS units are ideal for 100% outdoor air, variable air volume, and single-zone applications. Multiple unit sizes range in airflow rates from 500 to 18,000 cubic feet per minute (CFM), at external static pressures up to 3 in. wg.

For applications requiring 20 to 100% outside air or night setback operation, an optional recirculation damper can be specified and supplied.

Cooling capacities to cool and dehumidify outdoor air typically range from 3 to 70 tons utilizing cooling options that include packaged direct expansion, chilled water, air-source heat pump, and split direct expansion. Applications requiring humidity control are provided with modulating hot gas reheat to deliver neutral temperature air to the building spaces. The addition of an optional space thermostat with temperature and humidity sensors can be used to control building humidification to keep the space humidity between 30-60% RH during winter months. Heating capacities typically range from 75 to 1,200 mbh utilizing heating options that include indirect gas furnace, electric, and hot water coils.

Optimizing Energy Efficiency

DOAS units are a critical component of a healthy building ventilation system. Building ventilation occurs when fresh conditioned outdoor air is supplied to a building using DOAS, and the stale, spent, oxygen-depleted air is exhausted from the building. DOAS units are designed to efficiently condition large amounts of outdoor air. However, large thermal differences may exist between the outdoor air and a building's exhaust air depending on the building's geographic location and its heating and cooling requirements. In these applications, additional energy savings can be realized by the integration of air-to-air energy recovery within the DOAS unit.

DOAS units incorporating air-to-air energy recovery transfer thermal energy between the exhaust and supply airstreams without the two airstreams mixing. This preheats the supply air in colder months and precools the supply air in hotter months. The result of preconditioning the outdoor air using energy recovery significantly reduces the amount of energy (BTU/h or kW) needed to heat or cool the supply air.

The most efficient air-to-air energy recovery device options in DOAS units are available in two types: total enthalpy wheel or total enthalpy core. Each has distinct advantages. Examples of the operation and performance of the total enthalpy wheel and core are illustrated in Figure 1 and Figure 2 respectively.

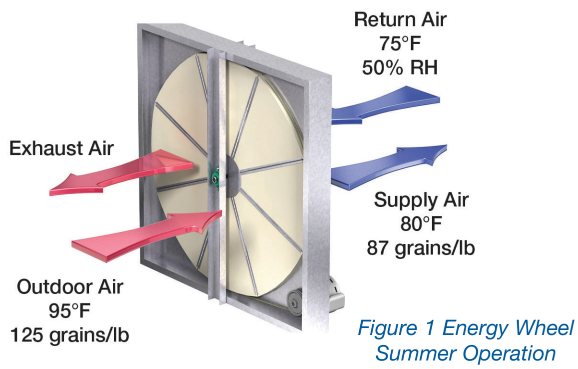


Figure 1 Energy Wheel Summer Operation

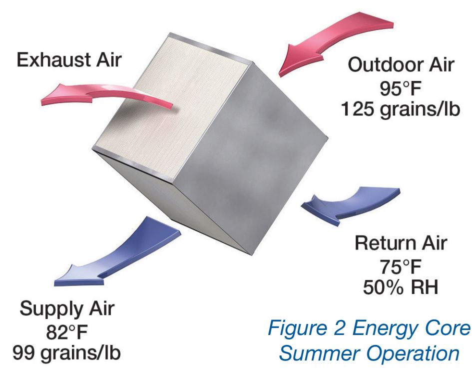


Figure 2 Energy Core Summer Operation

Both types of exchangers transfer sensible as well as latent energy (also referred to as total heat, total energy, or total enthalpy exchangers). They provide energy savings and meet ASHRAE 90.1 minimum efficiencies for sensible and latent heat transfer. These exchangers also dehumidify outdoor air in the more humid climates and humidify the outdoor air in less humid climates using the latent (moisture) content of the return air. The operation/application characteristics of the two energy recovery exchangers are shown in Table 1 below.

Energy Recovery Exchanger	Operation	Energy Transfer Effectiveness	Cross Leakage (EATR)
Total Enthalpy Wheel	Rotates	70-80%	3-5%
Total Enthalpy Core	Static	50-65%	0-1%

Table 1 Application Characteristics of the Energy Wheel and Core

Selecting either energy recovery exchanger type in a DOAS unit is an application/design preference.

- **Total Enthalpy Wheel exchangers** rotate, have motor drives and greater cross leakage, but are more compact in a DOAS unit, and have greater energy transfer effectiveness.
- **Total Enthalpy Core exchangers** are static, have less cross leakage but occupy more space in a DOAS unit, and have lower energy transfer effectiveness.

What is Energy Recovery Exchanger Cross Leakage (EATR) and how does it affect the application?

Energy Recovery Exchanger Cross Leakage or EATR (Exhaust Air Transfer Ratio) is the percentage of exhaust air that will transfer (or recirculate) to the supply air.

The maximum percentage of exhaust air that can be recirculated into the supply air is defined in ASHRAE Standard 62.1 as Types or Classes of air.

Comparing the EATR of the devices in Table 1 with Table 2 below, both types of available DOAS energy recovery exchangers apply to all building classes of air per ASHRAE 62.1 except for Class IV facility exhaust.

Air Classes per ASHRAE 62.1			
Class of Air	Description	Max Recirc EATR	Example
I	Normal Air, Non offensive Low contaminants	100%	Office
II	Non-Harmful	10%	Bathroom
III	Significant Contaminants	5%	Vet Office
IV	Hazardous	NONE	Lab/Bio

Table 2

Energy Recovery Considerations

The International Energy Conservation Code (IECC) section C403.7.4 states that *when an air economizer is required, the energy recovery system shall include a bypass **OR** controls that permit the operation of the economizer.*

A bypass damper is not required when the energy wheel is sized to handle the total supply airflow. There are reasons to avoid wheel bypass. Properly sized bypass dampers take up space in the DOAS unit. Two ways to address this extra required space are:

1. Increase the cabinet size
2. Decrease the energy wheel size

Both options, however, result in negative effects. A larger cabinet increases the size and weight of the unit as well as the unit cost, which lengthens the payback period of the energy recovery application.

Regarding the energy wheel size, larger wheels are more effective during cooling and heating hours. This is because larger wheels have higher recovery effectiveness. Also, many geographic locations have limited economizer hours. The fan energy savings that can be achieved using bypass dampers are therefore limited and oftentimes offset by the lower wheel effectiveness of a smaller energy recovery wheel. Stop/jog or modulating wheel economizer sequences are a more efficient and economical option in areas with limited economizer hours.

Proper defrost management is an additional consideration for the proper selection of energy recovery in DOAS units. A winter defrost cycle keeps the supply fan and heat source operational, not shutting down the unit to defrost while maintaining consistent space temperature and ventilation. Possible required maintenance of the energy recovery device should also be considered.

Table 3 summarizes DOAS unit system configurations with total enthalpy core versus total enthalpy wheel, typical airflow ranges, effectiveness, cross leakage (EATR), frost control, and economizer options.

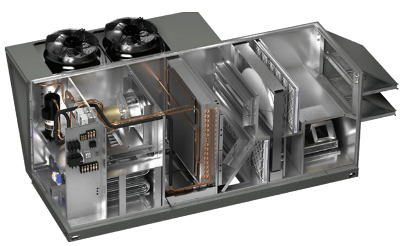
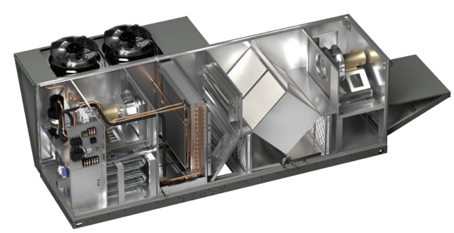
	Total Enthalpy Wheel	Total Enthalpy Core
		
Airflow Range	500-18,000 cfm	500-15,000 cfm
Effectiveness	70-80%	50-65%
Cross Leakage	3-5%	0-1%
Frost Control	Timed Exhaust Modulating Wheel Electric Preheater	Timed Exhaust Energy Core Bypass Electric Preheater
Economizer	Stop/Jog Wheel Modulating Wheel Energy Wheel Bypass	Energy Core Bypass

Table 3: Dedicated outdoor air system configurations with total enthalpy core versus total enthalpy wheel

The Importance of Independent Third-Party Certifications

DOAS unit assemblies and components should be independently tested and certified in accordance with accepted industry standards. This assures the specifier and owner that the unit will not only perform as the manufacturer states but also achieve the energy efficiency required and expected. The following standards apply to dedicated outdoor air systems:

- DOAS unit assembly shall be certified through the U.S Department of Energy (DOE) to meet minimum energy requirements.*
- Unit assembly sound data shall be tested and provided in accordance with AMCA 320-07.
- The entire unit shall be ETL certified per UL 1995 and bear an ETL label.
- DOAS unit energy recovery devices should be tested and certified in accordance with the AHRI testing procedure 1060.
- Heating and cooling Coils shall be Recognized Components for ANSI/UL 1995, CAN/CSA C22.2 No. 236.05, and AHRI (Air Conditioning, Heating and Refrigeration Institute) certified performance.
- Indirect gas-fired furnace shall be ETL certified as a component of the unit.
- Fans shall be tested for air and sound in accordance with AMCA standards.
- Dampers shall be tested and certified in accordance with AMCA standards.
- Electric heating coils shall be tested and certified to UL 1966 and bear a UL label.

** The Department of Energy (DOE) is the regulating body through Federal law that establishes minimum efficiencies for rooftop equipment as described in the Code of Federal Regulations (10 CFR 431 Subpart F). **To be able to sell products in the United States, a manufacturer must be certified through the DOE and meet minimum efficiency requirements.***

Specification Guidelines for Required Operation and Performance

Several product features should be considered when specifying a DOAS unit to meet the needs of a particular application. Many manufacturers assemble DOAS units using purchased standard components. Consideration should be given to manufacturers that design and construct their own fans, coils, dampers, indirect gas furnaces, and unit curbs that are specifically designed for DOAS applications. When evaluating manufacturers, pay attention to the product features offered as standard that will protect and enhance the unit's performance versus those offered as options. Exceptional DOAS designs include ease of unit start-up and control and sufficient access to unit components for future service if ever needed.

DOAS units must withstand weather and environmental conditions. Sunlight, heat, cold, wind, snow, rain, and air pollution all can negatively impact the DOAS cabinet exterior, potentially causing visible signs of deterioration. This deterioration may affect internal components. Two features that protect against this deterioration are a coated exterior finish on the DOAS cabinet and an injected foam insulation sealing the interior cabinet. Rusting or peeling finishes create more issues than aesthetics. Good finishes seal the metal, protecting it against chalking and corrosion. Baked powder coat finishes for DOAS units are superior and are salt spray tested which simulates years of continuous ambient exposure. The finishes can withstand the most severe conditions, maintaining the integrity of the cabinet.

The foam-injected double wall cabinet of a DOAS unit does more than protect the components against temperature extremes that may affect performance. The two-inch thick, double wall foam injected R-13 insulation reduces the amount of exterior condensation and maximizes thermal efficiency. The injected foam insulation goes into all the possible crevices of the cabinet frame to make sure no voids in the insulation exist. Additional benefits of the injected foam insulation are its ability to add extra strength (rigidity) to the cabinet and improve sound attenuation, making for quieter operation.

Real-world applications for DOAS units demand cost-effective solutions—many that should be standard features. DOAS units can be loud. Still, good manufacturers consider noise pollution reduction a fundamental feature. For example, the DOAS unit design should address the concern of radiated sound, providing more locations for installation. One solution to this challenge is using ultra-quiet condenser fans on a DOAS unit. These fans reduce noise by 12 decibels. The ramifications of this reduction are significant. Ultra-quiet condenser fans allow normal conversation even when standing next to the unit while it is operating. This feature allows for more freedom in placing units on rooftops without workers or building occupants complaining about excessive noise.

Digital scroll compressors used by many manufacturers, whether unloaded or loaded, generate much more noise than the inverter scroll compressor. DOAS units should have compressors that deliver efficient operation tied to the level of demand. Digital scroll compressors can handle the requirements, but inverter scroll compressors offer better efficiency, particularly at part-load operation. Inverter scroll compressors also offer smooth modulation based on the level of demand.

All DOAS units shipping from the factory, when installed, should provide the proper airflow required for a specific application, ensuring the expected performance. However, air distribution design and revisions over time can affect airflow. Applying airflow measurement as a feature on DOAS units provides a visual confirmation that the unit operates as required. This simple feature eliminates doubt that the unit is not operating at peak performance and reduces troubleshooting time to identify issues such as dirty air filters, clogged coils, and other operational challenges.

As previously discussed, saving energy is a must, particularly considering operating cost inflation. Energy recovery devices, such as enthalpy wheels and cores, reduce energy costs by transferring latent and sensible heat between the supply and exhaust airstreams. Many manufacturers offer these energy-saving devices as a standard feature. Still, it is critical to ensure the energy recovery devices perform as expected as these components significantly reduce the energy needed to heat or cool fresh, outdoor air. The enthalpy wheel must be sized for the full 100% outdoor air volume. If an enthalpy wheel is applied undersized, costly ramifications can occur reducing energy efficiency, adding unnecessary cooling, and increased moisture may result. This process, called short-circuiting, results from improper sizing of the wheel or the use of a smaller DOAS cabinet. Short-circuiting is different from the use of an economizer bypass. Enthalpy cores have a similar use as the wheels, but generally, for applications requiring less CFM. These cores have no moving parts reducing maintenance costs.

When heating of the outdoor air is required using natural gas, the indirect gas-fired furnace should be provided with 16:1 turndown for superior temperature control and energy efficiency. This is specifically important to prevent overheating of the space or eliminating excessive furnace cycling when small reheat temperatures are required.

A microprocessor controller provided as standard and pre-programmed is a must. The controller operates the DOAS unit as either “stand-alone” or integrated with a Building Management System (BMS) using BACnet® MS/TP or IP, or Modbus® RTU or IP protocols. This controller operates the unit in a safe and energy-efficient manner while maintaining temperature and humidity set points. Whether DOAS units will operate “stand-alone” or integrated with a building management system, accurate airflow and temperature control should be achieved by using a nonproprietary microprocessor controller. To ensure ease and timely unit start-up and operation, the controller must be factory-programmed for the specific application, wired, and tested prior to shipment. Microprocessor controls that are intuitive with a web-user interface allow users to monitor and control unit status remotely and aid in making performance adjustments and troubleshooting.

Installation and Maintenance

Additional items to consider when selecting DOAS units for ease of installation: unit-provided lifting lugs, early shipment of unit curbs for installation, and side or bottom duct connections for air inlets and outlets.

Regardless of DOAS unit quality, all equipment will require, at some point in time, maintenance to ensure proper operation. Good unit design includes adequate internal service space for quick and easy maintenance and repair of all serviceable components. Hinged access doors on all compartments of the unit to service internal components (coils, fans, etc.) with mechanical latches ensure repeatable opening access and proper sealing from weather that common access panels with screw fasteners do not provide.

Conclusion

The continuous good health of children in schools, employees at work, customers, and guests in the buildings we design, construct, and maintain is of paramount concern. Many good practices contribute to creating a healthy and safe environment for building occupants. But none is as important as the quality of air that we breathe. Stale, contaminated, spent, oxygen-depleted air from occupied zones in buildings must be exhausted and replaced with fresh, clean, oxygen-rich outdoor air. And doing so should be accomplished in a sustainable manner. The application of dedicated outdoor air systems incorporating total enthalpy air-to-air energy recovery supplies the required healthy air to protect occupants in commercial buildings of all types.

[1] “Cognition* and decision making and CO_2 / ventilation”, 2016 Harvard University

[2] “Indoor SARS-CoVid-2 Herd Immunity and Infection Probability Estimates based on Ventilation, Vaccinations, Infections and Face Masks”, Ty Newell, Ph.D., PE, University of Illinois

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