Getting the Most Out of DOAS: Energy Modeling Guidelines for Configuration and Verification

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Agenda

1. Review Goals of Webinar
2. About Very High Efficiency DOAS and efforts by NEEA
3. Creating a VHE DOAS Energy Model
   1. Configuring two systems serving one zone
   2. Ventilation fan power and control
   3. Bypass and supply air control
   4. HRV/ERV defrost
   5. DX-DOAS cooling
4. Lessons Learned in Modeling VHE DOAS
5. Steps to Verify and Self-Check a Model
Goal of Webinar

1. Provide a brief overview of what VHE DOAS is and where to find more information
2. Provide energy modeling techniques to configure a VHE DOAS systems.
About VHE DOAS

Very High Efficiency Dedicated Outside Air Systems

https://betterbricks.com/solutions/very-high-efficiency-doas
Relation to WA Code and ASHRAE 90.1

• **VHE DOAS, in efficiency criteria to WA Code**
  • sits above the WA 2018 base code and
  • has some aspects which are better than or worse than the WA 2018 Advanced DOAS Package
  • requires higher sensible recovery effectiveness and provides a prescriptive or design condition requirement.
  • Currently requires electric heat pump systems while WSEC allows a wider range of technologies.

• **VHE DOAS, in efficiency criteria to ASHRAE 90.1 2019**
  • Chapter 6 Considerations:
    • Ventilation Zone Isolation (6.4.3.3.4) may require multiple DOAS units in buildings > 25,000 sf to avoid active ventilation zone damper control (VAV boxes) to save cost
    • With Exhaust air heat recovery (6.5.6.1) systems can avoid demand control ventilation in units >3,000 cfm
    • To maintain ventilation only-duct work without a full economizer requires cooling fan coils < 54,000 Btu/hr or, higher efficiency rated cooling unit (exception 11 to 6.5.1)

https://betterbricks.com/resources/doas-comparison
VHE DOAS Configuration

In Energy Modeling Software

1. Configuring two systems serving one zone
2. Ventilation fan power and control
3. Bypass and supply air control
4. HRV/ERV defrost
5. DX-DOAS cooling
Configuring Ventilation and Space Conditioning Systems

1. High efficiency heat/energy recovery ventilator (HRV/ERV) with ≥82% sensible effectiveness

2. High performance electric heat pump system

3. Fully decoupled ventilation from heating and cooling

4. Right-sized heating and cooling system
Example of Two Systems Serving One Zone, VE-IES

Wizard systems builder showing the two systems serving one zone.

Active system diagram for system components, showing the system in one box and the sub-zone-system in the green box.
Example of Two Systems Serving One Zone, OpenStudio

DOAS System

Space Conditioning System

- OA Electric Backup Heat
- HRV/ERV Device
- DOAS Return Fan
- DOAS Supply Fan
- Zone Ventilation Air Diffuser
- Zone VRF Fan Coil
- Ventilation Air Diffuser

- NAV No Rm Core
- DOAS Air Loop
- Zone VRF Terminal Unit
- Block1 Core Thermal Zone
- Block1 East Thermal Zone
- Block1 North Thermal Zone
- Block1 South Thermal Zone
- Block1 West Thermal Zone
Example of Two Systems Serving One Zone, EnergyPlus

The order of sequencing is important specifically in EnergyPlus to ensure proper thermostat control. Ventilation must go first to introduce outdoor air and space conditioning systems second to fully condition all loads.
Example of Two Systems Serving One Zone, eQuest
DOAS Ventilation Fan Power

- The total power of the supply and exhaust fans providing ventilation.
- Not all drawings will list all information needed, typical will only give external static.
- Where information is lacking, estimating the operational fan power can greatly increase energy estimate vs assuming full power.

\[
\text{Fan power (Watts)} = \frac{746 \times TSP \times cfm}{6345 \times \text{fan efficiency} \times \text{fan motor efficiency}}
\]

- Design fan power for the supply and exhaust: 2.0 cfm/watt to 1.3 cfm/watt.
- Field measured with VHE DOAS: 2.7 cfm/watt to 1.3 cfm/watt.

\[TSP = \text{Internal Static} + \text{External Static}\]
Zone Fan Controls and Ventilation Configuration

Ensuring fans cycle fully off in an energy model.
Zone Fan Power: Fan Coils, Fan Cassettes

- The greatest energy savings and criterion of VHE DOAS is the ability to fully cycle fans off when not in use.
- Often non-ducted systems will be 0.75 inches or less of total pressure, ducted will be 1.5 inches or less.
- Peak fan power should be within the range of 0.3 to 0.65 watt/cfm.
- Most fan cassettes or fan coils operate at 75% or less of rated motor capacity.

![Image of fan cassette](image-url)
EnergyPlus Zone Fan Control Examples

Decoupled Fan, Able to Turn-Down to 0% Flow

Coupled Fan, Always On at 60% Minimum Flow
Office buildings and higher-education/office buildings.

Major observation between sites is the zone fan units configured in a decoupled configuration used less than 50% versus sites with coupled configurations.
Heat Recovery, Bypass, Supply Air Controls

Common Control Capabilities of VHE DOAS Units:

1. Supply air setpoint. Controller will modulate bypass to meet the setpoint.

2. Ventilation economizing, bypass limits to modulate free cooling.

3. CO2 control, where the controller will modulate the volume of OA within limits, based on return CO2 signal.
Ventilation Heat Recovery (HRV)

VHE DOAS Requires units be able to achieve a sensible heat recovery threshold in one of many ways:

- Passive House Institute (PHI) certified or,

- Minimum 82% Sensible Effectiveness of HX per AHRI 1060-2018 software at winter conditions and 75% nominal airflow and winter condition

- Minimum HRV HX of 82% sensible effectiveness at winter and summer design temperatures and airflows.

**Full heat recovery mode**
HRV/ERV Bypass and Supply Air Control

- **Non-Integrated bypass** – Bypasses the heat recovery device fully when conditions are satisfied

- **Integrated bypass** - modulate the bypassed airflow from partial bypass to full, often controlling the amount of air that is bypassed to achieve a set supply air temperature.
Analysis of Operational Bypass

Economizer Typical Range, 55-75F

Partial bypass operations

Full bypass operations
HRV Supply Air Temperature + Bypass

Observed control closest to Supply air control to a fixed setpoint (65) with partial bypass control

Energy 350 Office

EnergyPlus Sample HRV SAT Control Sequence
Implementing: EnergyPlus

The ‘Economizer Lockout’ effectively enables and disables the bypass when OA is within set limits. It is on or off.

The Supply Air Outlet Control modulates the bypass, allowing air to mix whenever it can achieve the set setpoint.

- **Integrated bypass** - modulate the bypassed airflow from partial bypass to full, often controlling the amount of air that is bypassed to achieve a set supply air temperature.

- **Non-Integrated bypass** – Bypasses the heat recovery device fully when conditions are satisfied.
EDSL-TAS allows for a more visual representation of bypass control of an air to air heat exchanger in an energy model and can allow the system to bypass not just based on a supply air setpoint but any temperature in a system. In the example below, the bypass is controlled based on outdoor air dry-bulb, bypassing when the outdoor air is above 42F until it is 65F and fully open.
HRV/ERV Defrost Configuration and Controls

Ice can build-up at this point in the core

Typically, this will control to an exhaust air setpoint above freezing such as 40F or above to ensure the unit is protected.
Defrost Heat Control Examples

- **control node**: Establishes a point of control. Can reference other nodes in the diagram.
- **heating element**:
DX-DOAS Cooling Coil Controls

• DX-DOAS cooling systems are intended to be used for dehumidification and moisture control.

• Ensure the model controls the cooling unit as configured. Several units use a simple OA lockout, enabling cooling above a set dry bulb or measurable moisture threshold.

• Recommendation:
  • In Pacific Northwest, with relatively dry-air, limit the DX-DOAS cooling element to times when OADB exceeds 70F.

Report includes example Energy Management System (EMS) to only allow the cooling coil in the DOAS to be available
Lessons Learned in Modeling
VHE DOAS
Calibrated Energy Model Field Studies

Single Story Existing Office, Portland OR

Two Story New Office, Portland OR

Multi-Family Housing, WA

Elementary School, WA
Building Data and Calibration Process

Building Data Available

• Calibration of 8 to 10 months of data for two different office buildings
• Calibration of 7 to 15 months of data for multi-family building phases
• Calibration goal: within 5% to 10% of each HVAC end use measured, fans, heating, and cooling
• Data sets obtained:
  • Interval, 15-minute data, on HVAC end uses for power and ventilation temperatures to estimate heat recovery
  • Monthly data for other end uses, equipment, lighting, misc.
  • Outdoor weather at 15-minute data

Calibration Process:

1. Calibrate internal gains based on end-use monthly / annual data
2. Calibrate HVAC run time and thermostats
3. Calibrate operational fan power, DOAS and zone
4. Calibrate HRV effectiveness, bypass control, operational SAT setpoints
5. Calibrate as-built envelope leakage to heating and cooling power use, based on as-designed system efficiencies (COP, EER)
6. Simulated Alternate HVAC System Options
With calibrated internal gains, HVAC usage increased by 67%, primarily in heating, vs using standard assumptions.
• Comparison of HVAC systems with standard system efficiencies, evaluated with two sets of assumptions for internal gains and envelope leakage; Prototype and Calibrated.
• With Calibrated assumptions on gains, heating energy and fan power to move the heat increase in both types of RTU units, CAV and VAV.
Not a full VHE DOAS system configuration:

- Use of coupled fan coils, remaining on when occupied
- DOAS fan power at 1 cfm/watt
Coupled zone fan coils and a DOAS unit with ventilation fan power at 1 W/ft².

With a full VHE DOAS configuration:
- The fan energy would have been reduced by 65%.
- Total HVAC costs could have been reduced by 27%
Multi-Family Building, Seattle WA

- Calibrated building envelope and internal gains from over 12 months of data on HVAC system trends, fan power, apartment heating.

- Developed a calibrated prototype building to then compare different HVAC system options:
  - Full VHE DOAS with apartment heat pumps
  - Exhaust Driven Ventilation with apartment heat pumps
  - WA DOAS with apartment heat pumps
In multi-family apartments, HVAC can be reduced by 32% with a conventional balanced ventilation system and by 43% with exhaust driven ventilation.
Key Energy Targets for Modelers

These targets can provide an energy modeler with a way to quality-check their work is reasonable for a building type.

From these sites key observations about the energy use of each component can be made based on also knowing how the systems were configured relative to one another and were analyzed to develop general system performance indicators for this report and systems in general.

**DOAS Unit Fans**

<table>
<thead>
<tr>
<th>Description</th>
<th>kBtu/sf·year (hrs/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DOAS ventilation fan energy when operating 24/7</td>
<td>3.6</td>
</tr>
<tr>
<td>Under normal hour (approx. 4,500 hrs/yr)</td>
<td>1.2 (67% less energy)</td>
</tr>
<tr>
<td>HRV/ERV site energy use (approx. 4,500 hrs/yr)</td>
<td>0.8 (78% less energy)</td>
</tr>
<tr>
<td>DX-DOAS + exhaust fan (approx. 4,500 hrs/yr)</td>
<td>1.8 (50% less energy)</td>
</tr>
</tbody>
</table>

**Zone Terminal Unit Fans**

<table>
<thead>
<tr>
<th>Description</th>
<th>kBtu/sf·year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coupled Fan Coils</td>
<td>2.8 (4,500 hrs/yr)</td>
</tr>
<tr>
<td>Decoupled Fan Coils</td>
<td>0.8 (71% savings)</td>
</tr>
<tr>
<td>Coupled Fan Coils + DCV Dampers</td>
<td>1.6 (43% savings)</td>
</tr>
</tbody>
</table>

**Cooling Energy in DX-DOAS**

DX-DOAS cooling elements were observed to use 0.3 to 0.7 kBtu/sf-year, with the number of warm days being the largest difference between sites for increased energy.
Key Findings of Calibrated VHE DOAS Process

Typical High Concerns with DOAS
1. DOAS fan energy will be high due to constant volume airflow
2. Cooling energy will be high due to no airside economizing and internal gains

Actual Areas of Concern Identified
1. Zone fans, if configured poorly, can use significant energy from being on all the time
2. Heating energy can be significant. Thermal bridging, old envelopes. High efficiency heat recovered extremely valuable

Typical Low Concerns
3. Zone fans are so small and are modular and likely use little energy
4. Commercial buildings use little heat, so basic heat recovery is good enough

Actual Low Concerns
3. DOAS fans tend to be low pressure, low energy and are over engineered.
4. Cooling energy tends to be far less than predicted (lower actual building use)
• Providing technical analysis support and recommendations using lessons learned and time-tested methods.

• Enhancing energy modelers’ accuracy in predicting energy use and future savings for very high efficiency DOAS in typical commercial building applications.

https://betterbricks.com/resources/energy-modeling-guide-for-very-high-efficiency-doas
Thank You & Questions

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