November 2016, Issue V

Improving Climate Beam Performance with Demand Control Ventilation

IN THIS ISSUE

- Comparing energy models for constant volume and VAV climate beams
- Thermal comfort improvements with VAV climate beams
- Sizing VAV climate beam systems

INTRODUCTION

Climate (chilled) beam designs are known for their high performance when considering thermal comfort, IAQ and energy. Over the last few years the climate beam design concept has been improved by introducing Variable Primary Airflow (VAV) controlled by indoor air quality (Demand Control Ventilation – DCV). Varying the primary airflow rate improves energy performance by reducing the amount of air being conditioned and the fan work to move the air to and from the occupied space. It also improves thermal comfort by providing 10 to 1 turndown on the climate beam capacity thus avoiding potential over cooling of the space.

In this Technical Bulletin a constant volume climate beam system will be compared to a DCV Climate beam design using Swegon's ESBO energy modeling software (see side bar).

BUILDING MODEL

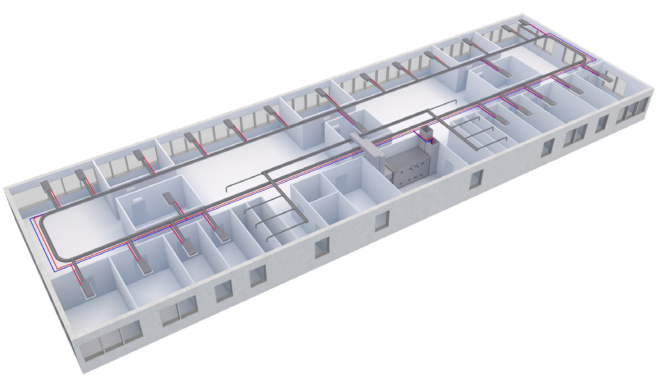


Figure 1 – Model building

SwegonESBO

Swegon ESBO building load and energy modeling software was developed in collaboration with EQUA. EQUA is a market leader in Europe for building design software. EQUA software is ASHRAE 140-2004, CEN Std 15255, 15265 and 13791 complaint. One key advantage of use European based software is their experience and ability to model constant volume and DCV climate beam systems.

For this comparison, an 8000 ft² (743 m2) office space in Chicago was modelled. The space includes private offices, general office, three conference rooms and a canteen for employees. The HVAC system comprises 32 Swegon Parasol 4-way throw climate beams with both heating and cooling capacity (4 pipe system). Parasol climate beams come in both constant volume and VAV versions (see back page). The Primary air handling unit is a Swegon GOLD RX 20 unit with AHRI 1060 certified enthalpy wheel, integrated controls and EC motor direct drive plenum fans. The Primary supply air temperature is 55 °F (12.8 °C).

DESIGN PARAMETERS

Design occupancy is 40 persons:

- Light load: 1 w/ft² (10.76 w/m²)
- Equipment (plug) load: 2 W/ft² (21.52 w/m²)
- Typical wall construction with 18% thermal window area
- Design primary airflow rate: 2800 cfm (1321 L/s) or 0.35 cfm/ft² (1.78 L/s/m²)
- ASHRAE Standard 62.1-2013 ventilation rate: 909 cfm (429 CFM) or 0.11 cfm/ft² (0.56 L/s/m²)
- The ASHRAE Std 62.1-2013 minimum unoccupied airflow rate: 508 cfm (240 L/s) or 0.063 cfm/ft² (0.0365 L/s/m²) based on the Rz calculation

The higher primary airflow rate (above Std 62.1) is based on meeting the latent space load.

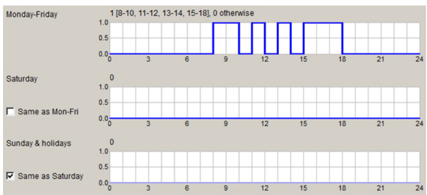
SCENARIO 1 – CONSTANT VOLUME CLIMATE BEAMS, 100% OCCUPANCY

As a baseline scenario, the building operates with a constant volume climate beam system and assumes 100% occupancy during business hours. Figure 2 shows the load profiles for lighting, equipment loads, occupancy and fan operation.

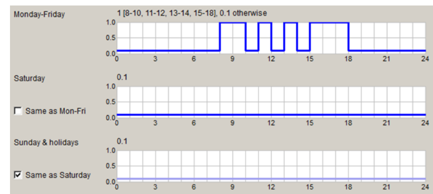
Figure 2 – Constant Volume Climate Beams, 100% Occupancy Load Profiles

PRIVATE OFFICE

Occupancy

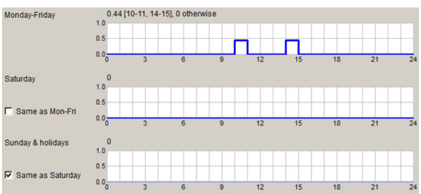


Equipment

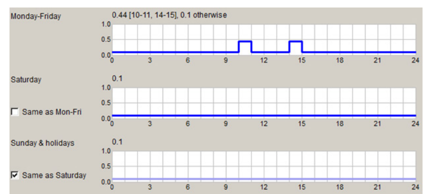


CONFERENCE ROOMS

Occupancy

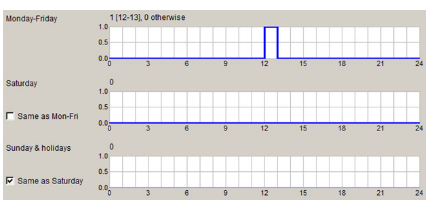


Equipment

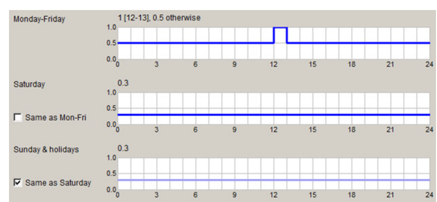


CANTEEN

Occupancy

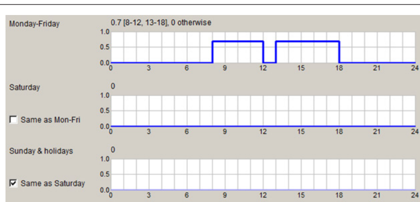


Equipment

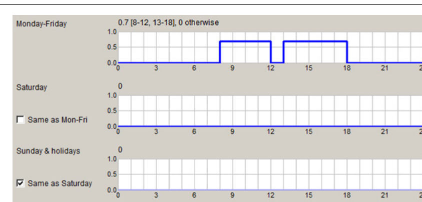


OPEN OFFICE

Occupancy

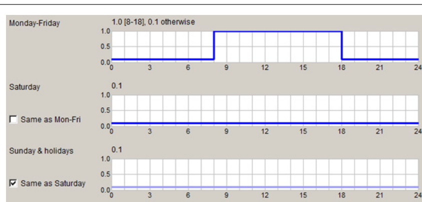


Equipment



LIGHTING AND FANS

Occupancy

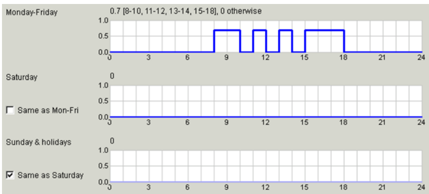


SCENARIO 2 – CONSTANT VOLUME CLIMATE BEAMS, 70% OCCUPANCY

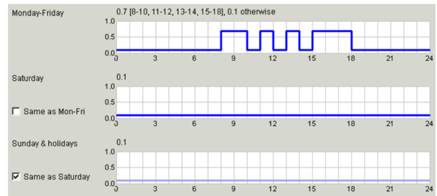
Figure 3 – Constant Volume Climate Beams, 70% Occupancy Load Profiles

PRIVATE OFFICE

Occupancy

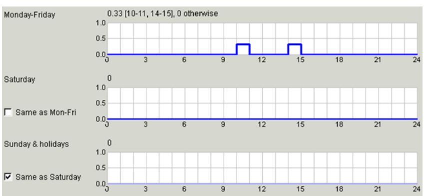


Equipment

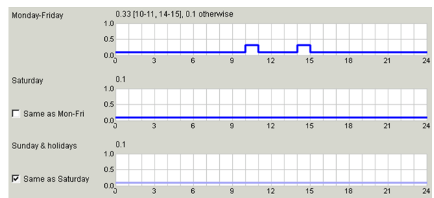


CONFERENCE ROOMS

Occupancy

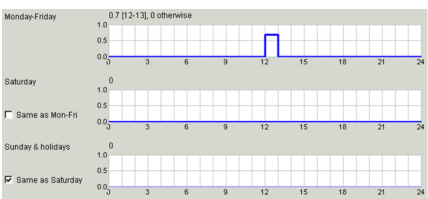


Equipment

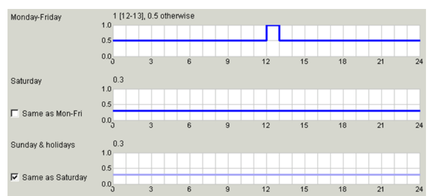


CANTEEN

Occupancy

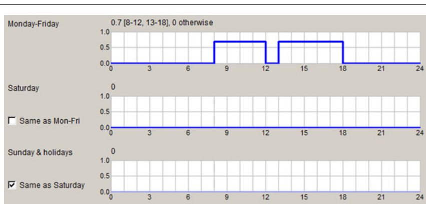


Equipment

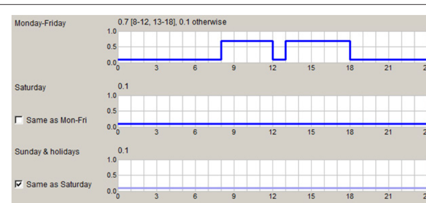


OPEN OFFICE

Occupancy

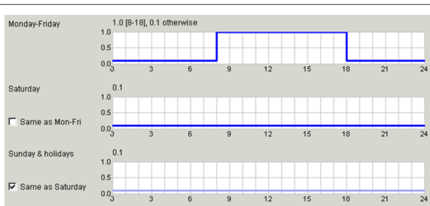


Equipment



LIGHTING AND FANS

Occupancy



Studies[1] have shown that office space occupancy ranges from 30% to 70%. In scenario 2, the occupancy is lowered to 70% and the occupancy profiles were adjusted as shown in Figure 3. Staff are moving around the building throughout the day. The equipment loads were also adjusted based on occupancy. Lighting loads remain unchanged and the fan operation is constant during occupied hours.

[1] Von Neida et al and Maiccia et al found daytime occupancy between 6 am and 6 pm was 40% for break rooms, 26% for class rooms, 20% for conference rooms, 33% for single person offices and 33% for restrooms.

SCENARIO 3 – DEMAND CONTROL VENTILATION (DCV) CLIMATE BEAMS – 70% OCCUPANCY

In the final scenario, DCV ventilation is introduced. All zones now have Swegon PARASOL VAV climate beams that can vary the primary airflow rate while maintaining proper induction rates. Each zone is equipped with Carbon Dioxide (CO_2) sensors that vary the primary airflow rate based on indoor air quality. The same profiles are used from Scenario 2 (see Figure 3).

ENERGY PERFORMANCE RESULTS

Figure 4 – Annual Energy Usage Summary

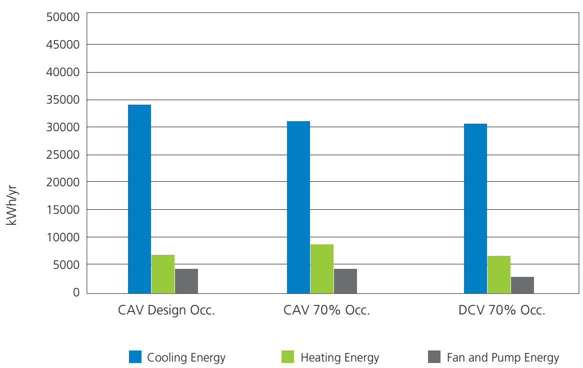


Figure 4 shows the annual heating cooling, and fan plus pump energy loads in kWh/yr for the three scenarios. Constant volume - 100% occupancy and constant volume 70% occupancy only differ by 2%. However, DCV uses 14% less energy than the constant volume – 70% occupancy scenario.

Figure 5 – Monthly Energy Usage Comparison

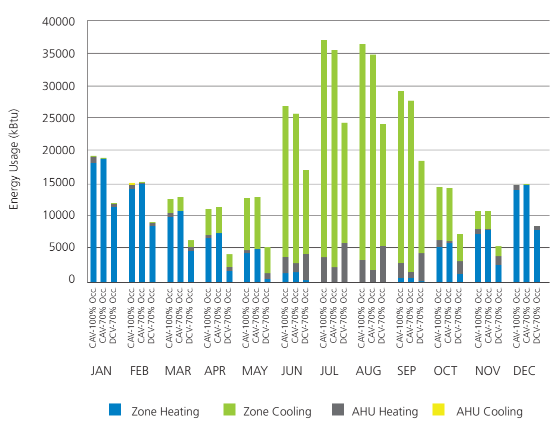


Figure 5 shows the monthly energy usage by the climate beams and primary AHU for all three scenarios. The DCV approach uses significantly less energy every month. Closer inspection reveals the following;

- The DCV system performs 60% of cooling at the beams annually while the constant volume approach only performs 34% of the cooling at the beams. While the annual building cooling load does not change (same building, people, lighting and equipment loads) there is a big difference in how the heat is removed. By using more water than air, the DCV uses 37% less fan + pump work.
- The constant volume system has higher zone heating loads indicating that reheat is occurring. The constant 55°F (12.8 °C) primary airflow overcools some zones.
- There is almost zero heating occurring at the primary AHU. The GOLD enthalpy wheel provides all the necessary heat greatly reducing the operating cost.

Figure 6 – Monthly Fan + Pump Energy Usage

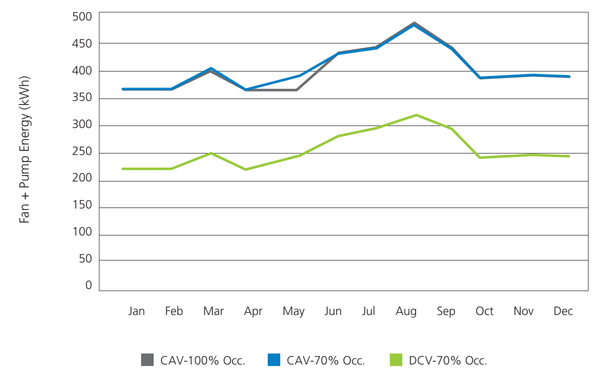


Figure 6 shows the monthly energy usage for the chilled and hot water pumps and the supply and return fans in the primary air unit. This represents the cost for transportation energy for the three scenarios. The two constant volume scenarios are virtually the same. The DCV system fan and pump work is 37% less than the constant volume system.

Figure 7 – Overall Annual Energy Usage

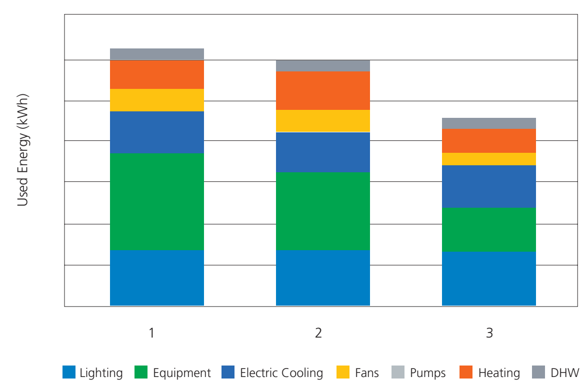


Figure 7 shows the whole building annual energy usage including equipment and lighting as well as HVAC. Improving the HVAC energy usage by 6% with DCV control gives significant improvement to the overall annual performance with the Energy Use Intensity (EUI)[2] improving from 25.4 kBtu/ft²-yr (80 kWh/m²-yr) to 23.8 kBtu/ft²-yr (75 kWh/ m²-yr).

Overall, energy savings offered by demand control ventilation make it the best way to improve a climate beam design.

[2] EPA Energy Star Portfolio Manager lists office EUI at 66,800 Btu/ft²-yr (210.73 KW/m2-yr).

REAL WORLD RESULTS

Figure 8 – Measured Airflow Log with DCV for 1 Year[3]

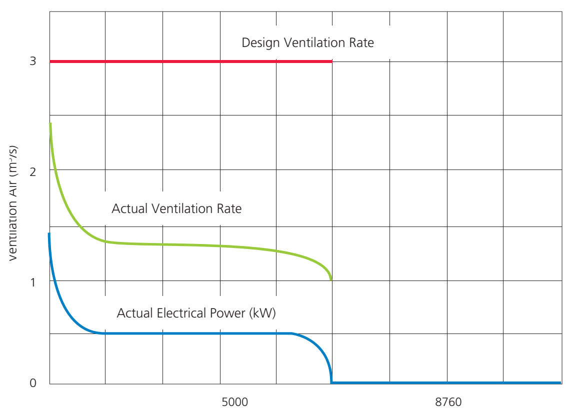


Figure 8 shows actual ventilation airflow data and energy usage for an office building in Sweden. The system was sampled every hour for a year and never exceeded 76% of design airflow. For 80% of the time it averaged less than 45% of design airflow. Real world experience supports the demand control opportunity.

THERMAL COMFORT IMPROVEMENTS

A climate beam applied in a typical office application will achieve about 1/3 of its cooling performance from the primary air (0.35 cfm/ft² of 55°F (1.78 L/s/m² of 12.8 °C) primary air will provide 7.6 Btu/h-ft² (0.024 KW/m²) sensible cooling) and 2/3 from the room air that is drawn through the beam coil and cooled by chilled water. This ratio is derived from the space psychrometrics and is heavily affected by the primary air dewpoint and space sensible heat ratio.

In a conference room, this ratio changes closer to half primary air and half chilled water in the beam. The primary airflow in conference rooms is 123 cfm (58.05 L/s) or 0.68 cfm/ft² (3.45 L /s-m²). Based on an occupancy of ten people, the ASHRAE Std 62.1 ventilation requirement is 60 cfm (28.3 L/s). The higher primary airflow rate is to meet the space latent load. The air cooling capacity for the climate beam is 2,669 Btu/h (0.78 KW) and the water cooling capacity is 2005 Btu/h (0.59 kW).

With a constant volume system and the conference room not in use, the primary air over cools the space. In the ESBO model, the room temperature drops to 66.6 °F (19.2 °C) when not in use.

To reduce the cooling capacity of the beam further with a constant volume system either the supply air temperature must be reset up from 55°F (12.8 °C) or the hot water circuit in the climate beam can be used to raise the supply air temperature.

Figure 9 – Climate Beam Turndown

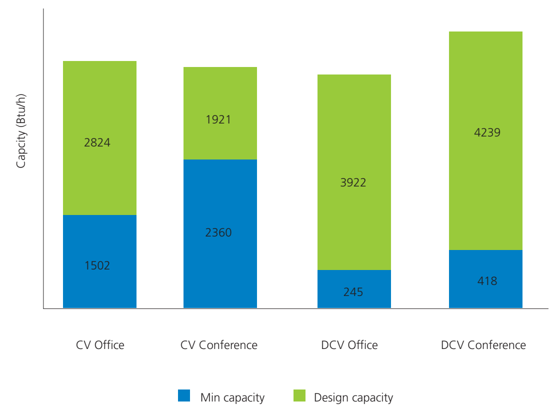


Figure 9 shows constant volume and DCV climate beam selections for office conditions and conference room (high density, high latent load) conditions. All the beams deliver approximately the same total sensible cooling capacity to the space. The conference beams can deliver 57% more latent cooling because the primary flow has been increased (the induction ratio is decreased). Even with the chilled water stopped, the constant volume climate beams are still providing significant cooling due to the primary air flow. With the DCV climate beams modulating both water and airflow, the minimum capacity can be 10% or less, offering excellent space temperature control.

DCV climate beam design will improve occupant comfort and avoid simultaneous heating and cooling offering more savings.

APPLYING DIVERSITY TO SYSTEM SIZING WITH DCV SYSTEM

Calculating the primary airflow rate in a constant volume climate beam system is accomplished by adding up all the primary airflows to the all the climate beams. There is no way to modulate or divert primary airflow so the primary air handling unit and the ductwork are sized for the connected flowrate. This is analogous to a constant volume all air HVAC system.

Even using the design occupancy of 40 people, it is not possible for the conference room's office areas and canteen to be at design load at the same time. With a VAV climate beam design, there is the opportunity to downsize the primary air handler and ductwork to meet actual peak primary airflow rate.

In this example, the constant volume primary airflow rate is 2800 cfm (1321 L/s). This is the sum of the all the primary airflows of all the climate beams. Primary airflow must be the larger of the ventilation requirement (i.e. ASHRAE Std 62.1 or Std 170), the latent load requirement or the zone cooling requirement. For office space, it is usually the latent load requirement that determines the primary airflow rate. In this example the necessary primary airflow rate to meet the 17 kBtu/h (5 kW) latent load is 2200 cfm (1000 l/s). This is a 20% reduction in the primary AHU and main duct sizing. The savings is equivalent to comparing a constant volume all air HVAC system to a VAV HVAC system. Sizing the equipment closer to the real world load will improve their efficiency as well (the equipment will operate closer to its design point instead of part load).

[3] Demand Controlled Ventilation (DCV) Systems in Commercial Buildings, Chalmers University of Technology, 2009, Maripuu, Mari-liis

SUMMARY

The best way to a take a very good climate beam system and improve it is to introduce Demand Control Ventilation. Varying the primary airflow so only the air that is required is brought into the building can improve the HVAC system annual energy performance by 14 percent.

The cost of demand control ventilation can be offset by taking primary airflow diversity into account in the air handling unit and ducting sizing.

Finally, the increased (10 to 1 or better) capacity turndown offered with Demand Control Climate beams greatly improves thermal comfort by avoiding possible overcooling.

Figure 10 PARASOL Climate Beams

To assist in the evaluation of concepts like DCV climate beams, Swegon offers the DesignEdge service for design professionals. Through this service, Swegon Engineers can assist in the technical details, load evaluations, system design, selections, etc. to see if climate beams are appropriate for your next project.

For more information, contact your local representative or Erdem Kokgil at Erdem.kokgil@swegon.com

PARASOL CLIMATE BEAMS

Swegon PARASOL 4-way climate beams are available in both constant volume and Demand Control Ventilation (VAV) options. Both options include 4-way air pattern with Anti Draft Control (ADC) and the ability to change nozzle setting on each side independently for optimum comfort. They are available in 2 x 2 and 2x 4 ceiling grid sizes as well an exposed model with painted casing.

Adding a VAV box upstream of a standard constant volume chilled beam will allow the primary air to be reduced to about 70% on design airflow. Below that, the loss of flow through the nozzles will cause the induction process to stop and minimal air will be drawn through the coil.

Figure 11-Varying Primary Air Through a Constant Volume Climate Beam

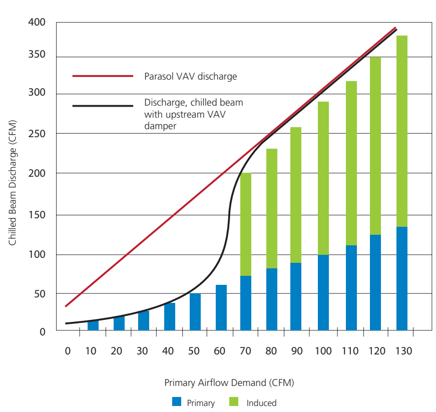


Figure 12 PARASOL VAV (DCV) Climate Beams

The PARASOL VAV model has an integrated VAV system including an actuator that accepts 0-10 vdc signal. When the beam is operated at minimum airflow the nozzles on the sides are closed. As the primary air flow is increased, the number of nozzles increase so that proper induction is maintained. Due to this design, a PARASOL VAV climate beam can offer 10 to 1 turndown for increased energy and comfort performance.

[2] EPA Energy Star Portfolio Manager lists office EUI at 66,800 Btu/ft^2-yr (210.73 KW/m2-yr).
[3] Demand Controlled Ventilation (DCV) Systems in Commercial Buildings, Chalmers University of Technology, 2009, Maripuu, Mari-liis