VARIABLE AIR VOLUME (VAV) SYSTEMS

Installation Principles and Operation

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we shape the air

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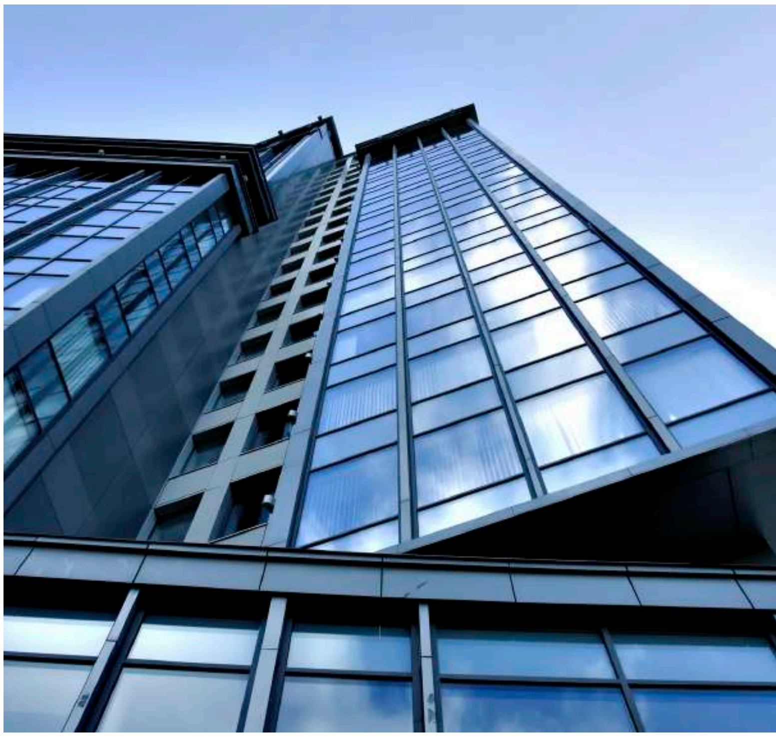
OPERATING PRINCIPLES

A Variable Air Volume (VAV) controller (or damper) is a crucial component in HVAC systems. Its main function is to regulate the airflow delivered to a specific zone, adjusting to the temperature and ventilation needs of that area.

These dampers allow for more efficient climate control as they can increase or decrease airflow based on factors like occupancy, desired temperature, and air quality.

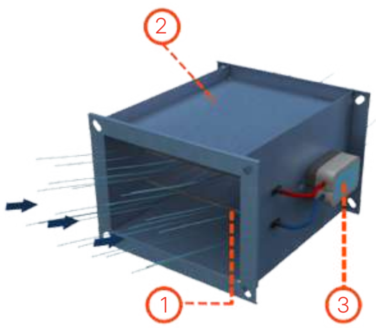
A VAV controller integrates a flow measurement sensor cross, an airtight regulating damper, and a proportional actuator into a single device, enabling precise control of the airflow passing through the regulator.

To ensure the precise energy supply to each zone, VAV controllers use dual-loop control between the controlled variable (T, CO2, etc.) and the measured airflow to meet the required demand conditions, providing the necessary airflow accordingly.



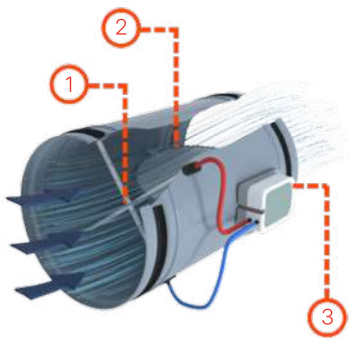
SVA-R

VAV regulating damper for rectangular duct.



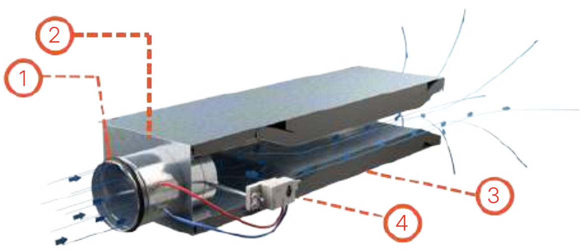
SVA-C

VAV regulating damper for circular duct.

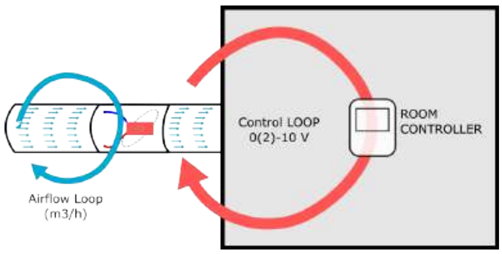


SHH

VAV regulating damper for systems with high acoustic demands.



1. Flow measurement sensor
2. Airtight regulating damper
3. Compact actuator-controller
4. Expansion silencer box



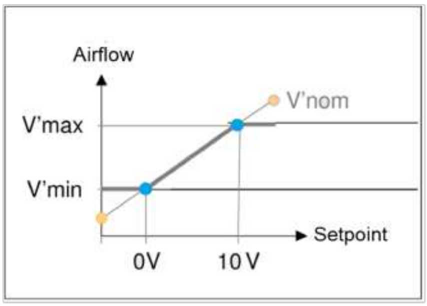
VAV controllers operate **independently of upstream pressure.**

The damper's position depends not only on the signal from the T/CO2 controller but also on the available inlet pressure. Even if the room controller signal does not change, the damper position may vary if other VAV controllers open or close, or if the air handling unit's variable frequency drive (VFD) acts.

MINIMUM / MAXIMUM / NOMINAL FLOW

(Vmin –V max –Vnom)

VAV dampers regulate airflow to maintain the setpoint temperature and/or ensure good indoor air quality.



Vnom used to measure the airflow through the damper via the feedback signal (U).

Vmin

Commonly determined by the air quality required in the controlled zone. Corresponds to a 0 V control signal.

Vmax

Typically defined by the maximum thermal load, generally for cooling. Corresponds to a 10 V control signal.

Vnom

The maximum flow capacity of the regulator is defined by the manufacturer and cannot be changed on-site.

AIRFLOW SETTINGS AND STANDARD CONNECTION

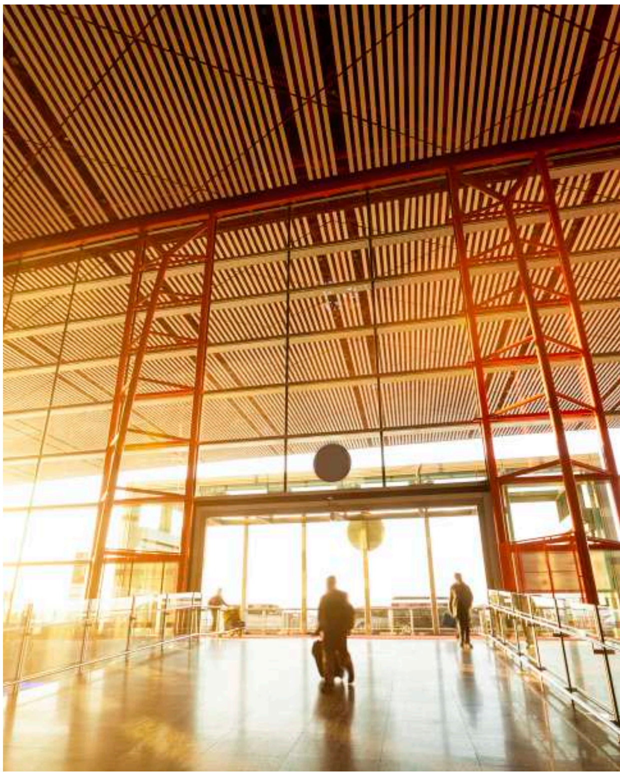
Dampers can be delivered with factory pre-set **Vmin** and **Vmax** values as per client specifications. These can be adjusted after installation using adjustment tools.

It's essential that the required set airflow rates are met in **VAV** systems. If minimum flows are not ensured, dampers will remain fully open and never regulate.

FORCED OR OVERRIDE CONTACTS

VAV-type actuators include forced contacts for full damper closure, full opening, or positioning at Vmin/max, regardless of the 0-10V control signal.

Typical uses include full closure when unoccupied, full opening for rapid setpoint achievement or forcing maximum ventilation.



TYPES OF VAV INSTALLATIONS

VAV controllers are used in two basic types of installations:

FLOW CONTROL	• Supply and return control with parallel connection • Supply and return control with Master-Slave connection • Supply-only control • Constant flow control
PRESSURE CONTROL	• Duct pressure control • Room pressure control There are combined installation types of duct pressure and flow control to optimize the number of VAV devices in complex applications.
COMBINED FLOW AND PRESSURE CONTROL	• Pressure control in the supply duct and flow control in return duct.

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PARALLEL SUPPLY-RETURN VAV INSTALLATIONS

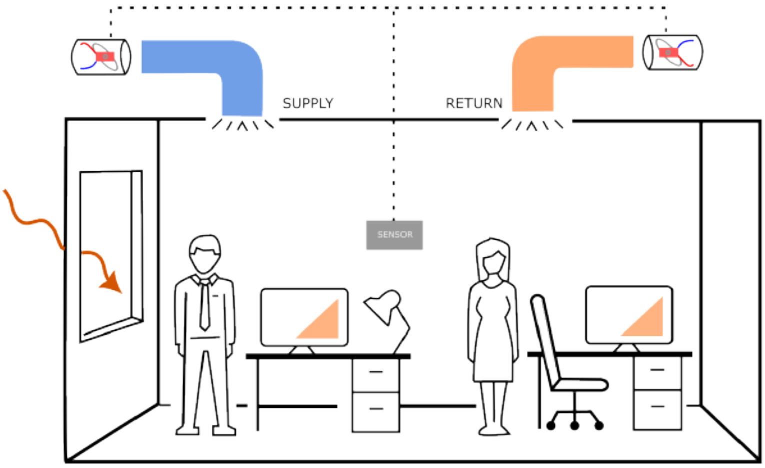
In parallel control, both supply and return controllers receive the control signal (0-10 V) directly from the regulator. Independent flow settings for supply and return are possible.

Used in:

- Installations with different sizes or flow rates between supply and return dampers.

- Multiple supply and return units.

- Preferred for easier design and commissioning.



MASTER-SLAVE IN SUPPLY-RETURN VAV INSTALLATIONS

In this configuration, the room regulator sends a setpoint signal (0-10 V) to the supply damper, which then sends it to the return damper acting as a slave.

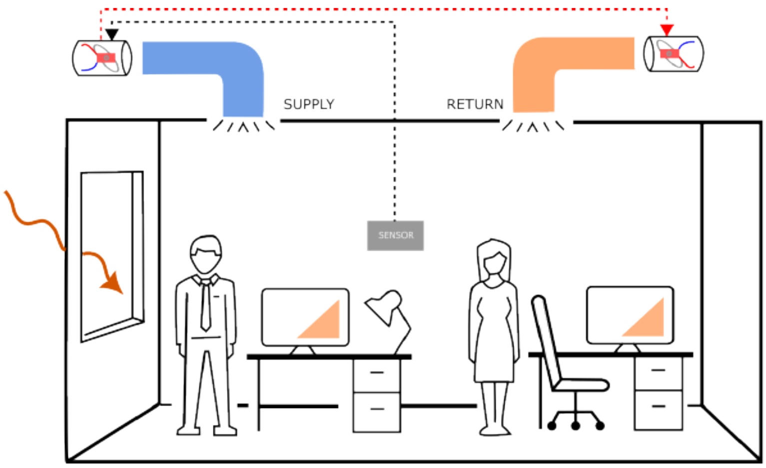
Used in:

- Installations with sequential return relative o supply.

- Zones with similarly sized supply and return dampers.

Drawbacks

- Requires correct identification during design, ordering, installation, and commissioning.



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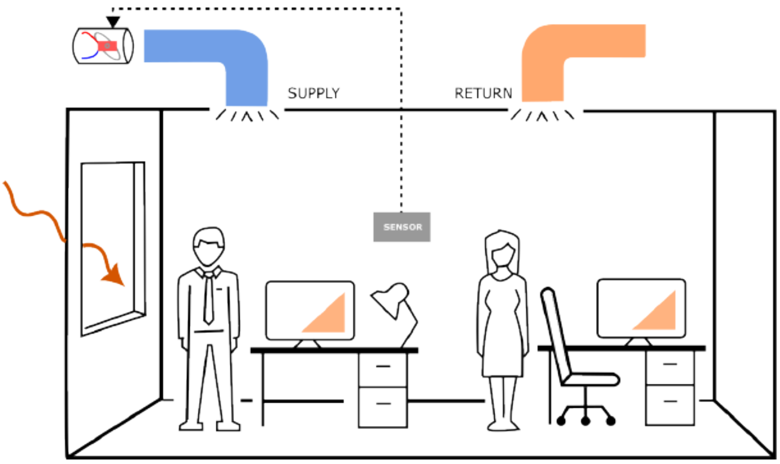
SUPPLY-ONLY CONTROL INSTALLATIONS

Only the supply damper receives a control signal. Returns are not controlled.

Used in:

- Cost-effective setups without return dampers.

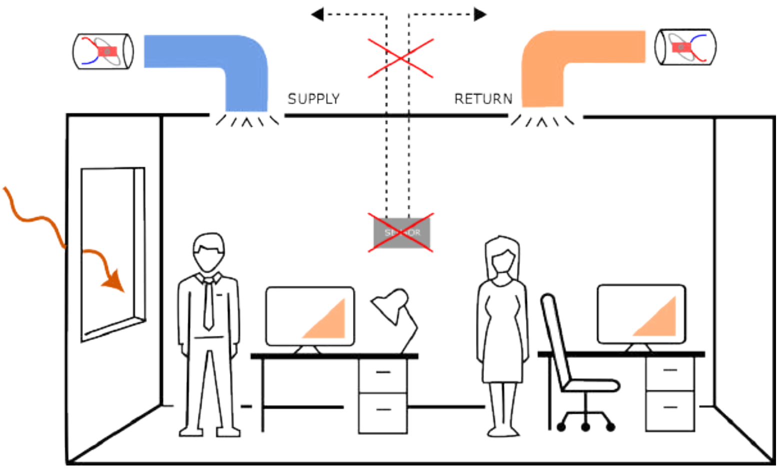
- May cause zone overpressure or under pressure due to lack of return airflow control.



CONSTANT FLOW INSTALLATIONS

Supply and/or return regulators are configured for constant flow. No 0-10 V modulation signal is used.

Used in:
- Common areas to ensure required airflow.
- To comply with ventilation regulations.



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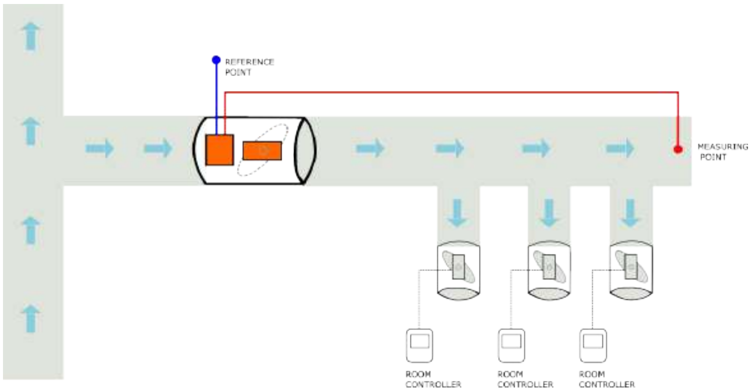
DUCT PRESSURE CONTROL

VRU controller with LM actuator manages duct pressure for balancing supply (or return) branches.

Used in:

- Reducing main branch pressure to avoid excess in terminal units, preventing noise and drafts.



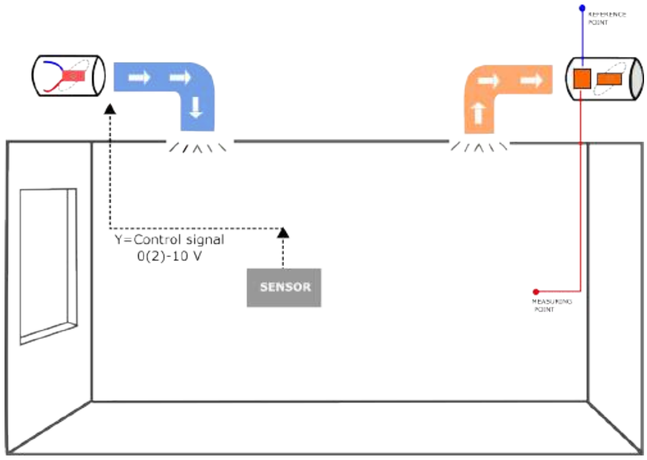
Controller:
Belimo VRU-D3-BAC or VRU-M1-BAC
Actuator:
Belimo LM(Q)24A-VST or NM(Q)24A-VST

ROOM PRESSURE CONTROL

VRU controller with LM actuator manages room pressure. A differential probe measures overpressure or under pressure, adjusting the damper accordingly.

Used in:

- Cleanrooms, operating rooms, labs.
- Simple control of room pressure regardless of airflow type.
- Can easily reverse room pressurization.



Controller:
Belimo VRU-M1R-BAC
Actuator:
Belimo LM(Q)24A-VST
Belimo NM(Q)24A-VST

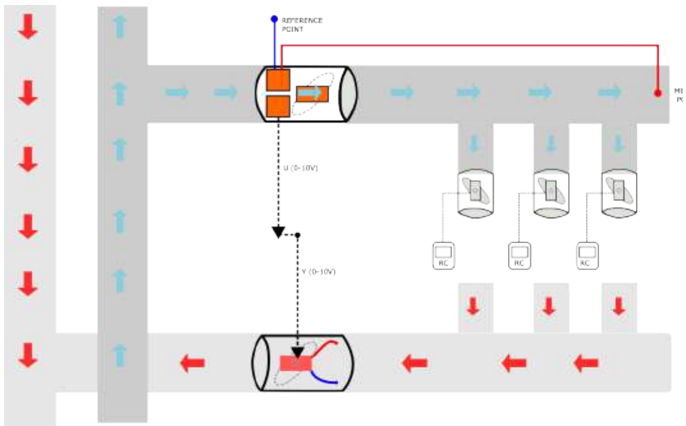
COMBINED FLOW AND PRESSURE CONTROL

Two universal controllers with a compact actuator allow for integrated applications.

Common use: measure pressure in secondary supply branches and balance return airflow.

Used in:

- Multi-story buildings with main supply ducts in shafts.
- Control pressure on each floor's supply and balance with return measurements.



For custom configurations, contact our technical support.

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FAN CONTROL IN VAV INSTALLATIONS

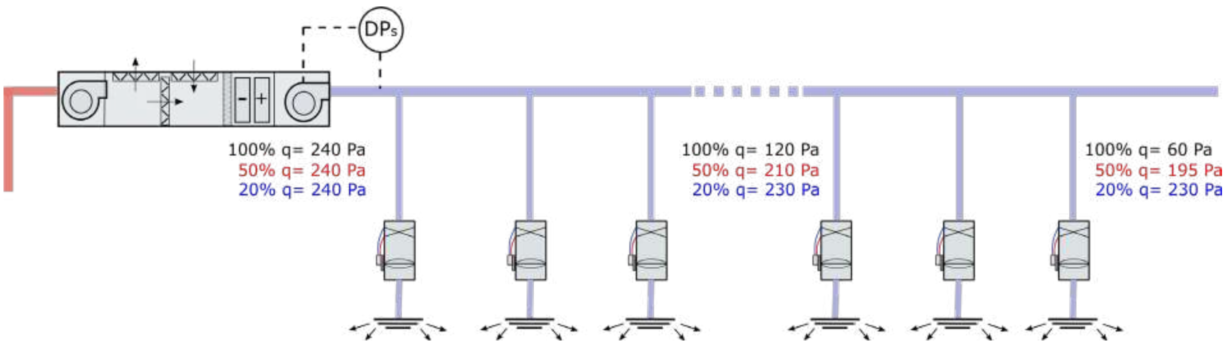
Autonomous VAV damper adjustments generate pressure variations in the system.
It’s essential that AHU supply and return fans can adjust pressure as needed.

3 typical pressure sensor locations:

1. At the fan discharge
2. Farthest point in the system
3. Intermediate point (2/3 rule)

FAN DISCHARGE

Traditional location but has limitations.



ADVANTAGES

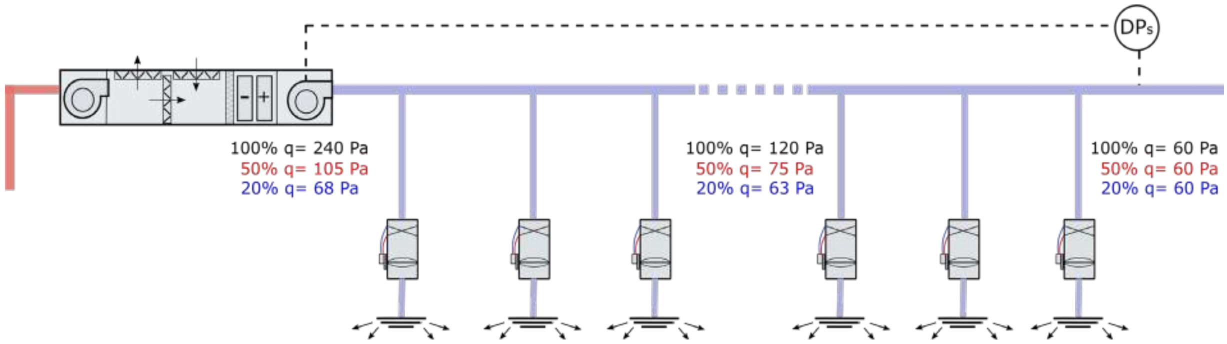
- Ensures available pressure for all circuits
- Easy sensor installation

DISADVANTAGES

- High fan power consumption
- Overpressure and noise from mostly closed dampers

FARTHEST POINT IN THE INSTALLATION

Ensures service at the most distant point.



ADVANTAGES

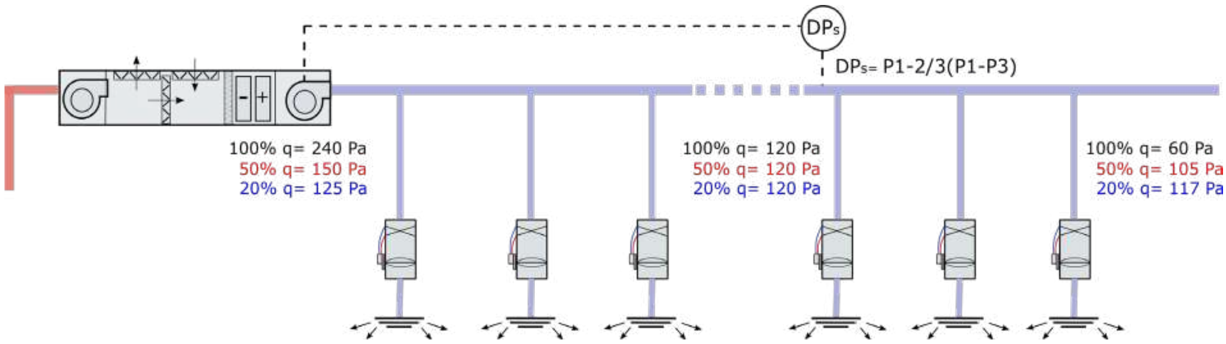
- Low fan power
- Low noise
- Best if all VAVs need similar pressure

DISADVANTAGES

- Risk of low flow in some branches
- Sensor difficult to place

INTERMEDIATE POINT (2/3 RULE)

Balanced approach.



ADVANTAGES

- Midpoint performance between the above options

DISADVANTAGES

- Sensor location challenging in branched networks

ACOUSTICS IN VAV SYSTEMS

Acoustics are crucial for comfort in VAV systems.

NOISE GENERATION

The vibration of an object generates a mechanical wave that propagates through the medium.

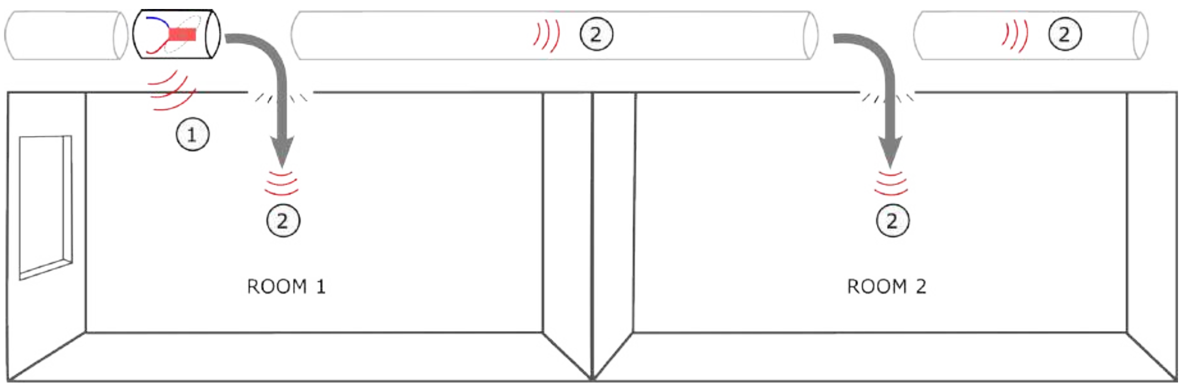
Lw: Sound power is the amount of acoustic energy emitted by a sound source, regardless of its location. It refers to the noise produced by the source.

Lp: Sound pressure level is a measure that quantifies the intensity of the sound perceived at a specific point. It refers to the noise we hear with our ears.

RADIATED VS REGENERATED NOISE

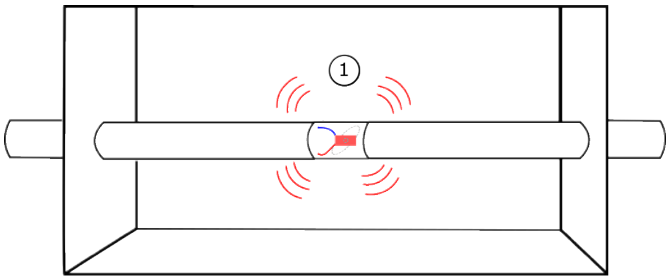
Radiated noise (1), on the other hand, refers to the sound transmitted from the HVAC system components into the occupied space. This noise can be caused by the vibration of duct walls or HVAC equipment, such as fans and terminal units. Unlike regenerated noise, radiated noise propagates through the building structure and can be heard in adjacent rooms.

Regenerated noise (2) is produced within the air ducts and is generated by the airflow passing through system components such as dampers, diffusers, and silencers. This type of noise occurs when the moving air interacts with the internal surfaces of these components, creating turbulence and vibrations that generate sound. Regenerated noise travels inside the ducts and can also be perceived in nearby rooms.

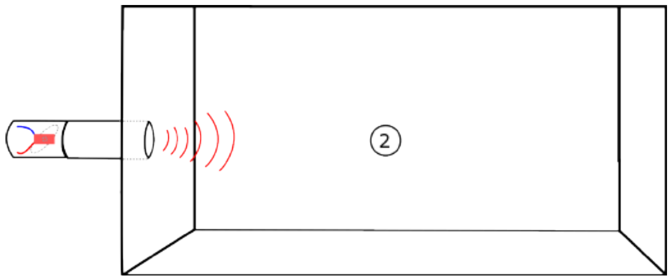


ACOUSTIC DATA IN VAV DAMPERS

The acoustic data shown in Madel's technical documents and selection software are determined through testing in a reverberation chamber (EN 3741) and in compliance with the EN 5135 standard.



Radiated noise test



Regenerated noise test

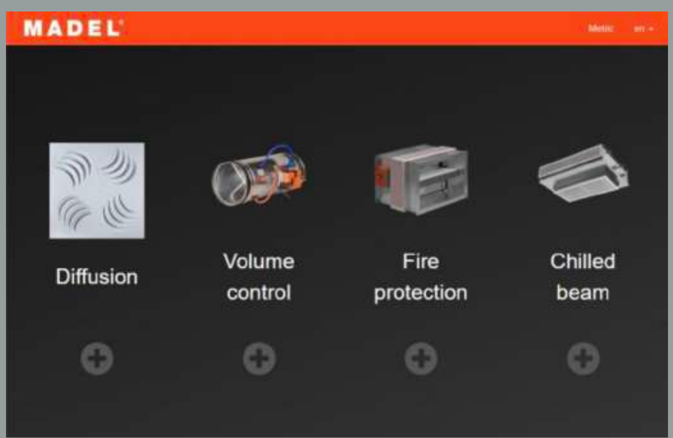
ACOUSTIC ATTENUATION

The sound power data Lw (radiated / regenerated) obtained in the laboratory represent values solely attributable to the noise source that generates them (damper).

On the other hand, the sound pressure level (Lp) that we perceive with our ears is the result of the generated sound power (Lw) plus the attenuation due to distance and position of the source, material absorption, duct branches, terminal reflections, etc.

The VDI 2081 standard (Noise generation and noise reduction in air conditioning) details the attenuation for each octave band. Essentially, the elements that cause attenuation in VAV systems include:
- Ductwork
- Elbows
- Branches/splits in the ductwork
- Plenums and terminal elements (diffusers)

To simplify calculations, it is common practice in the HVAC sector to use an average attenuation of -8 dB for both radiated and regenerated noise.



For a detailed noise calculation, both radiated and conducted, MADEL offers an advanced acoustic calculation software:

https://application.madel.com/en/home/index/1

This tool calculates the noise level at different available pressures in the damper, allows users to modify acoustic attenuation (generically), or export the data in Excel format so that the acoustic consultant can apply the precise attenuation values required for each project.

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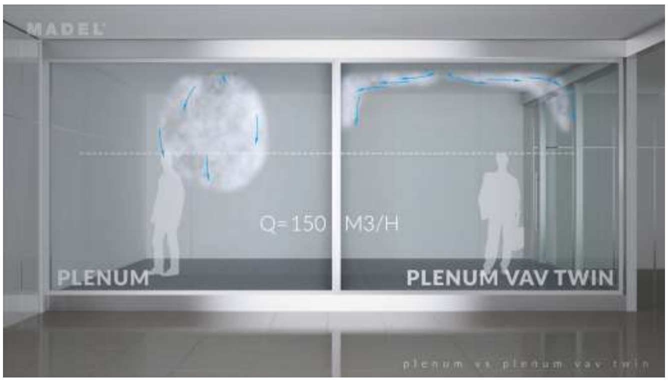
AIR DIFFUSION IN VAV SYSTEMS

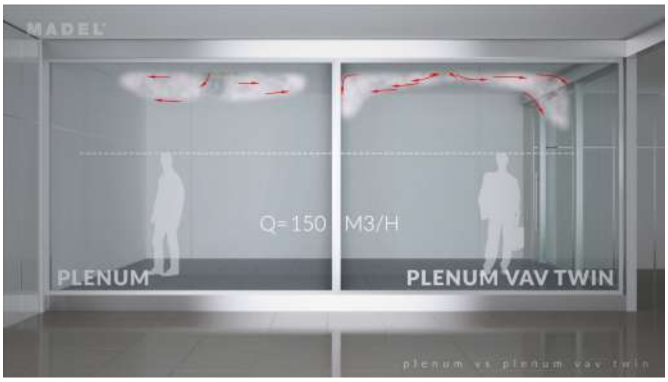
Poor air diffusion in VAV systems results from variable flow rates.

Low flows:
- Cooling: Loss of Coanda effect; air falls.
- Heating: Hot air stratifies, reducing efficiency.

High flows:
- Increased air velocity leads to noise and drafts.

The following images illustrate these issues (at low airflow rates), where the most significant problems typically occur—cold air drop during cooling and stratification during heating.



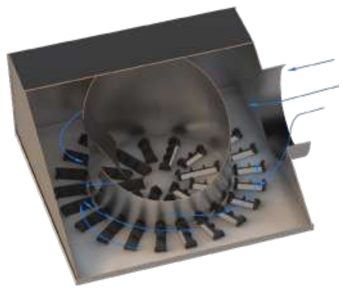


AXO-TWIN. Innovation in air diffusion

AXO-TWIN system uses dual air distribution chambers connected via a self-regulating membrane.

The primary chamber receives air at correct pressure. Increased flow causes the membrane to open toward the second chamber, maintaining internal pressure and diffuser velocity to preserve the Coanda effect.

Ensures efficient diffusion under varying flows, improving comfort and system performance.



VAV PRODUCT RANGE

MADEL offers a wide range of products for VAV (Variable Air Volume) installations, including both circular and rectangular models, as well as solutions specifically designed for systems with high acoustic requirements.

In addition to VAV regulators, there is also a complete range of Constant Air Volume (CAV) controllers. These devices allow fixed airflow limitation and control in each branch, helping to balance the entire system efficiently.

SVA-C

Circular duct VAV regulators

- Flows: 45–5500 m3/h
- Pressure: 50–1000 Pa
- Sizes: 100–400 mm
- Standard or insulated versions

SVA-CXL

Large circular VAV regulators

- Flows: 850–13500 m3/h
- Pressure: 50–1000 Pa
- Sizes: 450–630 mm

SVA-R

Rectangular duct VAV regulators

- Flows: 100–25000 m3/h
- Pressure: 50–1000 Pa
- Sizes: 200×100 to 1200×1000 mm
- Standard or insulated versions

SHH

High acoustic demand VAV terminal units

- Flows: 45–5500 m3/h
- Pressure: 50–1000 Pa
- Sizes: 100–400 mm
- Standard or insulated (/PLUS)
- Optional reheat coils

INTEGRATION OF VAV SYSTEMS INTO BMS

All MADEL VAV controllers are available with communication-capable actuators, allowing full integration into building management systems (BMS).

Modbus KNX ASHRAE BACnet™

MADEL®
we shape the air