ASHRAE Qatar Oryx Chapter

Qatar University, Doha-Qatar

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Variable Air Volume Fundamentals
Belimo Automation FZE

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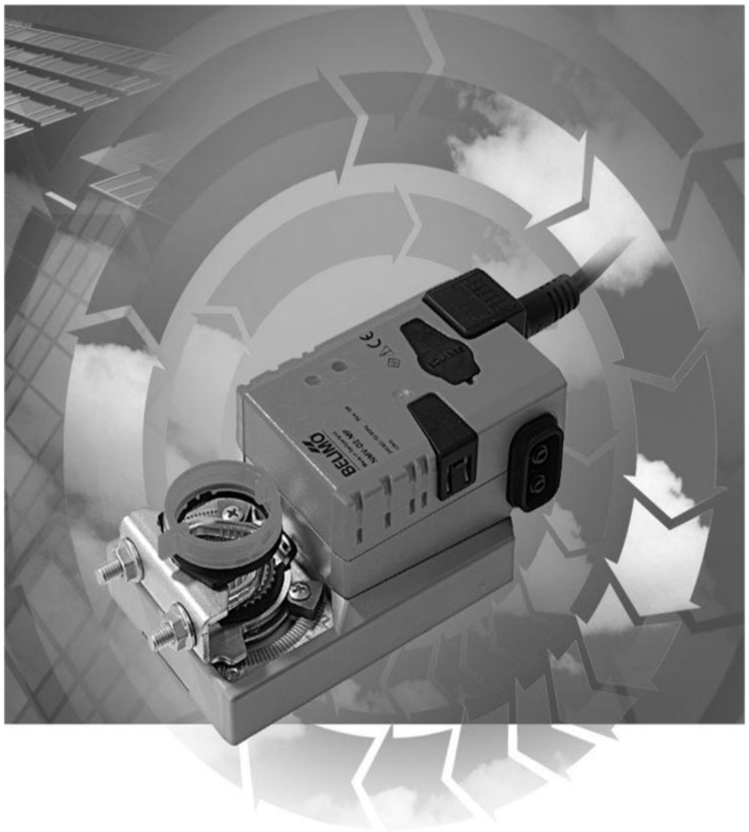
Content

- **VAV Overview and core concepts**
- **Keys of control loop of VAV terminal unit**
- **Fundamentals of VAV terminal unit**
  - ✓ Parts, Responsibility, Flow measurement,
  - ✓ Probe installation & placement, c-factor
  - ✓ Pressure drop, Specification, Information and Accuracy
- **VAV Flow-sensors**
- **Linearization and calibration**
- **Conclusions**

Target:



- Ductwork for VAV systems should be designed for the lowest practical static pressure loss, especially ductwork closest to the fan or air-handling unit.
- VAV systems must be selected to operate with efficiency and stability throughout the operating range.
- Sound data for VAV units should be obtained according to the procedures specified by the latest ARI Standard 880.
- General design consideration and precautions.

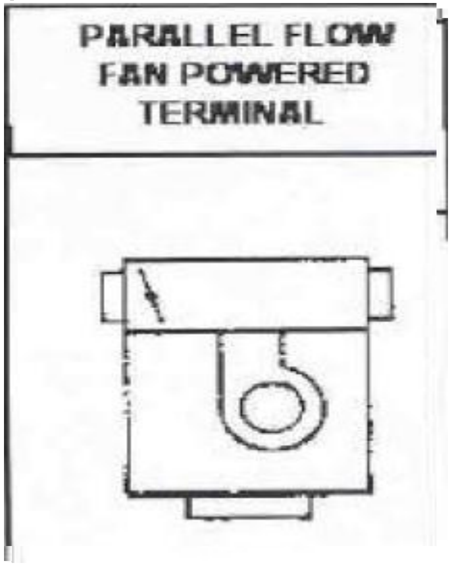
VAV Overview

A variable-air-volume (VAV) system is a single-path system that controls zone temperature by modulating airflow while maintaining constant supply air temperature. VAV terminal units, located at each zone, adjust the quantity of air reaching each zone depending on its load requirements. Reheat coils may be included to provide required heating for perimeter zones.

A VAV boxes provide constant or variable airflow depending on the temperature demands of the space. As the temperature raises the VAV damper opens to send a designed amount of airflow to the space/ or room.

There are many different types of VAV units:

- Single Duct / cooling only, or cooling with reheat
- Dual Duct terminal
- Induction VAV terminal
- Parallel Flow Fan Powered VAV terminal
- Series Flow Fan Powered VAV terminal



VAV Core concept

VAV terminals can also be classified as:

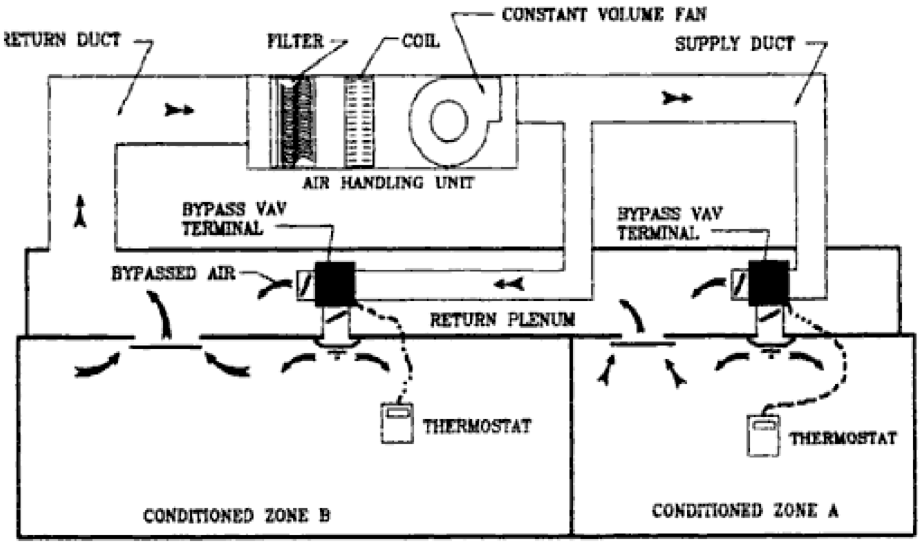
VAV - Pressure Independent:

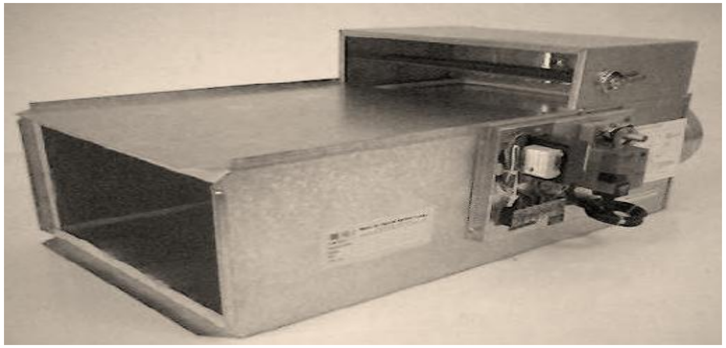
A pressure independent teriminal unit is equipped with a flow sensing controller that can be set to limit maximum and minimum primary air discharge from terminal unit.

VAV - Pressure dependent:

A pressure dependent terminal unit: is not equipped to measure and maintain primary air discharge volume. The actual airflow through the terminal unit is a function of upstream static pressure and damper ‘’plate’’ position.

Bypass VAV

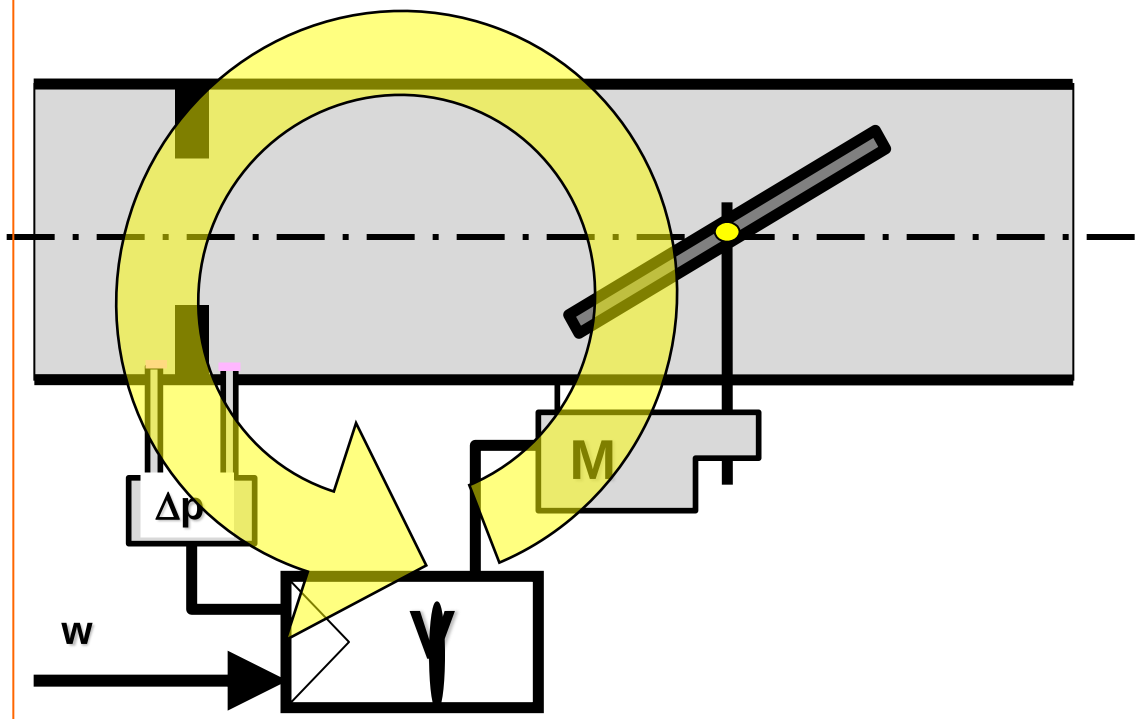




The Bypass terminal unit handles a constant supply of primary air though its inlet. The unit bypasses primary air to the ceiling plenum to meet the needs of conditioned space. This method provides a low first cost with minimum controls, but it is energy insufficient compared to other systems.

VAV – closed control loop

A closed loop or feedback control measures actual changes in the controlled variable and actuates the controlled device to bring about a change. The corrective action may continue until the variable is brought to a desired value within the design limitations of the controller. This arrangement of having the controller respond to the value of the controlled variable is known as feedback. Figure shows an example of feedback control.



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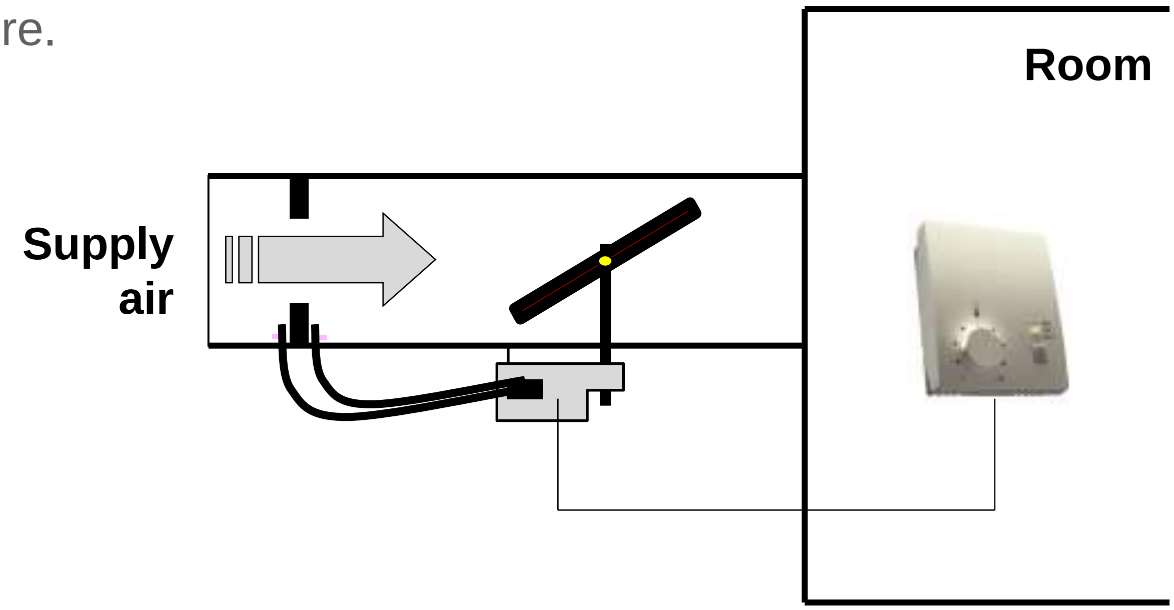
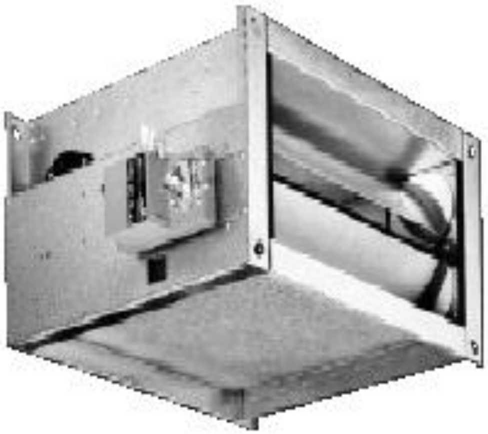
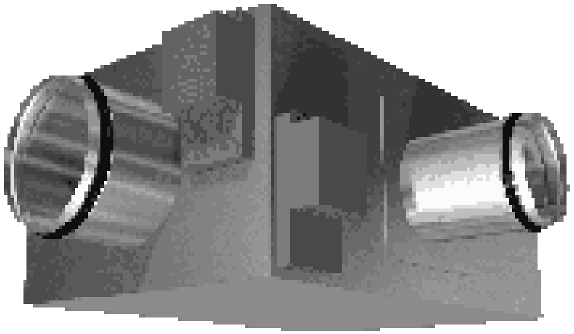
VAV – Mode of Operation

A VAV system maintains the air supply at a constant temperature while individual zone thermostats vary the flow of air to each space maintaining the desired zone temperature.



VAV box - Shapes and sizes





VAV box – The pickup devise (Air probe)

The essential Points:

- High differential pressure across the VAV box
- Low aerodynamic resistance
- Measurement over complete cross section
  (best image of airflow independent is the flow profile)
- Cost effective
- Robust against corrosion and pollution

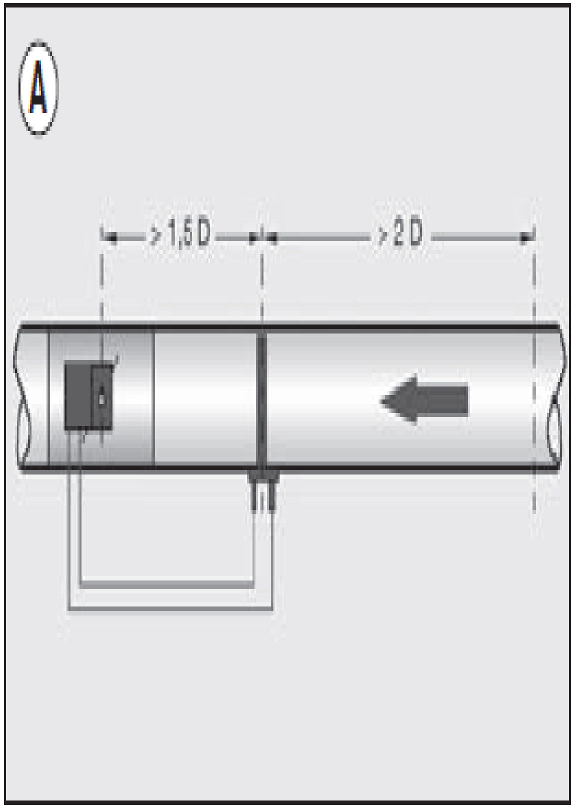
Know-how and accountability of VAV-box manufacturer

Placement of the air probe

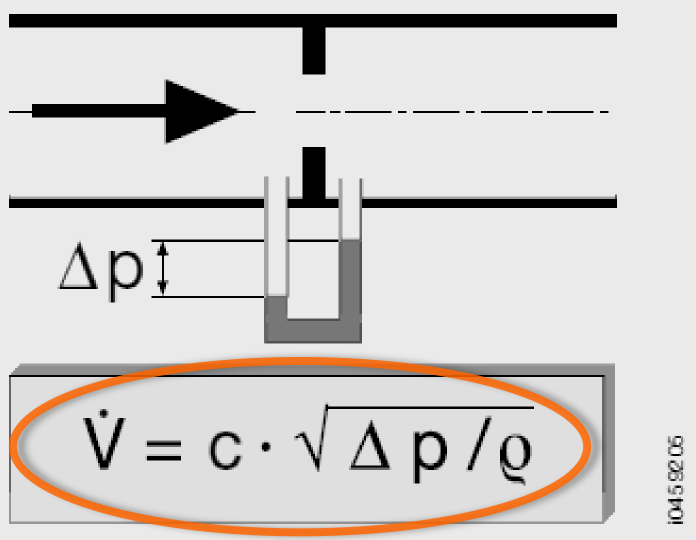
- Minimum distance of the pick devise is:
  = 2 x Diameter
  from inlet of the VAV.

- A minimum distance of pick devise and VAV damper Plate is: = **1.5 x Diameter**

(where D is diameter of inlet of the VAV)

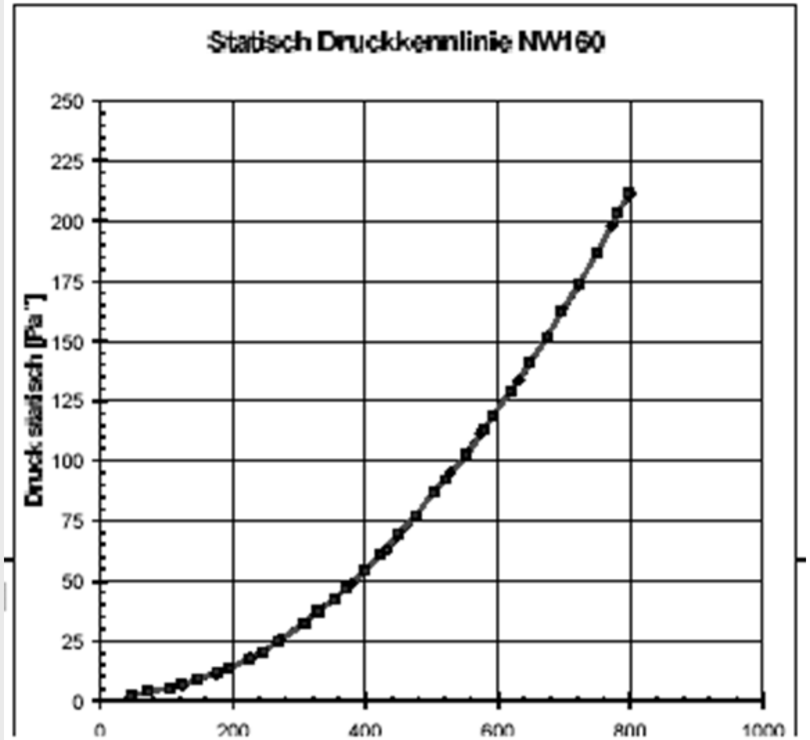


VAV box – Volumetric flow & Pressure characteristic



$$\dot{V} = c \cdot \sqrt{\Delta p / \varrho}$$

$\dot{V}$ = Volumetric flow
c = Geometry-related constant of the baffle device (differential-pressure pick-up device, dimensions, etc.)
Δp = Differential pressure
ϱ = Density of the flow medium



VAV box Pressure drop

ΔTP = ΔSP + ΔVP

where:
ΔTP: Total pressure drop
ΔSP: Static pressure drop
ΔVP: Velocity pressure drop

$$= \Delta SP + \left[\left(\frac{v_{in}}{4005} \right)^2 - \left(\frac{v_{out}}{4005} \right)^2 \right]$$

$$= \Delta SP + \left[\left(\frac{4Q}{4005 \pi D^2} \right)^2 - \left(\frac{Q}{4005 WH} \right)^2 \right]$$

where:

v_{in} and v_{out} *are the inlet and outlet velocities*

Q is the airflow rate

D is the box inlet diameter

W and H are the inside (clear) width and height of the box outlet (outside dimensions less insulation thickness)

4005 constant factor

Important:

The greater the pressure drop across the VAV box, the greater the fan power.

VAV Box- Specifications

Vnom

V nominal is the nominal or absolute airflow for a specific box size that is specified by the VAV manufacturer.

This value is the reference for Vmin and Vmax and for the control

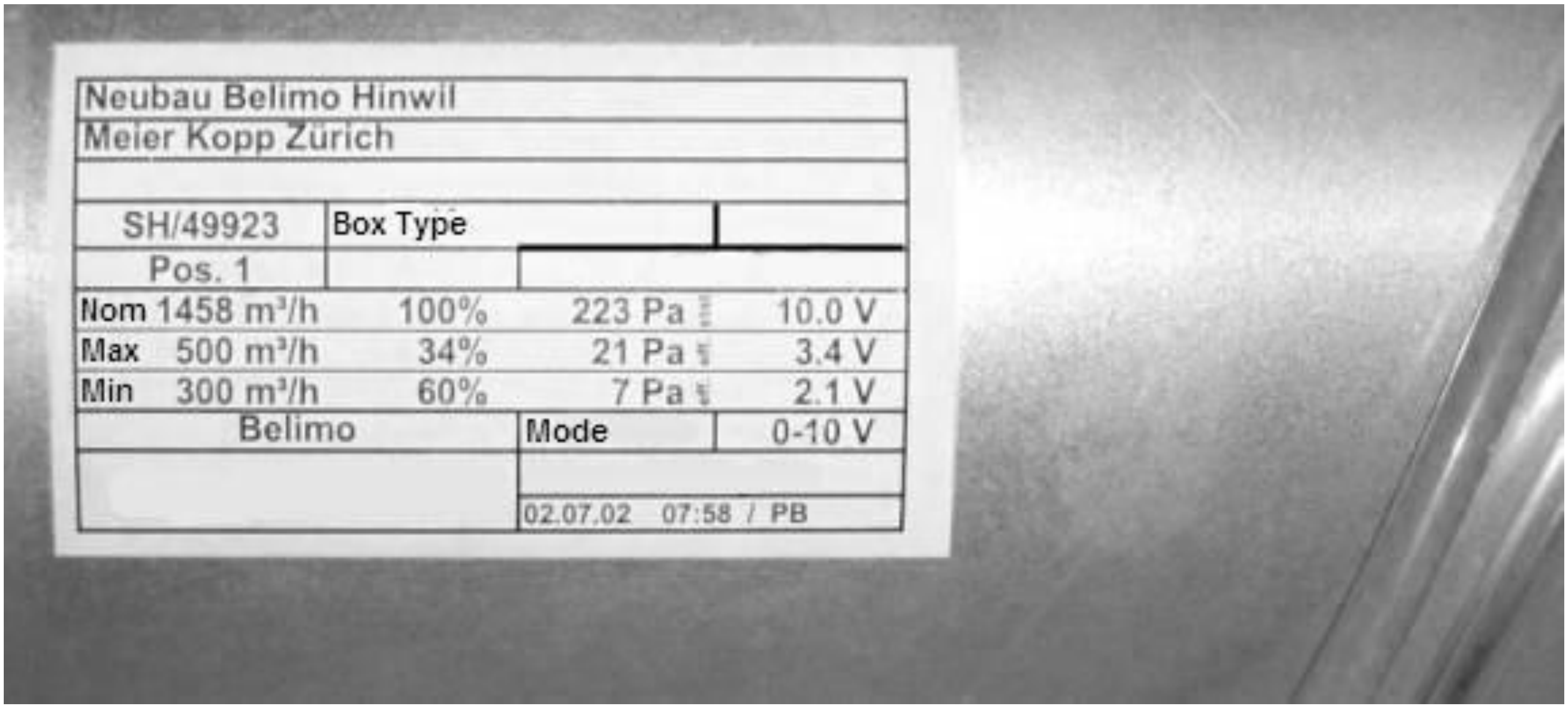
Vmin, Vmax

This two values depend on the project and the application, and refer to Vnom of the box.

Important:

Study the manufacturer's data before attempting to do the testing, adjusting and balancing/commissioning the VAV operation.

VAV Box- Information



VAV Box - Accuracy

Accuracy= %Vnom

Points of influences

- Linear control/ behaviour of the complete VAV- box
- Manufacturing tolerances of the metal part
- Tolerance of tubing
- Tolerance of the VAV- controller
- Accuracy of the calibration of controller
- The total pressure drop is the true indicator of the fan energy required to deliver the design airflow through the box since the fan has to generate both the pressure and velocity at the box inlet

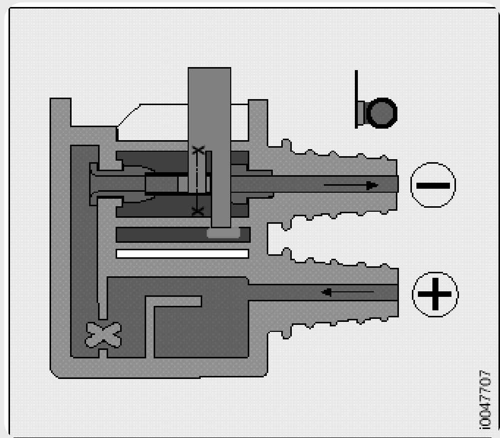
External influences

- Characteristic of the air stream (turbulence flow, VAV selections and sizing, space constraints, and noise generation)
  (calm down area before and after the VAV- Box)

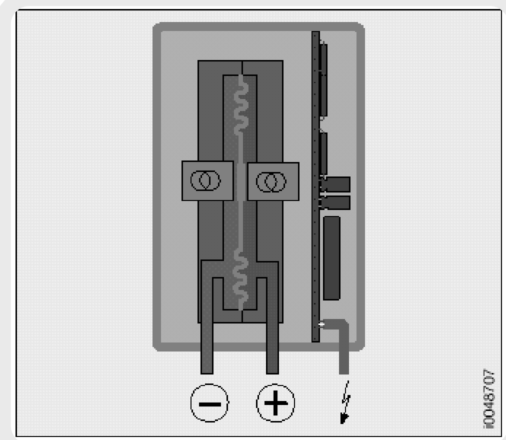
Methods of measuring volumetric flow

Air velocity sensing method

Dynamic differential pressure sensing method



Static differential pressure sensing method



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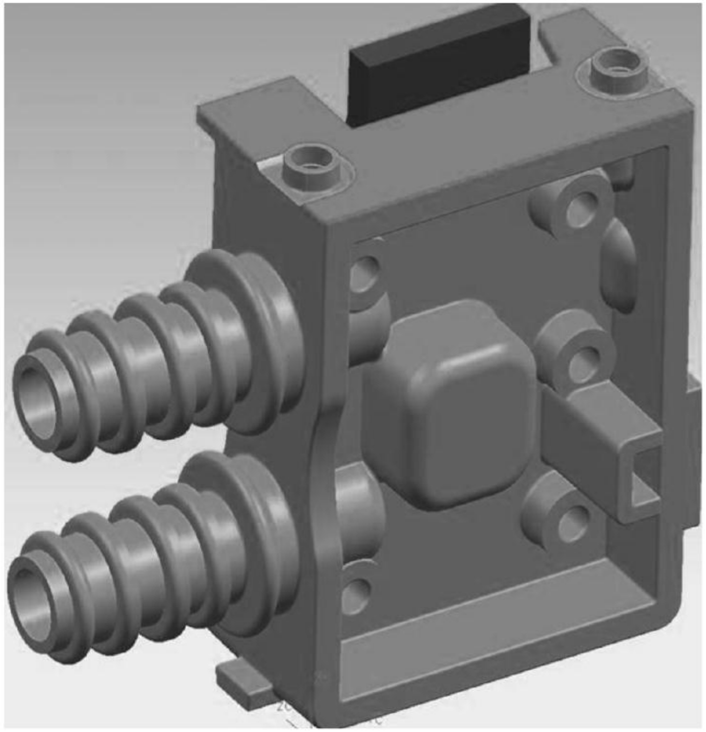
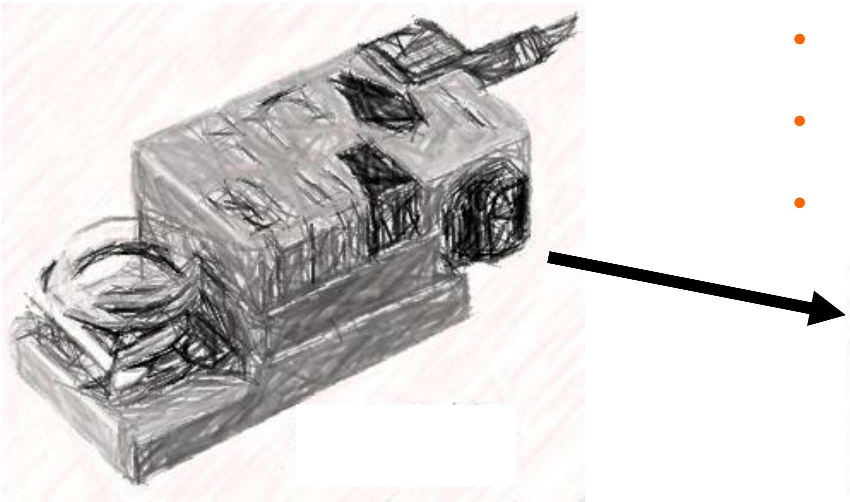
Flow sensor

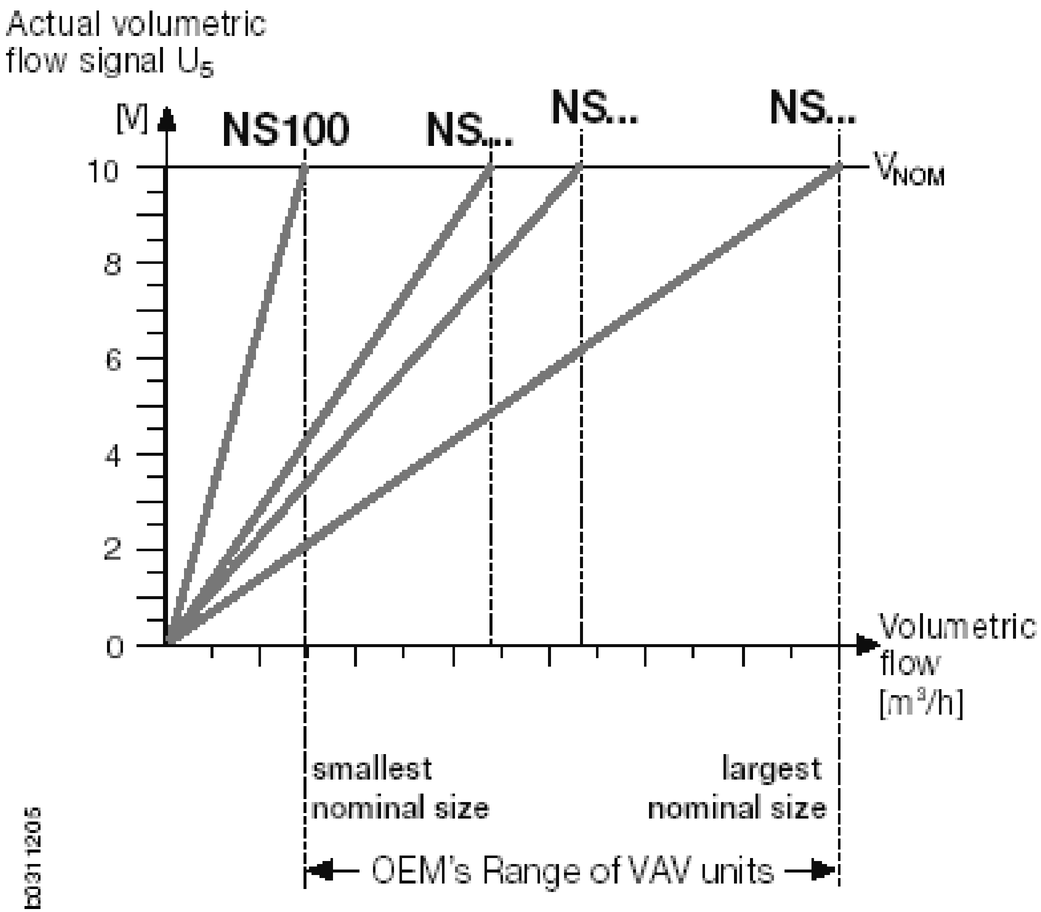


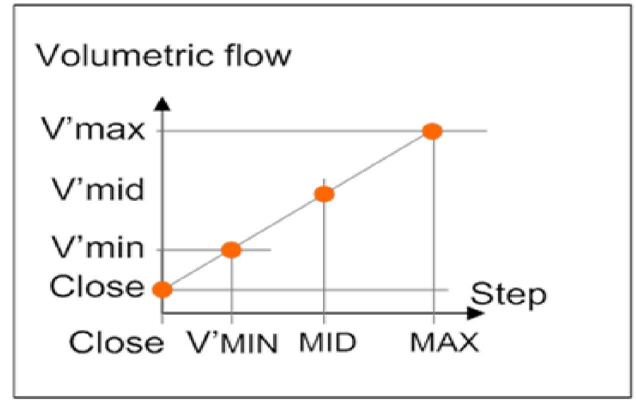
Flow sensor measuring features

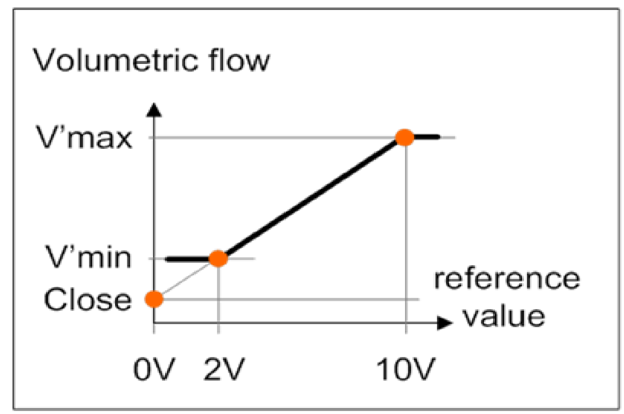
- Dynamic differential pressure sensor
- Minimal flow (~120 x less than the D2 sensor)
- Principle: heat transmission measurement
- Immune to dirt, dust and smoke
- Length of tubing has no impact
- Parallel measurement possible
- No zero point calibration required
- Long-term stability - Maintenance-free



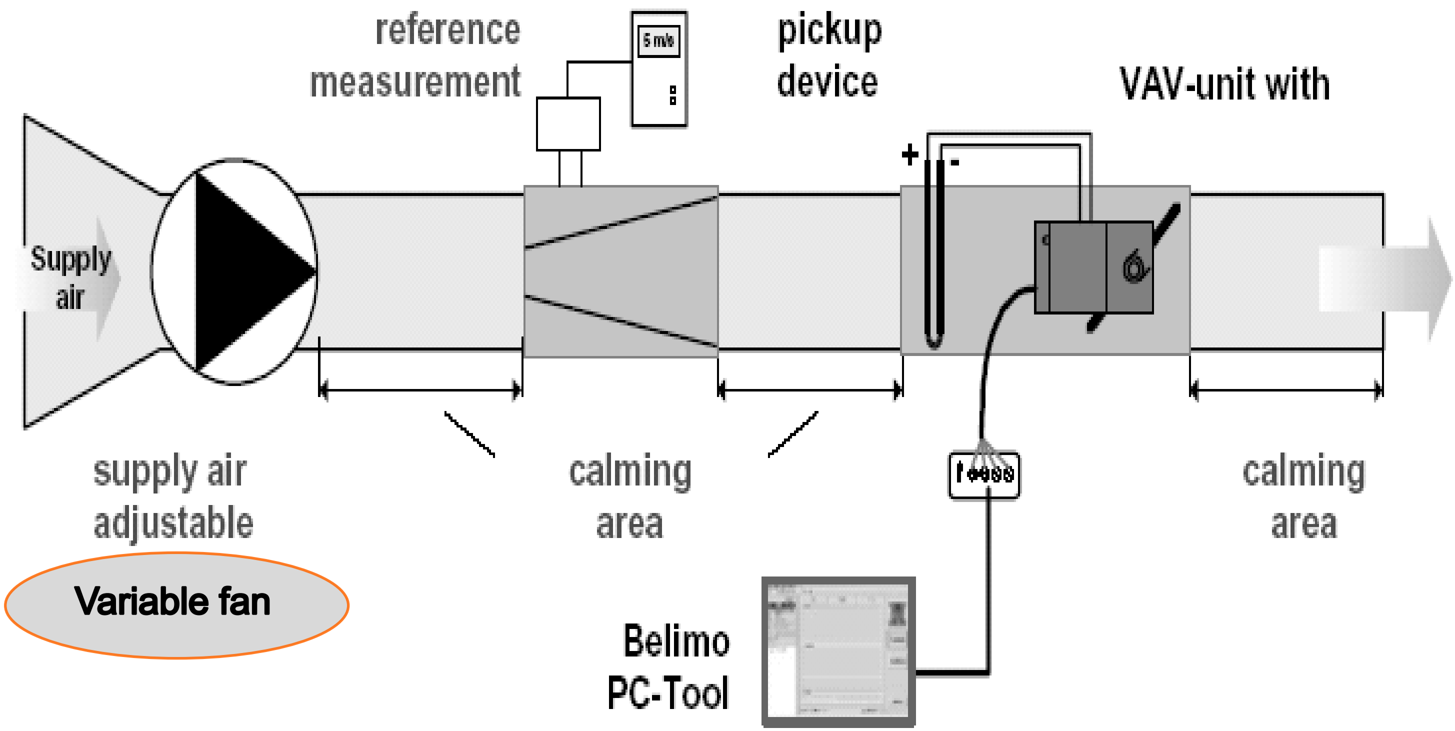
Linearization & Calibration Process







Calibration Rig



Installation and Application Precautions:

Avoiding Common Errors and Problems Sizing Terminals:

- Select terminals based on recommended air volume ranges. The pressure-independent terminal's main feature is its ability to accept factory-recommended minimum and maximum airflow limits that correspond to the designer's space load and ventilation requirements for a given zone.

- A common misconception is that oversizing a terminal makes the unit's operation quieter. In reality, the oversized terminal damper must operate in a pinched-down condition most of the time, which may actually increase noise levels to the space.

- Control accuracy may suffer because the terminal is only using a fraction of its total damper travel or stroke. In addition, the low inlet velocities may be insufficient to produce a readable signal for the velocity pressure measuring device and reset controller. This means minimum settings may not hold with a resultant loss of control accuracy and undesirable hunting.

Installation and Application Precautions:

- To maximize performance, size the terminal's maximum airflow limit for 70 to 85% of its rated capacity (approximately 10 m/s) in accordance with the catalog recommendations.
- For accurate control, the minimum setting guideline should not be lower than 2 m/s inlet neck velocity for units using inlet velocity sensors.
- Oversizing the discharge duct may create low static conditions, requiring the fan to operate outside its recommended operating range.
- A problem associated with oversizing terminals with electric heat is insufficient total pressure, which can occasionally trip the airflow safety switch.
- Space Restrictions. During design, try to ensure that terminals are located for ease of installation, optimum performance, and maintenance accessibility.

Conclusions

- A VAV is an individual comfort (efficiency) and cost/ energy saving.
- An accuracy of the box depends on the quality of:
  - the box construction
  - the calibration process
  - the flow characteristic trend.
- The box-manufacturer is responsible for the quality and accuracy of it VAV- Box construction.
- The air flow characteristic - position of VAV- Box has an impact to accuracy/or behaving of control and operation consequences.