Objectives

- Define Constant Volume and VAV Systems
- Describe Different Control Strategies for Modulating Supply Airflow
- Discuss Building Pressure Control Strategies
- Complying with Min OA Requirements
- Define Coil Controls Best Practices
- Discuss Safeties – When and How
- Review AHU Schematics and Points Lists
Constant Volume Systems
Constant Volume System

Air Movement

Supply Fan

Return Air

Supply Air
Constant Volume System
Air Movement + Ventilation

Outside Air
Supply Fan
Return Air
Supply Air
Constant Volume System
Air Movement + Ventilation + Heating/Cooling
Constant Volume System
Air Movement + Ventilation + Heating/Cooling + Filtration

Diagram:
- Outside Air
- Filter
- Cooling and Heating Coils
- Supply Fan
- Return Air
- Supply Air
Constant Volume System

Control:
Space Temperature – Staged Cooling and Heating

ON/OFF Control of Cooling, Heating, Fan

Thermostat

Cooling – 74°F
Heating – 72°F
Constant Volume System

Control:
Space Temperature – Thermostat
Staged Cooling and Heating

Leaving Air Temperature

90°F
72°F
55°F

Time
Constant Volume System

Control:
Space Temperature – Thermostat
Staged Cooling and Heating

<table>
<thead>
<tr>
<th>Time</th>
<th>Space Temperature</th>
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<tbody>
<tr>
<td>70°F</td>
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<td>72°F</td>
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<tr>
<td>74°F</td>
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Hysteresis
Constant Volume System

Control:
Space Temperature – Modulating Control

Modulating Heating:
- Hot Water
- Steam
- Modulating Gas
- Face and Bypass

Modulating Cooling:
- Chilled Water

Setpoint Controller:
- Compares Value to Target
- 0-100% Signals

Setpoint Controller: Cooling – 74°F
Setpoint Controller: Heating – 72°F
Constant Volume System

Control:
Space Temperature – Modulating Control

Leaving Air Temperature

90°F
72°F
55°F

Time
Constant Volume System

Control:
Space Temperature – Modulating Control

- Space Temperature: 74°F, 72°F, 70°F
- Time: Hysteresis

- Control chart showing temperature changes and hysteresis effect.
Constant Volume System

**Control:** Leaving Air Temperature (Master/Slave)

Space Temp calculation determines LAT setpoint. Control to LAT

**LAT Setpoints:**
- Cooling: 55°F – 65°F
- Heating: 75°F – 90°F

**Space Setpoints:**
- Cooling: 74°F
- Heating: 72°F

0-100% Signals
Constant Volume System

Control:
Leaving Air Temperature (Master/Slave)
Constant Volume System

Control:
Leaving Air Temperature (Master/Slave)
Constant Volume System

Zone Reheat – Space Control

Pros:
• Simple
• Comfortable

Cons:
• Highly Inefficient
Constant Volume System
Zone Reheat – Space Control
Constant Volume System
Zone Reheat – LAT Control
Variable Air Volume (VAV) Systems
VAV System

Basic Concept

Supply Airflow Modulation

Pressure Sensor

Space Temp

Space Temp

Space Temp

Space Temp
VAV System

Airflow Modulation: Discharge Damper

- Increase Resistance
- Variable Airflow
VAV System

Airflow Modulation: Discharge Damper

- **Full Speed Discharge Damper Full Open**
- **Full Speed Discharge Damper Partially Closed**
VAV System

Airflow Modulation: Adjustable Sheaves

Change Fan Rotational Speed

Variable Airflow
VAV System

Airflow Modulation: Adjustable Sheaves

Full Speed
Motor Sheave Normal

Full Speed
Motor Sheave Reduced
VAV System

Airflow Modulation: Bypass Damper

Constant Airflow

Variable Airflow
VAV System

Airflow Modulation: Bypass Damper

- **Full Speed Bypass Closed**
- **Full Speed Bypass Partially Open**
VAV System

Airflow Modulation: Inlet Guide Vanes (IGV)

Variable Airflow

Change Properties of Fan
VAV System

Airflow Modulation: Inlet Guide Vanes (IGV)
VAV System

Airflow Modulation: Variable Frequency Drive (VFD)

Change Fan Rotational Speed

Change Motor Rotational Speed

VFD

Power In

Variable Airflow
VAV System

Airflow Modulation: Variable Frequency Drives

[Diagram showing airflow modulation with Full Speed VFD at Full Speed and Full Speed VFD at Reduced Speed.]
VAV System

Return Fan

Return Fan Typically Less Airflow than Supply Fan. Less HP. Covers Static of Return Ductwork.
VAV System

Building Pressure Control
Fan Tracking

Supply Fan – 100%
Return Fan – 80%
Supply Fan – 80%
Return Fan – 64%
Supply Fan – 60%
Return Fan – 48%

80% of Supply Fan
VAV System

Building Pressure Control
Space Pressure

VFD

Reference to Ambient

Space Pressure

High Port

Low Port
VAV System

Building Pressure Control
CFM Differential

VFD
AFMS

CFM Differential = 500
Supply Air = 8000 CFM
Return Air = 7500 CFM

CFM Differential = 2000
Supply Air = 8000 CFM
Return Air = 6000 CFM

Return Fan Controls to Return Air CFM
VAV System

Building Pressure Control
CFM Differential

The Return airflow shall track the supply airflow less the direct exhaust with an offset (constant). Use the following formula to determine the desired Return Air CFM Setpoint:

\[ RA-CFM-SP = K \times (SA-CFM - DE-CFM) \]

\( K \) = Multiplier, reset between 0.90 and 1.00 as determined through test and balance to maintain 0.05” positive pressure in occupied area (relative to ambient pressure)

Direct exhaust CFM shall be determined by monitoring ON/OFF statues of exhaust fans and incorporating EF-CFM from T&B Report.
VAV System

Damper Control

Control Points

Control All Dampers with One Signal
Simpler Approach
Control Dampers with Independent Signals
Offers Greater Flexibility
VAV System

OA Damper Control
Minimum Air – Fixed Position

Exhaust Air

Outside Air

Design = 8,000 CFM

Design = 3,000 CFM

Minimum Air Control – Control to Fixed Position
VAV System

OA Damper Control
Minimum Air – Fixed Position

Exhaust Air

37%

M

63%

M

M

Outside Air

37%

Design = 3,000 CFM
Actual = 1,850 CFM

Actual = 5,000 CFM

Minimum Air Control – Control to Fixed Position
VAV System

OA Damper Control
Minimum Air - AFMS

Minimum Air Control:
Control to Maintain OA-AFMS Setpoint

Outside Air
AFMS

Exhaust Air

Actual = 5,000 CFM

Design = 3,000 CFM
Setpoint = 3,000 CFM
VAV System

RA Damper Control
Track Opposite OA Damper

Exhaust Air → 37%

Outside Air → AFMS → 37%

Supply Fan Sees Equal Resistance as Dampers
Modulate

Actual = 8,000 CFM

Setpoint = 3,000 CFM

Setpoint = 3,000 CFM
Supply Fan See Less Resistance
Less Work / Energy Consumption
VAV System

Leaving Air Temperature (LAT) Control
Chilled Water Coil – 3-Way Valve

Control to LAT Setpoint - 55°F is typical.
VAV System
Leaving Air Temperature (LAT) Control
Chilled Water Coil – 2-Way Valve

Control to LAT Setpoint - 55°F is typical.
VAV System

Leaving Air Temperature (LAT) Control

Hot Water Coil – Freeze Protection Pump

Start HW Circ Pump:
- Heating Mode
- Freeze Stat
- OAT < 40°F

Control to LAT
Setpoint - 85°F is typical
VAV System

Low Temperature Thermostat
Freeze Stat

- HW Circ Pump Starts
- HW Valve Full Open
- CHW Valve Open?
- OAD / EAD Close
- Supply and Return Fans Stop

Trip Setpoint: 35°F to 40°F
Action when Smoke Detectors Trips:
- Supply and Return Fans Stop
VAV System
Filter Differential Pressure Monitoring

Differential Pressure Switch:
- Less Expensive
- Trip Point Not Always Set Properly
- Difficult to Commission

Differential Pressure Transmitter:
- More Expensive
- No Trip Point – Compared to Alarm Value
- Easier to Commission
VAV System

Static Pressure Reset

Supply Duct Static Pressure Setpoint:
- Normally a Fixed Value (2.5"")
- Can be Reset Based on VAV Boxes

Speed = 85%

Pressure Sensor Setpoint = 2.5"

Space Temp

Space Temp

Space Temp

Space Temp

1,000 CFM

750 CFM

350 CFM

620 CFM

100%

75%

35%

62%

1,000 CFM

750 CFM

350 CFM

620 CFM
VAV System

Static Pressure Reset

As Boxes Close, Speed is somewhat Reduced, but Static Pressure Setpoint is Unchanged.
Reduce Static Pressure Setpoint until at least 1 box is full open

Power Input to VFD reduced by the Cube of CFM Reduction
Speed Reduced 1/2, Power to 1/8.
VAV System

Static Pressure Reset

When the supply fan is running in the occupied mode, initially control VFD speed to maintain initial static pressure setpoint (1.5" W.c.).

Monitoring the positions of the VAV and FPB primary air dampers. If ALL dampers are maintaining airflow setpoint and all dampers are positioned less than 90% open, reset the duct static pressure setpoint down in a gradual manner.

If ANY damper is indexed to 100% and cannot maintain its primary airflow setpoint, reset the duct static pressure setpoint UP in a gradual manner.

The duct static pressure setpoint shall remain unchanged if:
• All primary air dampers are indexed to less than 100%, AND
• At least one damper is indexed greater than 85%

Set minimum and maximum allowable ranges for the duct static pressure setpoint. Initially set minimum at 0.75" and maximum at 2.5" w.c.
VAV System
High/Low Pressure Safeties

Action when Pressure Safety Trips:
• Supply and Return Fans Stop

Hardwire directly to VFDs
Use Relay Logic
Other Considerations: Demand Control Ventilation

Control OA Airflow based on Carbon Dioxide (CO2) Level in the Occupied Space.

In Constant Volume System serving an Open Area:
• CO2 Sensor in Zone or Return Air Duct

In VAV System serving an Open Area:
• CO2 Sensor in Each VAV Box Zone

Typical setpoint for zone CO2:
• 1,100 ppm
• 700 ppm greater than outside air CO2 level
• CPS uses 1,000 ppm (unreferenced to OA)
VAV System

Other Considerations: OAT or Space Temperature Reset

Resetting the LAT Setpoint based on OAT or Space Temperature

**OAT Reset For VAV Cooling:**
• Will Reduce Work on DX or Chilled Water Plant
• Will also Increase Airflow, More Fan Energy
• Also Can Cause Humidification Issues

**Space Temperature Reset for VAV Cooling:**
• Same Issues as OAT Reset
• Can Fight Static Pressure Reset
VAV System

Other Considerations: OAT or Space Temperature Reset

Resetting the LAT Setpoint based on OAT or Space Temperature

**OAT Reset For VAV Cooling:**
- Will Reduce Work on DX or Chilled Water Plant
- Will also Increase Airflow, More Fan Energy
- Also Can Cause Humidification Issues

**Space Temperature Reset for VAV Cooling:**
- Same Issues as OAT Reset
- Can Fight Static Pressure Reset
### VAV Air Handling Unit (AHU-2) Points Lists

<table>
<thead>
<tr>
<th>POINT</th>
<th>TYPE</th>
<th>SIGNAL (NOTE-1)</th>
<th>POWER (NOTE-1)</th>
<th>DESCRIPTION</th>
<th>NOTES</th>
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VAV System

VAV Air Handler Schematic
### VAV System

#### VAV AHU Points Lists

### Points List - AHU-2

<table>
<thead>
<tr>
<th>Point Number</th>
<th>Point Name</th>
<th>HARDWired</th>
<th>VIRTUAL INTERFACE</th>
<th>POINT ON GRAPHIC</th>
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</tbody>
</table>
Conclusion

- Constant Volume Systems are Simple, Low Cost
- VAV Systems – Higher First Costs, Lower Operating Costs as compared to Constant Volume Reheat Systems
- VFDs are Cost Effective Today to Reduce Airflow
- Static Pressure Reset – Preferred Method of Energy Savings as compared to OAT or Space Temp Reset
- Include Schematic Diagrams and Points Lists in Design
- Sequence of Operation – Use clear language
Questions?