Learning Objectives

1. Explain the methods for variable air volume (VAV) laboratory control.
2. Identify “Fast Lab” control.
3. Identify “Slow Lab” control.
4. Explore the pros and cons of using a dedicated DDC lab control system versus using the building automation system for lab control.
Agenda

- Laboratory VAV Control Basics
  - Room airflow control
  - Air valves
  - Fume hood sash velocity determination
- BAS-Only Lab Controls
  - “Fast” Labs”
  - “Slow Labs”
- Separate Lab Control System (LCS) and Building Automation System (BAS)
  - History and current practice
  - Pluses and minuses
Agenda

• Laboratory VAV Control Basics
  • Room airflow control
    • Air valves
    • Fume hood sash velocity determination

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Laboratory VAV Control Basics

• **Room Airflow Control**
  • Ventilation: Air change rate (dilution)
  • Fume hood chemical containment: Face velocity control
    • Sash Position
    • Pressure sensing
    • Airflow tracking
  • **Space pressure control**
    • Room offset
    • Pressure sensing
  • **Thermal control: Heating and cooling**
Lab VAV Control Basics – Room Airflow Control

Ventilation Rate Control with Airflow Setpoints

- Supply air damper
- General exhaust air damper
- Hood air damper

Supply Air

General Exhaust Air

Infiltration/Exfiltration Air

Hood Exhaust Air
Lab VAV Control Basics – Room Airflow Control
Fume Hood Capture

- Supply air damper
- General exhaust air damper
- Hood air damper
- Supply Air
- General Exhaust Air
- Infiltration/Exfiltration Air
- Hood Exhaust Air
- Fume Hood Chemical Containment
Lab VAV Control Basics – Room Airflow Control
Spaced Pressure Control

- Supply air damper
- General exhaust air damper
- Hood air damper

- Supply Air
- General Exhaust Air
- Hood Exhaust Air

- Infiltration/Exfiltration Air

Space Pressurization Control
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Venturi/Cone Type

- VAV hoods must have very fast control to adjust to rapid changes in hood sash position
- Venturi valves maintain pressure-independent flow control through and internal spring.
- Spring response is not visible to controls. No feedback but it works.
- Feedback can be added.
Lab VAV Control Basics – Air Valves – Closed Loop

- VAV hoods must have very fast control to adjust to rapid changes in hood sash position
- Closed loop valves maintain pressure-independent flow control through feedback to the controls
- Conventional VAV boxes with fast actuators
Lab VAV Control Basics – Air Valves

Venturi/Cone Type

For VAV Hoods, must have very fast control to adjust to rapid changes in hood sash position

Closed Loop Type

Both Types Work!
Agenda

• Laboratory VAV Control Basics
  • Room airflow control
  • Air valves
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• BAS-Only Lab Controls
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• Separate Lab Control System (LCS) and Building Automation System (BAS)
  • History and current practice
  • Pluses and minuses
Fume Hood Chemical Containment

- Closed loop face velocity control uses two of these:
  - Sash position
    - PLUS
  - Airflow tracking
- OR
  - Pressure sensing
    - PLUS
  - Airflow tracking
Agenda

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“Fast Labs”

- “Fast labs” are variable air volume (VAV) labs that are fume hood dominated
  - Hood exhaust rates are greater than minimum air change per (ACH) hour rate
  - VAV control allows the airflow rate reduction when the hoods are not open
  - Controls must be fast-acting to track the speed of hood sash changes
“Fast Lab” Control Features

- A single controller is used to control the entire lab
  - Ensures network traffic issues do not affect speed and stability
  - Usually a BACnet Advanced Application Controller (AAC)
- Fast acting air valves with factory-built controllers
  - Minimum I/O
    - CFM setpoint from AAC or sash position; hood valve from sash position, the general exhaust valve (GEX) from CFM calculation
    - Actual CFM (for closed loop control, assumed from open loop control)
    - Damper position (closed loop) or DP across damper (venturi), either hardwired to AAC or by network
      - Required by Standard 90.1 for duct static setpoint reset
    - Any type or manufacturer may be used
“Fast Lab” Controls

- **Fast Lab** Controls
- **SA**
- **EA**
- **TS**
- **M**
- **H**
- **C**
- **GENERAL EXHAUST AIR VALVE**
- **FUME HOOD**
- **HOOD MONITOR**
- **SPECIFIED UNDER DIV. 11**
- **VAV AIR VALVE CONTROLLER**
- **VAV AIRFLOW & HOOD MONITOR- SEE PLANS FOR QTY**
- **SASH**
- **CLOSER**
- **SPECIFIED UNDER DIV. 11**
- **ZONE TEMP SENSOR**
- **AUX CONTACT ON LIGHTING OCCUPANCY SENSOR SUPPLIED BY DIV 26**
- **ADVANCED APPLICATION CONTROLLER**
- **ROOM TEMP SETPOINT ADJUST**
- **OVERRIDE**
- **OCC STATUS**
- **ONE CONTROLLER**
- **ADVANCED APPLICATION CONTROLLER**
- **FUME HOOD, VALVE & HOOD MONITOR- SEE PLANS FOR QTY**
- **SASH ZONE TEMP SENSOR**
- **SASH CLOSER**
- **SASH CLOSER SPECIFIED UNDER DIV. 11**
- **HOOD MONITOR SPECIFIED UNDER DIV. 11**
- **PRESENCE SENSOR**
- **FUME HOOD**

**Fast Lab Air Valves**

**Optional**
Agenda

• Laboratory VAV Control Basics
  • Room airflow control
  • Air valves
  • Fume hood sash velocity determination

• BAS-Only Lab Controls
  • “Fast” Labs’
  • “Slow Labs”

• Separate Lab Control System (LCS) and Building Automation System (BAS)
  • History and current practice
  • Pluses and minuses
“Slow Labs”

• “Slow lab”
  • Hood exhaust rates are less than air change per (ACH) hour rate
  • No hood lab spaces

• Hoods in “slow labs” (if there are any) must be constant air volume (CAV) type

• Controls may be standard commercial type
“Slow Lab” Controls

AUX CONTACT ON LIGHTING OCCUPANCY SENSOR SUPPLIED BY DIV 26

ZONE TEMP SENSOR

SUPPLY AIR VAV BOX

STANDARD VAV BOX CONTROLLER

ROOM TEMP OA TEMP

OVERRIDE

ZONE CONTROLLER

DIFF PRESSURE

AIRFLOW

HOOD ALARM

ZONAL TEMP SETPOINT ADJ OVERRIDE

HOOD MONITOR SPECIFIED UNDER DIV-11

HOOD MONITOR

AIRFLOW

FUME HOOD

DP SENSOR

AIRFLOW

GENERAL EXHAUST VAV BOX

DUAL DUCT VAV BOX AUX. CONTROLLER

FUME HOOD VALVE & HOOD MONITOR - SEE PLANS FOR QTY

GENERAL
EXHAUST
VAV BOX

STANDARD VAV BOX

DUAL DUCT VAV BOX AUX. CONTROLLER

FUME HOOD VALVE & HOOD MONITOR - SEE PLANS FOR QTY

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GENERAL
EXHAUST
VAV BOX

STANDARD VAV BOX
Optional Control Features – Occupancy status

• Occupancy status
  • Via the lighting control occupancy sensor
    • May be via BACnet (fail to “occupied” if network is lost)
  • Allows reduction of dilution ventilation rate when lab is both scheduled to be unoccupied and sensed to be unoccupied
    • E.g. from 6 ACH to 4 ACH
  • Allows reduction in hood face velocity rate when lab is both scheduled to be unoccupied and sensed to be unoccupied
    • E.g. from 100 FPM to 60 ACH (requires ASHRAE Standard 110 testing)
  • Significant energy savings
Optional Control Feature – Automatic Sash Closers

- Automatic sash closer
  - Now available factory installed so reasonable first costs
  - Cost may be offset by using more aggressive diversity factors to reduce HVAC system sizes
- Closing hoods not in use improves
  - Energy savings
  - Safety
- Emergency contact to BAS if loss of supply air
  - Forces hood closed despite occupant presence
  - Prevents lab negative pressure from causing excessive exit door forces
  - Best [one] solution for this problem
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History of VAV Lab Controls

• Old days
  • HVAC: pneumatic
  • Lab controls: pneumatic/analog electronic

• 1990s or so
  • HVAC: digital
  • Lab controls: pneumatic/analog electronic

• Current common practice
  • Central HVAC: digital (BAS)
  • Lab HVAC: digital (LCS or BAS)
  • Lab airflow controls: digital (LCS)

• Future?
  • All: digital (BAS only)
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Advantages of Separate LCS and BAS

• LCS control logic is “canned”
  • No special programming
  • No field debugging
• LCS technicians are usually more experienced with lab-related systems (lab air valves, hoods, etc.) than typical BAS contractors
• These are significant advantages now but they will fade over time if BAS control catches on
Advantages of Using BAS for Lab Control

• Lower first cost
  • One vs. two systems
  • Controls not tied to air valve manufacturer
• No LCS and BAS Contractor coordination
• No Integration issues
  • Communication problems
  • Speed

• Simpler for building engineer
  • Less training
  • One graphical user interface (GUI) and software platform
Sequences of Operation

Laboratory VAV Reheat Zone Sequence of Operation

A. Information Scheduled on Drawings
   1. Design setpoints shall be as scheduled on plans:
      a. Room schedule
         1) Pressurization offset ($\Delta p_{\text{press}}$). Initial pressurization offsets shall be shown
            on schedules. For some zones, final pressurization offsets shall be determined as specified under Section 2329.5.
            Testing, Adjusting, and Balancing.
      b. Supply air valve
         1) Maximum airflow setpoint ($V_{\text{MAX}}$).
         2) Minimum occupied airflow setpoint ($V_{\text{MIN,occ}}$)
         3) Minimum unoccupied airflow setpoint ($V_{\text{MIN,unocc}}$)
         4) Design heating coil leaving air temperatures ($\text{SAT}_{\text{MAX}}$).
      c. Heat exhaust (HX) air valve. Where there is more than one header (see plan
         for quantity), rates shall be added together.
         1) Maximum airflow setpoint ($V_{\text{MAX,head}}$)
         2) Minimum airflow setpoint ($V_{\text{MIN,head}}$)
      d. General exhaust (GEX) air valve. Where there is more than one GEX (one plan
         for quantity), rates shall be added together.
         1) Maximum airflow setpoint ($V_{\text{MAX,GEX}}$)
         2) Minimum airflow setpoint ($V_{\text{MIN,GEX}}$)
      2. Controllable minimum. Where there is more than one terminal, rates shall be
         added together.
         a. Supply controllable minimum ($V_{\text{MIN,cont}}$)
         b. General exhaust controllable minimum ($V_{\text{MIN,cont,GEX}}$)

B. Sequences of Operation

3. Sequences of Operation

   a. Zone temperature setpoint
      - Supply air temperature setpoint shall be reset from deadband $\text{SAT}_{\text{MIN}}$ at
        0% heating loop output proportionally up to $\text{SAT}_{\text{MAX}}$ at 50% heating loop output and above. $\text{SAT}_{\text{MAX}}$ shall be 55°F (13°C) unless otherwise indicated on drawings.
      - If the supply air temperature is greater than the zone temperature plus 5°F
        (2.8°C), the airflow setpoint shall be reset from $V_{\text{MIN}}$ at 50% heating loop output
        and below proportionally up to $V_{\text{MAX}}$ at 100% heating loop output.
      - The hot water valve shall be modulated using proportional plus integral loop
        to maintain the discharge temperature at setpoint. (Directly controlling the
        HW valve of the zone temperature PID loop is not acceptable.)
      - The VAV damper shall be modulated to maintain the measured VAV
        damper position 100% open at 100% heating loop output.

   b. Zone temperature setpoint
      - When the zone is in the deadband mode, the airflow setpoint shall be $V_{\text{MIN}}$.  
      - When the zone is in the heating mode:
        1) Supply air temperature setpoint shall be reset from deadband $\text{SAT}_{\text{MIN}}$
           at 0% heating loop output proportionally up to $\text{SAT}_{\text{MAX}}$ at 50% heating loop output
           and above. $\text{SAT}_{\text{MAX}}$ shall be 55°F (13°C) unless otherwise indicated on drawings.
           2) If the supply air temperature is greater than the zone temperature plus 5°F
              (2.8°C), the airflow setpoint shall be reset from $V_{\text{MIN}}$ at 50% heating loop output
              and below proportionally up to $V_{\text{MAX}}$ at 100% heating loop output.
   c. When the zone is in the deadband mode, the airflow setpoint shall be $V_{\text{MIN}}$.  
   d. When the zone is in the heating mode:
      1) Supply air temperature setpoint shall be reset from deadband $\text{SAT}_{\text{MIN}}$
         at 0% heating loop output proportionally up to $\text{SAT}_{\text{MAX}}$ at 50% heating loop output
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         and below proportionally up to $V_{\text{MAX}}$ at 100% heating loop output.
      3) The hot water valve shall be modulated using proportional plus integral loop
         to maintain the discharge temperature at setpoint. (Directly controlling the
         HW valve of the zone temperature PID loop is not acceptable.)
      4) The VAV damper shall be modulated to maintain the measured VAV
         damper position 100% open at 100% heating loop output.
Conclusions

Why use the BAS for lab control?

• Lower first costs
  • Agnostic to air valve and sash sensor type and manufacturer
  • One system to install and commission
• Improved performance and ease of use
  • Fully integrated airflow and HVAC control
  • Single interface tool for configuration/programming

• Key implementation recommendations
  • Use a single AAC controller for each Fast Lab to ensure fast-acting yet stable performance
  • Provide detailed, proven control sequences
    • Such as those published in the bibliography article
• Taylor, S. *BAS Control of VAV Labs*, ASHRAE Journal, April 2017
Questions

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