Presentation Overview

- Customer & Engineering Issues
- Fume Extraction Devices
- Lab Airflow Control
- Laboratory Airflow Balance
- Energy Efficiency
- Which Airflow Control System is Best for Your Application?
- Reference documents
Customer / Operational concerns

- Safety
- Energy costs
- Maintenance costs
- Flexibility
- Reliability uptime (cost of downtime)
- Ease of use
- Sustainable operation
- Data metrics & analytics
Critical Airflow Issues

Designers
- Safety
- Design flexibility
- Application solutions
- Product selection
- Installation concerns / total cost
- Commissioning
- On time project completion
What types of extraction devices?

- **Local exhaust devices**
  - snorkels, elephant trunks, cones
  - Typically heat extraction
  - Canopies

- **Chemical fume hoods**
  - Bench top, vertical or horizontal or combination sashes
  - Distillation hoods
  - Floor mounted (Walk-in), multiple sash configurations
  - Auxiliary Air hoods
  - Radioisotope & Perchloric Acid hoods
  - Low flow fume hoods

- **Biosafety cabinets**
  - Various types and classes for variety of applications
Constant volume or 2 position exhaust flow control devices which may also have shutoff capability.
Min / Max Volume Exhaust Ventilation

Lab Vent Controls

Constant volume or 2 position exhaust flow control devices which may also have shutoff capability.

Additional constant volume control needs. The CV valves maintain precise flow and eliminate the need for future re-balancing at each lab device.
On / Off Volume Exhaust Ventilation

Lab Vent Controls

Constant volume or 2 position exhaust flow control devices which may also have shutoff capability.

Additional constant volume control needs. The CV valves maintain precise flow and eliminate the need for future re-balancing at each lab device.
Bench top fume hoods
Distillation & Floor mounted

- Designed to accommodate extra-tall distillation set-ups.
- The superstructure is supported on a low base cabinet.
- Flexible configuration of lattice rod for apparatus support

- Constructed with additional interior height to accommodate large apparatus.
- Floor mounted, permitting roll-in loading of heavy or bulk apparatus.
- Although called walk-in hoods, the user should never stand inside the hood while fumes are being generated.
Auxiliary Air Hoods

Not recommended for laboratories
BIG walk-in fume hood
Fume hood Components

- Exhaust duct
- Vertical Sash
- Airfoil Sill
- Baffles
Fume hood Control

Requirements
- Safety / fume containment
- Speed of response
- Accuracy
- Turndown
- Sash sensing
- Alarming
- Emergency Override

Minimum sash position = minimum energy costs

CFM = FT^2 * FPM

100 fpm
Face Velocity

Sash Sensor
Accel II
Venturi Valve
ZPS

Fume Hood Monitor
Primary Barriers (BSCs)

Bio Safety Cabinets

- Class I, II, III
- Class II types A1, A2, B1, B2 most common
- If Canopy or hard duct a airflow regulator is needed
- Canopy flow may need HEPA filtration
- Good work practices are critical to containment and balance
Laboratory Control Objectives

- Fume hood capture and containment
- Laboratory pressurization
- Minimum ventilation control (ACH)
- Temperature control
- Energy Conservation

Let’s look at fume hood containment
Laboratory Airflow Strategies
The Options

- **Constant Volume**
  - Traditional Cv fume hoods
  - Low flow / high performance hoods

- **Two-state**
  - Sash Switch
  - Room Switch
  - Zone Presence Sensor®

- **Variable Air Volume**
  - VAV fume hoods

- **Usage Based Controls®**
Sash Switch Two State Hoods

Flow Switching:
- Based on vertical sash position
- switch by fume hood mfg
- various types depending on users

Flow in cfm

Switch Point

Supply Valve

Hood Valve

Fume Hood Exhaust

Room Supply (Make-up Air)
Flow Switching Options:
- In Use when students are scheduled
- Key switch, local control
- Building Automation Remote Control
Lab Vent Controls

VAV Flow Control = Constant Fv

Flow in cfm

- Fume Hood Exhaust
- Room Supply Air (Make-up Air)

Sash Position
6”  30”

Supply Valve
Hood Valve

Note:
ANSI Z9.5-2012 “.... 150 to 375 ACH with hood...
Usage Based Control

Lab Vent Controls

Fume Hood

Occupancy Sensor mounted on the fume hood
- Lower exhaust volume when no one in front of hood
- Restore 100 fpm within 1 second of occupancy at the hood
- Reduction in make up air flow and associated HVAC Energy Costs
- Reduction in capital costs if HVAC diversity is taken.
Room Pressurization

Lab Vent Controls

Exhaust
Supply
Offset
Lab Vent Controls

Typical Laboratory Module

Total Air or Radial Diffusers

Consider Room level diversity in dense labs

Airfoils on fume hoods

Combination sashes on fume hoods
“... specifying quantitative pressure differential is a poor basis of design. What really is desired is an airflow velocity through any openings... (doors).” – ANSI/AIHA Z9.5
System Response Time

- Response time for airflow changes of supply air into the lab must be similar to exhaust speed to maintain proper pressurization.

- Unbalanced system response can cause:
  - Loss of fume hood containment
  - Outflow from the laboratory
  - Pressure instability within the building
OFFSET = 10% OF TOTAL EXHAUST

Volumetric Offset Control
- Maximum Fume hood & Exhaust demand
- Occupied ventilation rate (ACH)
- Unoccupied ventilation rates (ACH)
- Temperature control / Thermal Demand
Fume hood exhaust airflow demand

CV 300 CFM Volumetric offset air, 10% of exhaust maximum.
CV 300 CFM Volumetric offset air, 10% of exhaust maximum.

If 10 ACH Occupied = 800 cfm then, min supply air = 800-300 = 500

General Exhaust must remove 200 cfm when sashes are closed
CV 300 CFM Volumetric offset air, 10% of exhaust maximum.

If thermal demand = 1,000 cfm then, supply air = 1,000 (no cooling for Offset air). Exhaust must remove 1,300 cfm when sashes are closed.
Variable Volume Fume Hoods
Diversity in high density fume hood labs
Typical Airflows Comparison

Constant Volume / VAV Design Point

VAV Risk

VAV or Usage Based Controls Design Point

Typical Cooling CFM Requirement
Balancing a real laboratory

8 Fume hoods x 1,200 cfm = 9,600 cfm exhaust

Fume hoods
1,200 cfm/Max
240 cfm/Min
5:1 Turndown

Canopy
424 cfm/Max
84 cfm/Min
5:1 Turndown

Supply Air
8994 cfm/Max
1800 cfm/Min
5:1 Turndown
### Lab Balance Worksheet

<table>
<thead>
<tr>
<th>Condition</th>
<th>Supply</th>
<th>Exhaust</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACH Flow (Occupied)</td>
<td>600 CFM</td>
<td>0 CFM</td>
<td>600 CFM</td>
</tr>
<tr>
<td>ACH Flow (Unoccupied)</td>
<td>430 CFM</td>
<td>0 CFM</td>
<td>430 CFM</td>
</tr>
<tr>
<td>Maximum Cooling Flow</td>
<td>0 CFM</td>
<td>0 CFM</td>
<td>0 CFM</td>
</tr>
<tr>
<td>CV Supply Quantity</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>VAV Supply Quantity</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>VAV GEY Quantity</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Hood</th>
<th>Supply</th>
<th>Office Min</th>
<th>Max</th>
<th>CV Supply</th>
<th>Hood Min</th>
<th>Other Exh. Min</th>
<th>GEY 1A</th>
<th>Total Exhaust</th>
</tr>
</thead>
<tbody>
<tr>
<td>9.053</td>
<td>1.006</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>9,800</td>
<td>424</td>
<td>35</td>
<td>10,859</td>
</tr>
<tr>
<td>1.036</td>
<td>1.006</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1,920</td>
<td>87</td>
<td>35</td>
<td>2,042</td>
</tr>
<tr>
<td>1.036</td>
<td>1.006</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1,920</td>
<td>87</td>
<td>0</td>
<td>2,042</td>
</tr>
<tr>
<td>1.036</td>
<td>1.006</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1,920</td>
<td>87</td>
<td>35</td>
<td>2,042</td>
</tr>
<tr>
<td>1.036</td>
<td>1.006</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1,920</td>
<td>87</td>
<td>35</td>
<td>2,042</td>
</tr>
<tr>
<td>1.036</td>
<td>1.006</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1,920</td>
<td>87</td>
<td>35</td>
<td>2,042</td>
</tr>
<tr>
<td>1.036</td>
<td>1.006</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1,920</td>
<td>87</td>
<td>660</td>
<td>2,576</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Tie Rail</th>
<th>Supply</th>
<th>Office Min</th>
<th>Max</th>
<th>CV Supply</th>
<th>Hood Min</th>
<th>Other Exh. Min</th>
<th>GEY 4A</th>
<th>Total Exhaust</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.570</td>
<td>1.006</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1,920</td>
<td>87</td>
<td>660</td>
<td>2,676</td>
</tr>
</tbody>
</table>
Diversity in high density fume hood labs

- Design supply air to a percentage of the maximum exhaust flow
- Variable Air Volume fume hoods
- Limit fume hood maximum flow
  - Sash stops
  - Usage based controls (user independent)
- Include a diversity alarm
- Use of low flow fume hoods
- Include ability for general exhaust shutoff
- Include for hood shutdown to reduce energy consumption when not in use
- User behavior initiatives
- Automatic sash closers (user dependent)
Laboratory Room Ventilation

- Safety! Fume hood containment
- Speed of response to flow & static pressure changes
- ANSI Z9.5 – 2012 minimum Fume Hood ventilation
- Room pressurization
- Air Change Rates and DCV
- Temperature Control
- Minimizing energy consumption
Ventilation Approaches

Exhaust equipment Control

- Constant volume low flow fume hoods
- 2 position fume hoods and variable room flows (low flow or standard hoods)
- Variable Volume (Constant Face Velocity)
  - Lowest energy consumption possible
  - Shut off when not in use (hibernation mode)
  - User feedback to lower the sash (new Sentry)
  - Lowest noise levels when sash closed
- Usage Based Controls (ZPS)
- General exhaust shut off.

Optimizer Analysis to determine best approach
Ventilation Approaches

Supply Airflow Control

- Constant volume. Energy intensive, noisy?
- Full Variable Air Volume with Occupancy setback
- Diversity (limit supply max) in high density laboratories
- Demand Control Ventilation (Sensing room contaminants)
- Thermal decoupling ventilation from cooling loads. Fan coils, chilled beams etc...

Optimizer Analysis to determine best approach
Additional Considerations

- Integration with the building management system
- Pressure Independence
- Airflow Accuracy
- Inlet conditions
- Noise
- Turndown (Airflow max to min)
- System Stability
- Corrosion Resistant
- Reliability/Simplicity
- Maintenance requirements
Energy Efficiency & Sustainability
Best & Safest Way to save energy

did you remember to shut the sash?
open fume hoods = energy waste

Courtesy of UBC
Best & Safest Way to save energy

Courtesy of UBC
Energy Efficiency & Optimization

- **Reduce laboratory exhaust**
  - Minimize Constant volume
  - Utilize VAV or low flow fume hoods to reduce exhaust
  - Lower fume hood minimums if possible (ANSI Z9.5 2012)
  - Hibernate or decommission hoods when not in use
  - Simple Occupied / Unoccupied control

- **Accurate control of supply air and exhaust demand**

- **Alternate ventilation technologies**
  - IAQ Sensing and Control (lower ACH) via Demand Controlled Ventilation
  - Chilled Beam / Fan coils units decouple vent / thermal loads

- **Lower pressure drop design where possible**

- **Fan static reset (ASHRAE 90.1)**

- **Conversion of existing CV systems**

- **Heat Reclalm systems**

Cost to condition 100% outside air = $5 - 8/CFM (location dependent)
University of Pennsylvania

- CV fume hoods
- 280,000 cfm exhaust total

**Challenges:**
- Occupied building
- Replace AHUs on floors
- Funding

**Goals:**
- Reduce energy costs
- Flexible open lab spaces
- Improve ventilation and temperature control

Chemistry 73 Wing

Courtesy of AHA Engineering
Retrofit Project Examples

University of Pennsylvania

37.6% energy savings annually

Courtesy of AHA Engineering
Retrofit Project Examples

McGill University, Otto Maass Chemistry Building

Complete building retrofit and upgrade engineering by PMA Engineering, Montreal, QC
- 125,000 sqft
- 235 fume hoods
The problems:
- biggest energy consumer on campus, air quality issues, 18 month timeline, occupied spaces, asbestos
The renovation of the Otto Maass Building's laboratories, mechanical rooms and distribution shafts for lab areas reduced the annual building energy consumption by 59%. Efficiency measures focused primarily on heat recovery and airflow control based on user needs.
The plan...
- Retrofit during occupancy using temporary ventilation systems
- Ventilation transfer air from write up rooms to lab space
- VAV fume hoods with Zone Presence Sensors for:
  Airflow reduction, diversity and compliance management
- Comprehensive ventilation strategy
- Heat transfer from Burns building and heat recovery

Results….  
- 59% reduction of energy or $1.3M annual cost savings
- indoor & outdoor air quality improvements.
Stanford University, Stauffer Chemistry Research
- Campus energy assessment study in 2002
- 12 buildings combined operating cost of $15.3 Million
- Stauffer 1 building selected due to its high energy consumption
- Fan systems at capacity
- Changes required a complete building rebalance
- Maintaining room pressurization was problematic
- Complaints related to temperature and sound issues

The Plan…
- Convert existing CV fume hoods to VAV
- VAV Room controls
- Occupancy sensors (ZPS) at the fume hoods
- DDC Controls & Dynamic reset of supply air systems
- IAQ systems

The Results…
- **46% Energy Reduction**
- Significant improvement in air quality & noise
- Diversity allows additions and changes much easier
- Retrofit of additional buildings on campus

Retrofit Project Examples
Memorial University
St. John’s, NFLD
Chemistry Building Renovation

- Existing dual duct supply air system
- Safety, energy & operational concerns
- 87 fume hoods in base project
- Implemented a fume hood compliance program (see diagram)
- ESCO program (multi-bldg) $13M investment
- Achieved almost $10M savings over 5 years.
- Overachieved guarantee by almost $1.6M
- 15% CO₂ emission reduction.
PC Optimizer is an energy consumption / ROI payback analysis tool.

- Wizard Style user Interface
- Accurate VAV Modeling
- Detailed Analysis
- Reporting Options
- What-If Scenarios
Airflow Energy and Lifecycle Analysis Software

### Annual Energy Usage

<table>
<thead>
<tr>
<th>Control Type</th>
<th>Energy Cost ($USD)</th>
<th>Savings ($USD)</th>
<th>Cooling Energy (kWh)</th>
<th>Heating Energy (mcf)</th>
<th>Reheat Energy (mcf)</th>
<th>Supply Fan Energy (kWh)</th>
<th>Exhaust/Return Fan Energy (kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CV VAV Box</td>
<td>$24,536</td>
<td>$0</td>
<td>84,700.3</td>
<td>0.8</td>
<td>716.9</td>
<td>64,067.8</td>
<td>42,711.9</td>
</tr>
<tr>
<td>VAV Boxes</td>
<td>$23,023</td>
<td>$1,513</td>
<td>84,700.3</td>
<td>0.8</td>
<td>716.9</td>
<td>58,861.1</td>
<td>35,312.1</td>
</tr>
<tr>
<td>VAV VV</td>
<td>$23,023</td>
<td>$1,513</td>
<td>84,700.3</td>
<td>0.8</td>
<td>716.9</td>
<td>58,861.1</td>
<td>35,312.1</td>
</tr>
<tr>
<td>VAV VV w/UBC</td>
<td>$18,546</td>
<td>$5,980</td>
<td>70,414.1</td>
<td>27.2</td>
<td>557.3</td>
<td>46,120.6</td>
<td>27,668.9</td>
</tr>
</tbody>
</table>

### Financial Analysis ($USD)

<table>
<thead>
<tr>
<th>Control Type</th>
<th>NPV</th>
<th>IRR</th>
<th>SIR</th>
</tr>
</thead>
<tbody>
<tr>
<td>CV VAV Box</td>
<td>$0</td>
<td>0 %</td>
<td>0</td>
</tr>
<tr>
<td>VAV Boxes</td>
<td>$320,646</td>
<td>192.1 %</td>
<td>16.55</td>
</tr>
<tr>
<td>VAV VV w/UBC</td>
<td>$352,008</td>
<td>160.4 %</td>
<td>13.77</td>
</tr>
</tbody>
</table>

### 10 Year Life Cycle Cost ($USD) and Payback

- **Energy Costs**
- **O & M Costs**
- **Product Initial Costs**
- **HVAC Initial Costs**

**Immediate**:
- CV VAV Box: $1804,156
- VAV Boxes: $1804,156
- VAV Venturi Valves: $268,938
- VAV VV w/UBC: $216,787

**0.2 yrs**:
- CV VAV Box: $12,500
- VAV Boxes: $12,500
- VAV Venturi Valves: $22,500
- VAV VV w/UBC: $24,500

**2.1 yrs**:
- CV VAV Box: $263,434
- VAV Boxes: $263,434
- VAV Venturi Valves: $263,434
- VAV VV w/UBC: $263,434

### Annual Greenhouse Gas Emissions Equivalency

<table>
<thead>
<tr>
<th>Control Type</th>
<th>CV VAV Box</th>
<th>VAV Boxes</th>
<th>VAV Venturi Valves</th>
<th>VAV VV w/UBC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metric Tons of Carbon Dioxide Equivalent (thousands)</td>
<td>1.32</td>
<td>(0.09)</td>
<td>(0.09)</td>
<td>(0.33)</td>
</tr>
</tbody>
</table>
Reports

- Project Summary
- Room Balance
- Room Detail
- Fume Hood Summary
- Corridor Detail
- Fan Systems Summary
- System Design Flow Comparison
- Project Cost Comparison
- Incremental Financial Analysis Comparison
- System (Global) Defaults
- Energy Usage and Savings
- Sustainability Report

Financial Analysis Comparison

Please select the system types to compare

<table>
<thead>
<tr>
<th>Base Type</th>
<th>Option 1</th>
<th>Option 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Non-Phoenix CV</td>
<td>Non-Phoenix CV</td>
</tr>
<tr>
<td>Phoenix CV</td>
<td>Phoenix CV</td>
<td>Non-Phoenix VAV</td>
</tr>
<tr>
<td>Non-Phoenix VAV</td>
<td>Non-Phoenix VAV</td>
<td>Phoenix VAV</td>
</tr>
<tr>
<td>Phoenix 2-State UBC</td>
<td>Phoenix 2-State UBC</td>
<td>Phoenix VAV</td>
</tr>
<tr>
<td>Phoenix VAV-UBC</td>
<td>Phoenix VAV-UBC</td>
<td>Phoenix VAV-UBC</td>
</tr>
</tbody>
</table>

(The two options will be compared against the base type)

Cancel  OK
## Sustainability Report

### Annual Greenhouse Gas Emissions Equivalency

<table>
<thead>
<tr>
<th>Metric</th>
<th>Phoenix VAV: (BASE CASE)</th>
<th>Phoenix VAV UBC (vs base case)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metric Tons of Carbon Dioxide Equivalent (thousands)</td>
<td>3.24</td>
<td>(1.47)</td>
</tr>
<tr>
<td>Barrels of Oil Consumed (thousands)</td>
<td>7.54</td>
<td>(3.42)</td>
</tr>
<tr>
<td>Gallons of Gasoline Consumed (thousands)</td>
<td>363.48</td>
<td>(164.77)</td>
</tr>
<tr>
<td>Number of Homes Electricity Use for One Year</td>
<td>404.27</td>
<td>(183.26)</td>
</tr>
<tr>
<td>Number of Tanker Trucks Worth of Gasoline</td>
<td>42.76</td>
<td>(19.38)</td>
</tr>
<tr>
<td>Number of Passenger Cars Annual Emissions</td>
<td>635.73</td>
<td>(288.19)</td>
</tr>
</tbody>
</table>
So....

Which airflow control method fits your application?
The Options

- **Constant Volume**
  - Traditional Cv fume hoods
  - Low flow / high performance hoods

- **Two-state**
  - Sash Switch
  - Room Switch
  - Zone Presence Sensor®

- **Variable Air Volume**
  - VAV fume hoods

- **Usage Based Controls®**
Factors to Consider

- Hood density (# of hoods/room volume)
- Energy costs (rising???)
- Room ventilation rates (ACH)
- Hours of operation (occ/unocc hours)
- Cooling load: Heat generation in labs
- Number of researchers per fume hood
- Lab space requirements and research applications
Reference Documents
Thank you

Don MacDonald
Phoenix Controls
dmacdonald@phoenixcontrols.com