Demand-Based Control of Laboratory Air Change Rates

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Chairman
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Aircuity Project: Bank of America Tower, NYC
Lab Energy Usage:
- 5 to 10 times office usage

For many universities:
- 2.5 to 10% sq. footage
- 10 to 40% site energy usage

Laboratory ventilation rates are the single largest factor affecting lab energy use & potentially for an entire campus!
The Controversy Around Air Change Rates

- Minimum air changes still fixed at 6-12 / 10-20 ACH
- Far majority of time lab air is “clean”
- However, there are many times when more air is better
  - Dilute vapors from a spill when lab is occupied or unoccupied
  - Dilute vapors or particles caused by poor practices
    - Working outside the hood, improper storage
    - No localized exhaust for instruments
    - Improper bedding changing

There is no one ventilation rate that is right all the time!
Impact of Higher Air Changes

- Test Case– Teaching Lab
- Acetone at 4 ACH
- CFD courtesy of Glenn Schuyler’s ASHRAE Presentation

Relative contaminant level: 27 PPM (black)
Impact of Higher Air Changes

- Test Case– Teaching Lab
- Acetone at 8 ACH
- CFD courtesy of Glenn Schuyler’s ASHRAE Presentation

Relative contaminant level: 2.5 PPM (light blue): Factor of 10 improvement!
“..greatest improvement in room air quality occurred between about 6 & 8 ACH..”

✓ Spill testing showed large impact from increasing ACH rate from 6 to 8 ACH

Yale’s conclusions for their campus:

✓ “New acceptable range: 8 - 12 ACH”
✓ “< 8 ACH only for truly low hazard labs, unoccupied set-backs, or approved demand control systems”
Lab Multi-parameter DCV: Dynamic control of min. ACH

- Now all three factors affecting lab airflow can be varied
- Significantly cuts energy & first cost, while enhancing safety

<table>
<thead>
<tr>
<th>Ventilation Rate (cfm)</th>
<th>Hoods</th>
<th>Thermal Load</th>
<th>ACH / Dilution Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>VAV</td>
<td></td>
<td>VAV</td>
<td></td>
</tr>
<tr>
<td>2-4 ACH</td>
<td></td>
<td>6-8 ACH*</td>
<td>6-12 ACH</td>
</tr>
<tr>
<td>6-12 ACH</td>
<td></td>
<td>10-20 ACH*</td>
<td>*vivariums</td>
</tr>
</tbody>
</table>

Significant energy waste
Lab/Vivarium Demand Controlled Ventilation

Varies dilution/ min ACH’s by sensing room IEQ
- If room air is clean, dilution airflow can be reduced
- Yet greater room dilution is provided when needed

Most lab controls can vary min ACH levels

Critical piece: Sensing of IEQ parameters:
- Lab TVOC’s, particles, ammonia, RH, CO, & CO2

Barriers to date: Cost effectiveness & practicality
- Sensor cost, long term reliability, & calibration exp.

A new cost effective sensing concept is required
A New Approach: Multiplexed Sensing

- Routes multiplexed air samples to central sensors
  - Integrated into BMS for monitoring & control
  - Includes web based data collection & analysis
Multiplexed Sensing Operation

Room 101

Room 102

Room 103

Outdoor Air Probe

Vacuum Pump

Air Probe

Sensor Suite

Server

Web Based User Interface

Connectivity

Air Data Router
**Sensed Parameters**

- **Air Cleanliness**
  - Total Volatile Organic Compounds
    - Photo-Ionization Detector & Metal Oxide Sensor
  - Particles – laser based particle counter
  - Carbon Monoxide (CO)

- **Comfort & Ventilation**
  - Temperature
  - Humidity or Dew point
  - Carbon Dioxide (CO2)
Dynamic ACH Control Saves Energy Safely

- There is no need to dilute clean air with clean air
  - 99% of the time the air will be clean, no need to dilute

- Set min dilution levels per OSHA or as desired
  - For highest concern: 4 ACH occupied & 2 ACH unoccupied
    - OSHA guidelines have a minimum at 4 ACH (range of 4 to 12)
  - For normal lab applications, use 2 ACH as occ min.
    - ASHRAE fresh air min for science lab is .18 cfm/sq. ft. or 1.2 ACH

- Set max dilution for 12 to 16 ACH for safest purge

System responds to great majority of contaminants with high ACH’s vs. a lower fixed ACH rate
2008 Lab IEQ Performance Monitoring Study

- Largest known study done to date
  - 1,500,000 lab operating hours analyzed
  - 20 Million sensor data values recorded

- 18 different sites selected
  - 6 East, 7 Central, 3 West, 2 Canada

- Over 300 different lab areas
  - Research: Life sciences, bio, physical chem, etc.
  - Almost all low density labs w/ dynamic control
  - 3 animal facility sites
Average TVOC Levels at 18 Different Sites

At ~0.2PPM, site value range: ~ .05% to 2.25%

Significant savings at all sites

Average for all sites
At 1M PCF, Site value range: ~ 0% to 1.4%

Data shows significant savings at all sites
Centralized Demand-Controlled Ventilation (CDCV) Analysis

Additional Construction Cost: $49,321

Annual Energy Cost Savings: $26,926, 20.2%

Simple Payback: 1.8 years

Table:

<table>
<thead>
<tr>
<th>Option J (CDCV)</th>
<th>Additional Construction Cost:</th>
<th>$49,321</th>
</tr>
</thead>
</table>

Graph:

- First Cost: $6,600 to $7,400
- Annual Cost: $6,600 to $7,800
- Baseline: $6,800

Image courtesy of Aircuity, Inc.
### Summary of Energy Analysis Options

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
<th>Additional First Cost (versus Baseline Costs)</th>
<th>Annual Energy Cost Savings (versus Baseline Costs)</th>
<th>Simple Payback (Years):</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Dollars: Dollars per GSF: Dollars: Percent:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A1</td>
<td>Building rotated 90 deg. (facing East)</td>
<td>$17,130 $1.01</td>
<td>$(1,495) -1.1%</td>
<td>No Payback</td>
</tr>
<tr>
<td>A2</td>
<td>Building rotated 180 deg. (facing South)</td>
<td>$12,500 $0.74</td>
<td>$(1,903) -1.4%</td>
<td>No Payback</td>
</tr>
<tr>
<td>A3</td>
<td>Building rotated 270 deg. (facing West)</td>
<td>$42,350 $2.50</td>
<td>$(2,942) -2.2%</td>
<td>No Payback</td>
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<tr>
<td>B1</td>
<td>Improved exterior walls</td>
<td>$1,200 $0.07</td>
<td>$521 0.4%</td>
<td>9.6</td>
</tr>
<tr>
<td>B2</td>
<td>More improved exterior walls</td>
<td>$1,900 $0.11</td>
<td>$865 0.7%</td>
<td>21.6</td>
</tr>
<tr>
<td>B3</td>
<td>Most improved exterior walls</td>
<td>$2,400 $0.14</td>
<td>$1,128 0.8%</td>
<td>18.7</td>
</tr>
<tr>
<td>C1</td>
<td>Improved windows</td>
<td>$13,440 $0.79</td>
<td>$281 0.2%</td>
<td>47.8</td>
</tr>
<tr>
<td>C2</td>
<td>More improved windows</td>
<td>$15,600 $0.92</td>
<td>$892 0.7%</td>
<td>17.5</td>
</tr>
<tr>
<td>C3</td>
<td>Most improved windows</td>
<td>$15,600 $0.92</td>
<td>$1,724 1.3%</td>
<td>9.0</td>
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<tr>
<td>D1</td>
<td>Alternative lighting approach</td>
<td>$45,260 $2.67</td>
<td>$7,959 6.0%</td>
<td>5.7</td>
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<tr>
<td>D2</td>
<td>Reduced ceiling height (9'-6&quot;)</td>
<td>$(32,720) $(1.93)</td>
<td>$4,393 3.3%</td>
<td>4.4</td>
</tr>
<tr>
<td>D3</td>
<td>Reduced ceiling height (8'-6&quot;)</td>
<td>$(55,170) $(3.26)</td>
<td>$6,375 4.8%</td>
<td>4.4</td>
</tr>
<tr>
<td>G1</td>
<td>High-efficiency chillers and boilers</td>
<td>$49,501 $2.92</td>
<td>$13,411 10.1%</td>
<td>3.7</td>
</tr>
<tr>
<td>G2</td>
<td>High-efficiency air handling units</td>
<td>$53,050 $3.13</td>
<td>$1,282 1.0%</td>
<td>41.4</td>
</tr>
</tbody>
</table>

**Demand Based Control had greatest impact of all ECM’s**
Lab Case Study: Arizona State University

- ASU Biodesign Institute Bldgs A & B Retrofit
  - Retrofit of Labs and Vivarium (location of Tradeline tour)
- LEED NC Platinum, R&D 2006 Lab of the Year
- Started as pilot in 2007, **now includes 300 lab zones**

**Old Average Supply: 15,978 CFM**

Average Savings: 10,757 CFM
- In 11 Zones (~8,000 ft²)
- At $5.14/CFM annually
  - $55,290 annually
  - $6.91/ft² annually
- < 11 month payback!

**New Average Supply air : 5,221 CFM**

**Pilot Study Results**

- June 4, 2007 System Activation
- 10,757 CFM Savings
ASU Biodesign Institute Lab & Vivarium Project

- Full project installed
  - Further ACH reductions in process
- ASU has estimated full savings when done of $1 million a year
  - Savings of ~$5 per net sq ft/year
- Savings equivalent to:
  - 4.5 MW solar array ~$31M cost
    - ~ 450,000 sq ft of installed panels
- 10 other ASU retrofits underway
  - Office, classroom, library, & sciences buildings

90+ Zones Sensed in Bldg B Vivarium
Significant Impact for Zero Emissions Labs & Bldgs

- **Craig Venter Institute – San Diego**
  - Zero emissions lab with **Lab DCV & chilled beam design**

- **Cal Poly at San Luis Obispo lab**
  - Also net zero project designed w/ Lab DCV & chilled beams

- **Masdar City – Abu Dhabi, UAE**
  - World’s largest zero emissions project (6 sq. km. project)
  - Lab DCV is being used on multiple lab projects:
    - **MIST (Masdar Institute of Science & Technology):** large mixed use lab bldgs.

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**Masdar HQ Bldg:** 1.3M sq. ft.  
**MIST 1A:** 500K sq. ft.
Another Lab Application: Exhaust Fan Control

- Variable exhaust velocity for high plume fans
  - Saves energy by safely reducing exhaust velocity
  - 2008 Labs21 paper on this presented with CPP
  - Reduce fan exit velocity when exhaust stream clean
  - Monitor air intakes w/ to verify system efficacy
  - Potential savings: ~50\% reduction in fan power
Exhaust Fan Monitoring: Medical Research Building

1 Hr Event

PID TVOCs Graph


PID TVOCs Graph


1 Hr Event
Demand Based Control of Labs Summary

- Significant energy savings & Enhanced IEQ
- A building wide sensing infrastructure
- For new & existing facilities
- Cost effective LEED points
- Also applicable to other bldgs.
  - Office buildings
  - Classroom & Educational
  - Healthcare
  - Public Assembly & Arenas

ASHRAE Journal: Feb 2010
Questions???