Demand Based Control of Lab & Commercial Building Ventilation

- Bank of America: Largest LEED Plat.
- Garvan Cancer Center, Australia
- Richardsville Elementary: 1st net-zero school
- Masdar City, UAE: MIST 1A
- ASU: Biodesign Institute

Aircuity
The Statistics of Laboratory Energy Use

Lab Energy Usage:
- 5 to 10 times office usage

Example: Universities:
- 2.5 to 10% sq. footage
- 10 to 40% site energy usage

>65% of lab energy: HVAC

In Singapore, HVAC load will typically be >80% of lab energy!
The Goal: Dramatically Reduce Lab Energy Use

Outside air use: Largest energy driver
- Reducing OA reduces many energy uses
  - Supply fans, Heating, Cooling, Reheat, Exhaust fans

New technologies can help:
- Demand Based Control of ACH
- Chilled beams & hydronic/non-air cooling

Additionally codes are changing:
- New versions of NFPA 45 & ANSI Z9.5:
  - Changes to the fume hood min requirements

Result: Labs can often run at 2 - 4 ACH
- May require combining multiple approaches

Like peeling layers of an onion, multiple approaches may need to be combined to dramatically cut energy use
Achieving Down to 2 ACH Safely in Labs

- **Goal:** Achieve 2 ACH day/night or 3-4 day/night

- **What are the drivers of lab airflow that affect this?**
  - Hood flows, thermal loads & ACH rates

To achieve lab flows down to 2 ACH to reduce energy & 1st cost, *all* flow requirements need to be reduced.
Reducing the ACH Rate Flow Drivers:

- Min lab ACH often fixed at 6-12 ACH
  - Typically becomes largest energy driver
- However, lab air is clean > 98% time
- But, events happen requiring >6ACH
  - Dilute vapors from a spill
  - Eliminate fugitive vapors
  - Dilute vapors or particles caused by:
    - Working outside the hood, improper storage
    - No localized exhaust for instruments
    - ……

There is no one ventilation rate that is right all the time!
Laboratory Demand Control Ventilation

- Vary min ACH rate by sensing room IEQ
  - If room air is clean, maintain low dilution airflow
  - When contaminants detected, Increase airflow

- Set min dilution level at 4 to 2 ACH
  - One option is run at 4 ACH occupied & 2 ACH unocc.

- Set max dilution to 8 - 16 ACH for safest purge
  - Typically set max ACH to max capacity of VAV device

- Critical piece: Sensing of IEQ parameters:
  - Lab TVOC’s, particles, RH, CO, & CO2
  - **Barriers to date: Cost effectivity & practicality**
    - Sensor cost, long term reliability, & calibration exp.

New cost effective sensing approach required
A Cost Effective Approach: Multiplexed Sensing

- Supply Air Duct
- Lab Room 101
- Lab Room 102
- Classroom 103
- Supply Air Reference Probe
- GEX Duct (typ.)
- Room Sampling Port
- General Exhaust Duct
- Sensor Suite with TVOC, CO2, dewpoint & particulate sensors
- Air Data Router
- Server
- Web Based User Interface
- BMS Connectivity to command ACH increase/decrease
- Vacum Pump
- BACnet
Normal Lab Operation w/ Lab DCV System

VOC event sensed at GEX

ACH varies 4 to 12.7
Industry Recommendations on ACH Rates

- No codes other than ASHRAE 62.1
  - At best for Univ/college labs: 1.2 ACH fresh air

- Most fixed ACH values are being dropped:
  - NFPA 45 - 2011: 8 Occ / 4 Unocc rates were removed
  - ANSI Z9.5 does not advocate for any fixed rate:
    - “An air exchange rate (air changes per hour) cannot be specified that will meet all conditions.”
    - “Furthermore, air changes per hour is not the appropriate concept for designing contaminant control systems.”
New 2011 ASHRAE Handbook, Lab chapter 14:

- Occ/Unocc Control scope is being limited:
  - “There should be no entry into the laboratory during unoccupied setback times”
  - “…Occupied ventilation rates should be engaged possibly one hour or more in advance of occupancy to properly dilute any contaminants.”

- Active/Demand Based Control is recommended:
  - “Reducing ventilation requirements in laboratories and vivariums based on real time sensing of contaminants in the room environment offers opportunities for energy conservation.”
  - “This approach can potentially reduce lab air change rates down safely to as low as 2 air changes per hour when the lab air is ‘clean’...”
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

*ASHRAE Journal
Feb 2010
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
Avg. Differential Particle Levels at 18 Sites

Data shows significant savings at all sites

At 1M PCF,
Site value range:
~ 0% to 1.4%

Average Level
Detection of Improper Lab Practices: Lynch Life Sciences Labs

The graph below illustrates what happens to the TVOC levels in a lab when a researcher improperly vents his experiment.

A researcher in lab 331 was sticking the exhaust of his mass-spec. into the local snorkel exhaust, then pinched it off with the blast gate. This created elevated TVOC levels in the lab.
Lab Case Study: Arizona State University

- ASU Biodesign Institute Bldgs A & B Retrofit
  - Retrofit of Labs and Vivarium
- LEED® NC Platinum, R&D 2006 Lab of the Year
  - Lab DCV pilot in 2007 to look for EE: 65% savings achieved
  - Full building retrofitted in 2009: $1 Million saved annually
  - Currently 24 buildings have been retrofitted:
    - Office, classroom, library, & sciences bldgs plus sports arena and more

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**Pilot Study Results**

<table>
<thead>
<tr>
<th>June-4, 2007 System Activation</th>
<th>Old Average Supply: 15,978 CFM</th>
<th>New Average Supply air: 5,221 CFM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exhaust CFM</td>
<td>Supply CFM</td>
<td>Average Savings: 10,757 CFM in 11 Zones (~8,000 ft²)</td>
</tr>
<tr>
<td>Average Savings: 10,757 CFM</td>
<td>At $5.14/CFM annually</td>
<td>= $55,290 annually</td>
</tr>
<tr>
<td></td>
<td>= $6.91/ft² annually</td>
<td>&lt; 11 month payback!</td>
</tr>
</tbody>
</table>


Exhaust CFM  Supply CFM
Masdar City, Abu Dhabi - Largest net/near zero project

- Near zero emissions lab w/ Demand Control & chilled beams
  - 150K m² total, ~ 40K m² of labs: MIST 1 A (Built) & 1B (Under const.)
- Projected total energy savings: $2 M $ or 9,000 MWh /year
  - Labs operate at 2 ACH (day & night), purge up to 14 ACH
- Downsized mechanical system to save HVAC capital costs
- Cuts solar PV capacity by ~ 3.75 MW or ~$20M first cost!
Other Case Studies using Demand Based Lab Control

- Acadia University
- Arizona State University
- Beth Israel Medical Center
- Chicago Botanic Garden
- Cal State Univ., Monterey
- Cal Tech
- Case Western Reserve Univ.
- Colorado Sch. Of Mines
- Children’s Hospital of Phil.
- Dalhousie Univ.
- Dartmouth College
- Eli Lilly
- Ferris State University
- Food & Drug Admin. (FDA)
- Ferris State University
- Grand Valley State Univ
- Harvard (HSPH)
- Indiana/Purdue Fort Wayne
- LabCorp – BioRepository
- Masdar Institute (MIST)
- Michigan State University
- Midwestern University
- Ministère de l’agriculture,
- Montreal Heart Institute
- Nevada Cancer Institute
- Ohio State University
- Oklahoma State University
- Rice University
- SUNY Stony Brook
- Texas Children’s Hospital
- University of Cal Irvine
- University of Iowa
- University of Louisville
- University of Pennsylvania
- Univ. Health Network: MaRS
- Van Andel Institute

UPenn: “Demand Based Control is our #1 campus
Singapore Example: Energy & 1st Cost Analysis

- Model typical bldg. w/ 12.5K GSM
  - Lab & lab support area: 5K NSM
  - Office area: 3K NSM
- Base dilution ventilation:
  - 8 ACH occupied, 6 ACH Unocc.
- Energy Cost Assumptions:
  - Electric: SGD 0.20/kWh Avg
- Low to moderate hoods:
  - One 1.8m hood/ 62.5 sq.m. module
- Uses Singapore weather data
  - In Singapore dollars (SGD)
Singapore Example Analysis Assumptions

- Room Temp setpoint:
  - 24 DegC cooling
  - 22 DegC Heating/reheat

- HVAC System Eff:
  - Cooling:
    - Total COP of chilled water plant: 3.3
    - Eff. Chilled Beam “COP”: 4.0
  - Heating: electric

- Typical thermal loading used
  - 80% of labs at 35 W/m² avg.
  - 20% of labs at 60 to 90 W/m² avg.
Baseline Energy Costs For Singapore Example

- Cooling dominates energy use: >60% of total
- Skin & solar gains typically small compared to OA
- Assumes a VAV lab air controls w/ reheat
- Total baseline energy use is SGD 1.6M

**HVAC Energy Use Breakdown**

<table>
<thead>
<tr>
<th>Component</th>
<th>Total in Millions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooling</td>
<td>1,603</td>
</tr>
<tr>
<td>Heating</td>
<td>996</td>
</tr>
<tr>
<td>Reheat</td>
<td>310</td>
</tr>
<tr>
<td>Exhaust Fan</td>
<td>175</td>
</tr>
<tr>
<td>Supply Fan</td>
<td>121</td>
</tr>
<tr>
<td><strong>Baseline</strong></td>
<td><strong>1,808</strong></td>
</tr>
</tbody>
</table>

**Base HVAC Energy Use Breakdown in % Energy Use**

- Cooling: 62%
- Reheat: 19%
- Exhaust Fan: 11%
- Supply Fan: 8%
- Heating: 0%
Demand Based Control reduces lab HVAC energy by $908 SGD or by 57%. Payback is 0.65 years!
Demand Based Control at 4/2 ACH reduces peak HVAC airflow by 18% or ~ $553K for ~ breakeven on first cost!
No savings for sensible HR, actually wastes energy due to increased pressure drop of coils.
Savings using 75% Enthalpy Wheel vs. DBC 4/2 ACH

Enthalpy wheel heat recovery (room exhaust only, no FH exhaust allowed) savings: $401K or 25% vs. $908K for DBC
Savings using DBC 4/2 ACH w/ 75% Enthalpy Wheel

Added HR savings is $197K or 12.3% added reduction,

**Total lab HVAC energy reduction is 69%!**
DBC is single greatest means to cut lab energy

- Lab HVAC energy can be cut by 40 to 70%

DBC is often >2X savings of best heat recovery

- Adding heat recovery to DBC also beneficial

DBC is also applicable to non-lab bldg & retrofits

- Healthcare, educational, commercial office, assembly

Questions?

For a copy of the presentation:
contact Gordon Sharp at
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Impact of Dynamic Control on Dilution Rates

1.5 L spill of acetone in 200 sq ft lab room, 1 sq. m spill
After vaporized, dynamic system hits TLV in 20 vs. 60 min
After 2 hours dynamic control has dropped level to 2.6 PPM
✓ After 2 hours, 6 ACH system is at 302 PPM or 116 times higher!

Dynamic control approach is always less than 6 ACH baseline
Impact of Air Velocity on Actual Yale Spill Results