Maximizing Energy Savings in Laboratories

Wendell Brase, UC Irvine
Chuck McKinney, Aircuity
Tom Smith, Exposure Control Technologies
Is the Key to Exemplary Lab Efficiency Technical, Organizational, or Both?

Wendell C. Brase
Vice Chancellor, Administrative & Business Services, University of California, Irvine
Co-Chair, University of California President’s Global Climate Leadership Council
Smart Building

*Just enough energy at just the right time*

How:

– Challenge all accepted design practices
– Use software and sensors to make building systems dynamic and “smart”
Smart Lab Key Elements

1. Retrofit constant volume to variable-air volume
2. Optimize safe air-change rates
3. Improve lighting efficiency
4. Optimize exhaust fan discharge airspeed
5. Reduce pressure drops throughout system
6. Optimize fume hood standby ventilation
7. Continuously commission
Smart Labs Resources

• Boston Green Labs Symposium Videos
  http://green.harvard.edu/campaign/green-labs-symposium

• UC Irvine Smart Labs Initiative
  http://www.ehs.uci.edu/programs/energy/
Critical-Path Steps to Exemplary Performance

1. Get the organizational culture ready
2. Adopt a challenging goal
3. Understand true scale of the challenge
4. Develop scalable strategy
5. Adopt interim milestones
6. Governing board/leadership alignment and support
7. “Mainstream” delegated responsibilities
8. Staff with appropriate talent
9. Build a team
10. Foster breakthrough thinking
11. Prepare to weather setbacks
12. Dedicated source of program financing
13. Simple project approval process
14. Pilot new concepts initially
15. Use “information layer” to verify and sustain performance
Organizational Development

• Get the organizational culture ready!
• Build a team
• Foster breakthrough thinking
  – Challenge status quo
  – Question accepted limits
  – Think comprehensively: re-engineer whole systems
• Prepare to weather setbacks
Performance Improvement Resources

• Sustainable Performance Improvement
  http://www.abs.uci.edu/resources/sustainable.html

• Survey of Management and Organizational Patterns
  http://www.abs.uci.edu/resources/deptsurvey.html
RESULTS
Where did we start?

<table>
<thead>
<tr>
<th>Laboratory Building</th>
<th>BEFORE Smart Lab Retrofit</th>
<th>More efficient than code?</th>
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<tbody>
<tr>
<td>Name</td>
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<td>VAV or CV</td>
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<td>6.6</td>
</tr>
<tr>
<td>McGaugh Hall</td>
<td>B</td>
<td>9.4</td>
</tr>
<tr>
<td>Reines Hall</td>
<td>P</td>
<td>11.3</td>
</tr>
<tr>
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<td>9.1</td>
</tr>
<tr>
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<td>B</td>
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</tr>
<tr>
<td>Calit2</td>
<td>E</td>
<td>6.0</td>
</tr>
<tr>
<td>Gillespie Neurosciences</td>
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<tr>
<td>Engineering Hall</td>
<td>E</td>
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</tr>
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</table>

Averages: 8.2 VAV ~20%

- All of these are existing buildings
- Multiple types of science represented
- Starting air change rates often higher than we expected
- Mix of mechanical system designs
- Most buildings were already very very efficient.

Type: P = Physical Sciences, B = Biological Sciences, E = Engineering, M = Medical Sciences
## UC Irvine’s Smart Labs Initiative

**Laboratory Building**

<table>
<thead>
<tr>
<th>Name</th>
<th>Type</th>
<th>Estimated Average ACH</th>
<th>VAV or CV</th>
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<td>VAV</td>
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<tr>
<td>McGaugh Hall</td>
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<td>9.4</td>
<td>CV</td>
<td>No</td>
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<tr>
<td>Reines Hall</td>
<td>P</td>
<td>11.3</td>
<td>CV</td>
<td>No</td>
</tr>
<tr>
<td>Natural Sciences 2</td>
<td>P,B</td>
<td>9.1</td>
<td>VAV</td>
<td>~20%</td>
</tr>
<tr>
<td>Biological Sciences 3</td>
<td>B</td>
<td>9.0</td>
<td>VAV</td>
<td>~30%</td>
</tr>
<tr>
<td>Calit2</td>
<td>E</td>
<td>6.0</td>
<td>VAV</td>
<td>~20%</td>
</tr>
<tr>
<td>Gillespie Neurosciences</td>
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<td>CV</td>
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<td>VAV</td>
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<td>Hewitt Hall</td>
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<tr>
<td>Engineering Hall</td>
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<td>8.0</td>
<td>VAV</td>
<td>~30%</td>
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<tr>
<td><strong>Averages</strong></td>
<td></td>
<td><strong>8.2</strong></td>
<td><strong>VAV</strong></td>
<td>~20%</td>
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</table>

**AFTER Smart Lab Retrofit**

<table>
<thead>
<tr>
<th>kWh Savings</th>
<th>Therm Savings</th>
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<tr>
<td>48%</td>
<td>40%</td>
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<tr>
<td>57%</td>
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<tr>
<td>67%</td>
<td>77%</td>
<td>69%</td>
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<tr>
<td>48%</td>
<td>62%</td>
<td>50%</td>
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<tr>
<td>45%</td>
<td>81%</td>
<td>53%</td>
</tr>
<tr>
<td>46%</td>
<td>78%</td>
<td>58%</td>
</tr>
<tr>
<td>58%</td>
<td>81%</td>
<td>70%</td>
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<td>71%</td>
<td>83%</td>
<td>75%</td>
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<td>58%</td>
<td>77%</td>
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<td>59%</td>
<td>78%</td>
<td>69%</td>
</tr>
<tr>
<td><strong>57%</strong></td>
<td><strong>72%</strong></td>
<td><strong>61%</strong></td>
</tr>
</tbody>
</table>

Type: P = Physical Sciences, B = Biological Sciences, E = Engineering, M = Medical Sciences
Unforeseen Benefits of Smart Labs Retrofits

- Deferred maintenance
- Safety/air quality longitudinal data
- No need for periodic commissioning
- Data to understand and target more opportunities
- Reduced wear and failure rates for fan motors and bearings
- Cleaner air in laboratories
CFO Concerns

• Low-risk investment
• Consistency of costs and benefits
• Sustainable performance
• Debt-coverage ratio
Laboratory Energy Saving Solutions

Reducing energy, improving operation and enhancing safety goals

Chuck McKinney, VP Sales & Marketing
May 27, 2015
Learning Objectives

Understand "Airside Efficiency"

Demand Based Control

Energy Reduction

Use ROI analysis to identify candidates for Airside Efficiency
Commercial buildings account for 20% of all US energy consumption.

HVAC energy accounts for 30% of total energy consumption in commercial buildings.
Labs use 6-10 times as much energy as a commercial office building.
Holistic Strategies for Increased Savings

- To optimize lab safety, first cost & energy:
  - Combining systems appropriately is best
  - Use a layered or pyramid approach:

- **HR**
  - Recover some of heating and cooling energy

- **Chilled Beams**
  - Decouple heat load from ventilation flows

- **VAV Exhaust Fan**
  - Demand Based VAV Exit Velocity/Flow

- **Demand Based Control/ FH Min**
  - Reduce flow requirements

- **VAV Lab Control**
  - Basic control approaches
Demand Based Control: adjust air change rates based on IEQ information

- Hood Flows
- Thermal Load
- ACH/Dilution Requirement
Measure air sample for each lab area

Is lab activity generating contaminants?

Inform building controls

Monitor response

What is Demand Based Control?
Normal lab operation with dynamic control

VOC event sensed at GEX

ACH varies 4 to 12.7
A week of energy savings

CFM

ACH

TOTAL ACH

6 ACH

4/2 ACH
The impact of DBC in labs

General Lab

8-10 ACH

4/2 ACH

Vivarium

15-25 ACH

6-8 ACH
It’s hard to know what’s going on in all labs all the time.
“Our goal is to find the sweet spot where we maximize energy savings without compromising safety.”

Marc Gomez
Assistant Vice Chancellor
Facilities Management/
Environmental Health & Safety
University of California, Irvine
DBC: because one ACH is never correct

VOC event sensed at GEX

ACH varies 4 to 12.7
Detection of improper lab practices

A lab researcher sticks the exhaust of his mass-spec into the local snorkel exhaust then pinches it off with the blast gate, creating elevated TVOC levels in the lab.
I can see what is driving energy use in the lab.

I can use this data to continuously commission my building.

I can use data to help determine proper air flow and ensure safe labs.

I can stop the “safety vs. energy” arguments between departments.
Laboratory Ventilation Savings Analysis
for Onion University of America
Plant Research Laboratory and Odor Studies Center
Vidaliaville (Using weather data from Boston, Massachusetts)

Submitted by
Gordon P. Sharp, Aircuity, Inc.

Copyright 2010

Energy Analysis & ROI Tool
A report customized for each building’s unique conditions
Graphically displays your current energy usage
Compares the results of the status quo versus taking action

**HVAC Energy Use Breakdown**

- **Energy Cost in '000's**
  - Baseline: 1,603
  - DBC 4/2 ACH: 0.695

- **Comparative Approach**

<table>
<thead>
<tr>
<th>Energy Cost in '000's</th>
<th>Baseline</th>
<th>DBC 4/2 ACH</th>
</tr>
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<tbody>
<tr>
<td>Total in Millions</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cooling</td>
<td></td>
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<tr>
<td>Heating</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reheat</td>
<td></td>
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</tr>
<tr>
<td>Exhaust Fan</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Supply Fan</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Thank You!
Deliver Return on Investment with a Lab Ventilation Management Program

Thomas C. Smith

ECT, Inc.

Exposure Control Technologies, Inc.
919-319-4290
tcsmith@labhoodpro.com
Critical Control Environments

- Chemical and Rad Labs
- Biology Labs (BSL 2-4)
- Nanotechnology Labs
- Animal Vivariums
- Clean Rooms
- Isolation Suites
Exposure Control Devices (ECDs) & Ventilation Systems

- Laboratory Utilities ≈ $5 to $20 per sq. ft.
- Lab HVAC ≈ $3 to $9 per cfm-yr
- As much as 50% of energy can be wasted by inefficient and ineffective HVAC
- Excess flow can be due to poor design and operation of fume hoods and high air change rates
- 15% - 30% of fume hoods may not meet ANSI standards for performance and many labs do not maintain proper air balance

ECDs provide primary protection.
The lab environment provides secondary protection.
Potential for Adverse Health Effects from Airborne Hazards in Labs

Inhalation Hazards

- Types of Materials
- Toxicity
- Generation Rate
- Concentration
- Duration of Exposure

Physical Hazards

- Dermal Exposure
- Fire & Explosion

Dose = Concentration x Duration of Exposure
High Performance Laboratories

Optimize Safety & Energy Efficiency

Safe & Productive

Efficient & Sustainable

- Common Objectives
- Realistic Goals
- Teamwork
Lab Energy & Safety Optimization Process

1. Planning and Assessment

2. Funding & Project Execution

3. Performance Management
Lab Energy & Safety Optimization Process

Phase 1 – Planning & Assessment

• Interdisciplinary Team

• Lab Energy and Safety Assessment
  • Survey Labs, Hoods and Systems
  • Evaluate the Demand For Ventilation
  • Determine Required Operating Specifications
  • Determine Performance Improvement Measures
  • Predict Energy Savings
  • Determine Scope of Work and Costs

• Prioritize Opportunities by Benefits & ROI
Demand for Ventilation

• Safety
  – Hood Exhaust Flow
  – Laboratory Pressurization
  – Dilution (ACH)

• Comfort & Productivity
  – Temperature
  – Humidity

• Occupancy & Utilization

Minimum flow and range of modulation required to meet the functional requirements of the lab
Laboratory Ventilation System

Modulation of flow is based on the Demand for Ventilation

Gex High = 500 cfm
Gex Low = 0 cfm

Sash Open = 1000 cfm
Sash Closed = 200 cfm

Supply High = 900 cfm
Supply Low = 100 cfm
Determine the Demand For Ventilation and Required Operating Specifications

Laboratory Ventilation Risk Assessment

- Survey Laboratory Environment
- Survey and Inventory Ventilated Devices
- Evaluate Hazards & Processes
- Categorize Risk Using Control Bands
- Establish Appropriate Operating Specifications
  - Minimum Laboratory ACH
  - Minimum Fume Hood Flow
  - Exhaust Stack Discharge Requirements
Laboratory Ventilation Control Bands

Control Band Parameters

- Chemical Hazard Rating
- Quantity of Hazardous Material
- Chemical Generation Potential
- Method and Duration of Generation
- Generation Source Location(s)
- ECD Availability and Appropriateness
- Potential for Change
- Housekeeping - Lab Practices
- Ventilation Effectiveness (Sweep)

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<th>Description</th>
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<td>1</td>
<td>Low</td>
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<td>2</td>
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<td>3</td>
<td>High</td>
</tr>
<tr>
<td>4</td>
<td>Very High</td>
</tr>
<tr>
<td>5</td>
<td>Extreme</td>
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Laboratory Ventilation Control Bands

- Parameters and Weighting Adapted to Unique Labs
- Recommend ACH & Risk of Recirculating Lab Air
- Evaluate Lab Construction, Pressurization, Need for Monitoring, etc.

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<th>Total Score</th>
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<th>ACH</th>
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<tr>
<td>9 - 17</td>
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<td>&lt; 4</td>
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<td>18 - 34</td>
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<td>35 - 51</td>
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<td>&gt; 6</td>
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<td>52 - 67</td>
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<td>≥ 68</td>
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### Distribution of Labs by Control Bands

#### Lab Control Band Parameters

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<tr>
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Distribution of Fume Hoods by Control Bands

<table>
<thead>
<tr>
<th>Fume Hood &amp; Sash Dimension</th>
<th>Dimensions</th>
<th>Current Hazard Control Band</th>
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<tbody>
<tr>
<td>LOWER LEVEL NON-LAB SPACES</td>
<td>Shipping Area</td>
<td>012  Fume Hood A (38Wx18H)</td>
</tr>
<tr>
<td>LOWER LEVEL LAB SPACES</td>
<td>010 Chemical Dynamics Research Lab</td>
<td>Fume Hood A (38Wx18H)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fume Hood B (38Wx18H)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Relocated Fume Hood from Penthouse</td>
</tr>
<tr>
<td></td>
<td>011 Physical Chemistry Research Lab</td>
<td>Fume Hood A (38Wx18H)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fume Hood B (38Wx18H)</td>
</tr>
<tr>
<td>FIRST FLOOR LAB SPACES</td>
<td>110 Organic Chemistry Lab</td>
<td>Fume Hood A (10 Hoods 30Wx18H)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fume Hood B (10 Hoods 30Wx18H)</td>
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<tr>
<td></td>
<td></td>
<td>Fume Hood C (Walk In 86.5Wx66H)</td>
</tr>
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<td></td>
<td>111 Organic Chemistry Teaching Lab</td>
<td>Fume Hood A (10 Hoods 30Wx18H)</td>
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<td>Fume Hood B (10 Hoods 30Wx18H)</td>
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<tr>
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<td>Fume Hood C (Walk In 86.5Wx66H)</td>
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<td>118 Advanced Chemistry Research Lab</td>
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<td>Fume Hood E (96Wx28.5H)</td>
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<td>Fume Hood F (96Wx28.5H)</td>
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<td></td>
<td>Fume Hood G (62.5wx66H)</td>
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<tr>
<td></td>
<td></td>
<td>Fume Hood H (62.5wx47H)</td>
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</table>

Distribution of Fume Hoods According to Risk Control Bands

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<tr>
<th>Risk Control Band</th>
<th># of Hoods</th>
<th>% of Hoods</th>
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<td>1</td>
<td>27%</td>
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<tr>
<td>2</td>
<td>38%</td>
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</tr>
<tr>
<td>3</td>
<td>19%</td>
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<td>12%</td>
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<tr>
<td>5</td>
<td>0%</td>
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</tbody>
</table>

Legend: # of Hoods, % of Hoods
## Lab Environment Airflow Spreadsheet

**Air Supply Flow**

**Transfer Air**

### Airflow Set Points

<table>
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### Supply Terminal

**Min and Max Flow**

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### Exhaust Flow

- **System Info**
  - Qex-Cond
  - Qex-ED
  - Qex-dP
  - Qex-ACH

### Calculated Room ACH

- **Exhaust Flows**
- **Resultant ACH**
- **Max/Min based on Exh Devices, dP, Cond., or ACH**
- **Max/Min of Qs Conditioning, Qs dP, Qs ACH**

### Hood and Gex Terminal

**Min and Max Flow**

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### Lab Min and Max ACH

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Lab Safety & Energy Optimization Process
Modify Systems to Meet Demand

- Remove or Hibernate Unnecessary Hoods
- Modify Inefficient Hoods
- Replace & Retrofit Traditional Fume Hoods
- Upgrade CAV & VAV Controls
- Optimize Temperature & Humidity Controls
- Install Demand Control Ventilation
- Reduce / Reset System Static Pressure
- Optimize Exhaust Fan and AHU Operation
- Implement Energy Recovery
Lab Energy & Safety Optimization Process

Phase 2 – Funding & Project Execution

- **Phase 2a - Funding Sources**
  - Internal Facility Budget
  - Utility Rebates & Incentives
  - Performance Contracts

- **Contractor Qualification & Selection**

- **Phase 2b – Project Engineering**
  - Design Upgrades & System Modifications
  - Develop TAB & Cx Plans

- **Phase 2c – Renovation/Construction Project**
  - Implement Selected PIMs & ECMs
  - Retrofit Lab Hood Systems
  - Verify Performance and Energy Savings
Lab Ventilation System - VAV Flow Specifications

Max Supply

Min Supply

Max Exhaust

Min Exhaust

Ex. Fan(s)

BAS Trend of Combined Flow for AHUs 11&12, 13&14, 15&16, 19&20
(Week September 1 - September 9, 2012)

Max Flow

Average Flow

Min Flow – all VAV terminals at Min

Flow - cfm

9/1/12 12:00:00 AM PDT
9/1/12 6:00:00 AM PDT
9/1/12 12:00:00 PM PDT
9/1/12 5:30:00 PM PDT
9/1/12 11:00:00 PM PDT
9/2/12 5:00:00 AM PDT
9/2/12 11:00:00 AM PDT
9/2/12 5:00:00 PM PDT
9/2/12 11:00:00 PM PDT
9/3/12 5:00:00 AM PDT
9/3/12 11:00:00 AM PDT
9/3/12 5:00:00 PM PDT
9/3/12 11:00:00 PM PDT
9/4/12 5:30:00 AM PDT
9/4/12 11:30:00 AM PDT
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9/6/12 10:30:00 AM PDT
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9/6/12 10:00:00 PM PDT
9/7/12 4:00:00 AM PDT
9/7/12 10:00:00 AM PDT
9/7/12 3:30:00 PM PDT
9/7/12 9:30:00 PM PDT
9/8/12 3:30:00 AM PDT
9/8/12 9:30:00 AM PDT
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9/9/12 3:30:00 AM PDT
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9/9/12 9:00:00 PM PDT
Demand for Ventilation and System Utilization

Demand for Ventilation - Utilization Trend for Combined AHUs

Frequency of Operation above Minimum Flow (Percentiles)

Number of Trend Data Points

- <10%: 9%
- 10-20%: 33%
- 21-30%: 20%
- 31-40%: 12%
- 41-50%: 10%
- 51-60%: 7%
- 61-70%: 5%
- 71-80%: 2%
- 81-90%: 1%
- 91-100%: 1%

Operation at minimum flow maximizes energy savings.
Airflow Trend Based on Demand For Ventilation

Current Minimum Flow

New Minimum Flow = 50,000 cfm reduction

Combined AHU VFD Output
SOMT Measured Min
Terminal Box Design Min
Average VFD
Safe & Energy Efficient, but Sustainable?

Campus Wide Aggregate Energy Reduction

Energy Baseline

Energy Target

Billion BTUs

Maintaining Performance of VAV Controls
Quality Data - Accuracy and Precision

VAV Controls Can degrade 30-50% within 5 years
Laboratory Ventilation Management Plan
Lab Energy & Safety Optimization Process

- Phase 3 – Lab Ventilation Management (LVMP)
  - Organization and Responsibilities
  - Collaboration & Communication
  - SOP’s for Testing and Maintenance
  - Metrics, Monitoring & BAS Utilization

- Management of Change

- Personnel Training

- Design & Commissioning Standards

- Required By ANSI Z9.5-2012
## Components of a LVMP

- Component 1 - Program to Coordinate Stakeholder Efforts
- Component 2 - Specific Operating Plans for Buildings

<table>
<thead>
<tr>
<th>Component 1</th>
<th>Component 2</th>
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<td>LVMP</td>
<td>LVMP - Building Operational Plans</td>
</tr>
<tr>
<td><strong>Coordinate Efforts</strong></td>
<td></td>
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<tr>
<td>- Management</td>
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<td>- Facilities Engineering</td>
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<td>- Environmental Health &amp; Safety</td>
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<td>- Lab Staff</td>
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| **Standardize Operations** |
| - Lines of Communication |
| - Management of Change |
| - Guidelines and Specifications |
| - Generic Procedures |
| - Training |
| - Document Control |

| **Building Documentation** |
| - Equipment Inventory |
| - As Built Drawings |
| - Flow and Operating Specs |

| **Building Operation** |
| - Tasks |
| - Schedules |
| - Specific SOPs |
| - Reporting |
Maximize Effectiveness of Maintenance

- Optimize Sequence of Tasks
- Utilize BAS and Monitoring Tools
- Quickly identify problematic components
- Target PM and Repairs
- Minimize Diagnostics
- Minimize Resource Expenditures
- Maintain Performance
Lab Energy & Safety Optimization
Train Personnel

- Lab Personnel
- Facility Maintenance
- Building Operators
Conclusions and Recommendations

• Laboratories can be safe, energy efficient and sustainable

• The Demand for Ventilation determines the required operating specifications

• A Lab Ventilation Risk Assessment determines the Demand for Ventilation

• VAV systems modulate flow based on the demand for ventilation

• Special tests and methods are required to manage complex VAV systems

• Maintaining safe and energy efficient operation requires maintaining performance and managing change over time

• The Return on Investment depends on maintaining performance

• A Lab Ventilation Management Program provides the tools to maintain the systems, manage change and protect the return on investment

LVMP = ROI
Lab Energy & Safety Optimization Process

High Performance Laboratories

- Safe
- Energy Efficient
- Sustainable

Thomas C. Smith

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Exposure Control Technologies, Inc.
919-319-4290
www.exposurecontroltechnologies.com
tcsmith@labhoodpro.com
Importance of the LVMP

Management of Change
My lab is really hot!

I’ll take care of it.
Our technician decides the lab needs more air, so he increases the supply air by 200 cfm. This should be plenty.
The differential pressure monitor is now indicating positive pressure.
Oh No!! A spill...
It’s much cooler now...
Air now moves from the positively pressurized lab, through the transfer grill, into the adjacent office.
Our office worker has now been exposed.

So sleepy...
This never would have happened if our technician had a Laboratory Ventilation Management Program.