Laboratory Ventilation
Flow Rates at Cornell:
Rethinking the Tradition

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Agenda

1. Laboratory Ventilation as part of the Laboratory Safety System

2. Cornell’s lab air reduction practices

3. Moving forward: the Laboratory Ventilation Management Plan
What is a Lab?

- Laboratories are workplaces where people do unusual things with hazardous materials.
- Generic strategies are used to protect the workers and their science:
  1. *Hazard replacement or downsizing*
  2. *Facility design and operation*
  3. *Worker training and oversight*
  4. *Personal protective equipment and emergency response plans*
- This flexible approach to safety maximizes the kinds of work the facility can host.
Today’s Lab Ventilation System

- Fume hoods
- General Laboratory Ventilation
- Chemical Storage Cabinets
General Lab Ventilation Specifications for Safety Purposes

- **Air Quality**: use 100% outside air to avoid recirculating contaminants originating in the lab

- **Air Quantity**:
  - The late 20\textsuperscript{th} century approach:
    10-12 ACH 24/7 in all labs
  - The 21\textsuperscript{st} century approach:
    ACH depends on what’s happening in the room and how effective the ventilation is

- Ventilation requirements can be driven by:
  - Control of chemicals and other hazards
  - Local exhaust requirements
  - Temperature (solar and plug load)
Energy Conservation Initiative Program

- Goal is to reduce year-2000 energy use 20%
- Program includes energy conservation focused maintenance, studies, and projects – data driven
- Program supported by NYSERDA rebates
Key energy conservation opportunities in laboratories

- Re-commissioning control systems to reduce outside air use
- Use occupancy sensors to control occupied / unoccupied air flows and lighting
- Relax temperatures during unoccupied time to reduce reheat requirements
- Retrofit environmental chambers
Reducing General Air Flow using CFD modelling

- A full 3D CFD model was built in Fluent software for 3 buildings (one 1950’s, one 1980’s, one 1990’s renovation)

- Results showed that in the 1980’s building (Bioteach), 8/4 was not clearing spills effectively

- Model results were verified by qualitative smoke tests
Biotechnology existing ductwork

Five foot VAV fume hood

Existing 8" round perforated supply

Existing general exhaust grille
Biotechnology new ductwork design
Biotechnology building results

• CFD modeling found that, after redesign, spills were cleared well enough at 6/3 to avoid OSHA PELs

• 90 fume hood zones = ~ $180,000 renovation cost

• Savings ~ $1200/lab each year, less than a 2 year simple payback!

• Building operating costs went from $1.2 million/year to $900,000/year
Lessons Learned (2008)

• Cornell’s historic building stock means that the general ventilation decision is not as simple as “just do it”

• Ventilation effectiveness in a lab must be evaluated on a room basis

• CFD is a cost effective tool to evaluate current and proposed designs
The Next Phase: Control Banding Labs

• We start with a standard minimum of 8 ACH when the lab is unoccupied and 4 ACH when unoccupied to control chemical concentrations (temperature and exhaust can override these minimums).

• We review the current chemistry to identify labs where 6 ACH and 3 ACH can be expected to control chemical hazards.

• There are special cases outside these generic categories (e.g. animal areas, BSL rooms and machine shops (once through air at around 2 ACH)).

• Over the last 1.5 years, we have visited about 600 laboratories at Cornell and the majority can run at 6/3, *if fumes hoods are used and ventilation is effective*.
Evaluating the Ventilation Effectiveness Caveat

- We use fire extinguishers to release CO2 and measure chemical concentration decay patterns within a laboratory.

<table>
<thead>
<tr>
<th>Location of sensor</th>
<th>sink</th>
<th>table</th>
<th>window</th>
<th>BCS ach rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of data points</td>
<td>122</td>
<td>126</td>
<td>150</td>
<td></td>
</tr>
<tr>
<td>Observed ACH</td>
<td>34.84</td>
<td>37.06</td>
<td>32.40</td>
<td>per hour 38</td>
</tr>
<tr>
<td>r-squared</td>
<td>0.95</td>
<td>0.97</td>
<td>0.98</td>
<td></td>
</tr>
<tr>
<td>Concentration half life</td>
<td>1.19</td>
<td>1.12</td>
<td>1.28 minutes</td>
<td></td>
</tr>
</tbody>
</table>
Another Ventilation Reduction Opportunity

- Weill Hall: large, open lab concept building occupied in 2008
- Has been running at 8/4, as designed, with some labs in “Vacant mode”
- Can this building run at 6/3?
## Decay Measurement Results

<table>
<thead>
<tr>
<th>Run number</th>
<th>Source room(s)</th>
<th>260 ach</th>
<th>260 aisle</th>
<th>260 middle</th>
<th>260 window</th>
<th>260 average</th>
<th>264 ach</th>
<th>264 aisle</th>
<th>264 middle</th>
<th>264 window</th>
<th>264 average</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>264 and 260</td>
<td>8</td>
<td>10.1</td>
<td>7.2</td>
<td>-</td>
<td>8.6</td>
<td>8</td>
<td>10.2</td>
<td>8.0</td>
<td>8.9</td>
<td>9.0</td>
</tr>
<tr>
<td>2</td>
<td>264</td>
<td>6</td>
<td>53.2</td>
<td>32.2</td>
<td>11.3</td>
<td>32.2</td>
<td>6</td>
<td>17.9</td>
<td>16.3</td>
<td>14.9</td>
<td>16.4</td>
</tr>
<tr>
<td>3</td>
<td>260</td>
<td>6</td>
<td>9.2</td>
<td>11.0</td>
<td>13.2</td>
<td>11.1</td>
<td>6</td>
<td>4.4</td>
<td>8.3</td>
<td>10.4</td>
<td>7.7</td>
</tr>
<tr>
<td>4</td>
<td>264</td>
<td>8</td>
<td>8.3</td>
<td>10.4</td>
<td>11.6</td>
<td>10.1</td>
<td>6</td>
<td>10.3</td>
<td>9.8</td>
<td>10.9</td>
<td>10.3</td>
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</table>

### r-squared

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.98</td>
<td>1.00</td>
<td>0.81</td>
<td>0.82</td>
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</table>

### half life (minutes)

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>5.2</td>
<td>6.9</td>
<td>6.9</td>
<td>5.2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Room</th>
<th>Pressure</th>
<th>Supply</th>
<th>Exhaust</th>
<th>ach</th>
</tr>
</thead>
<tbody>
<tr>
<td>264A</td>
<td>neutral</td>
<td>866</td>
<td>864</td>
<td>8</td>
</tr>
<tr>
<td>260A</td>
<td>negative 100</td>
<td>672</td>
<td>772</td>
<td>6</td>
</tr>
<tr>
<td>260a</td>
<td>negative 100</td>
<td>918</td>
<td>1010</td>
<td>8</td>
</tr>
<tr>
<td>264A</td>
<td>neutral</td>
<td>626</td>
<td>629</td>
<td>6</td>
</tr>
</tbody>
</table>

Ceiling tiles are 1 by 4 feet
Diffuser to window distance is about 16 feet
Wall to window distance is about 20 feet
260 and 264 are 41 feet wide collectively
Conclusions

• The open lab concept increases ventilation effectiveness by providing more room for chemicals to diffuse

• There are specific areas of concerns at the edges of the room – windows, doorways, etc.

• It is important that odoriferous chemicals are used in fume hoods

• This building can run at 6/3 safely
Operational Results

• Effectiveness testing began in February, 2012 and was completed in May
• Recommendations were delivered to building management and occupants in August, 2012
• Implementation hurdles are being addressed
• Switch over of second floor on pilot base is underway.
• Savings expected to be $300,000/year and 100 homes of carbon/year
Maintaining the Lab Vent System

• Managing within Systems
  • Systems include multiple priorities associated with a variety of stakeholders
  • Systems can be simple (a change results in a predictable outcome) or complex (a change results in a variety of outcomes, some predictable)
• Managing within a system requires flexibility and practice
• Laboratory ventilation managers face competing priorities (science, safety and sustainability)
• Fortunately, we have ANSI Z9.5 and Z10 to help guide the system
Questions?
The LVMP Management System

**Plan** - Reduce laboratory energy use over time to support the university's goal of being carbon neutral by 2050.

**Management review** - Are the actions implemented under the LVMP maintaining the safety of the lab occupants? (review process outlined by ANSI Z10).

**Check** - review of energy costs (in carbon and dollars) associated with laboratories: Is the LVMP supporting the University's goal of carbon neutrality?

**Do** - Provide adequate ventilation to assure safe laboratories (operationally managed by the ANSI Z9.5).

Coming to a web site near you soon!
### The LVMP: Lab Ventilation for Science, Safety and Sustainability

<table>
<thead>
<tr>
<th>Stakeholder Group</th>
<th>Primary Phase</th>
<th>Specific Activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Facility designers</td>
<td>Plan</td>
<td>Specify laboratory equipment and operating parameters</td>
</tr>
<tr>
<td>Laboratory users</td>
<td>Do</td>
<td>Use of hazardous materials in a way that manages those hazards</td>
</tr>
<tr>
<td>Facility operators and management</td>
<td>Check</td>
<td>Continuously commission lab ventilation systems; certify hood face velocity; track HVAC energy use in labs</td>
</tr>
<tr>
<td>EHS staff and academic management</td>
<td>Act</td>
<td>Review laboratory ventilation practices for opportunities to improve safety and sustainability</td>
</tr>
</tbody>
</table>
# Tracking Improvement: Identifying Indicators and Setting SMART Goals

<table>
<thead>
<tr>
<th>Stakeholder Group</th>
<th>Indicators</th>
<th>Specific Activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Facility designers and academic management</td>
<td>Average ACH specified</td>
<td>Reduce specified ventilation rates by greening chemistry and improving hoods purchased</td>
</tr>
<tr>
<td>Laboratory users</td>
<td>Hood housekeeping scores</td>
<td>Maintain good housekeeping</td>
</tr>
<tr>
<td>Facilities management</td>
<td>Total energy used to maintain lab ventilation parameters</td>
<td>Track HVAC energy use in labs</td>
</tr>
<tr>
<td>EHS staff and academic management</td>
<td>Number of events related to ventilation rates</td>
<td>Track hazmat responses and IAQ concerns related to ventilation rate</td>
</tr>
</tbody>
</table>
Other ACH’s

• “Occupancy” ventilation rate (20 cfm/person) where there is no chemical driver – for example, electron microscopy and other instrument heavy labs
Summary: Key Laboratory Ventilation Conservation Opportunities

• Identify hoods that can be hibernated
• In exhaust-driven labs, reduce face velocity on hoods that can maintain containment at lower flowrates, either through VAV or low flow hoods
• Set default general lab ventilation ACH to 6 when chemical processes allow