Lessons Learned from 12 Years of Laboratory Conversions to VAV and Control Retrofits

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Learning Objectives

- Plan renovation projects where energy conservation pays for improved ventilation and safety
- Plan renovation projects that add today's BAS technology to existing mechanical equipment, enhancing access to information needed to manage safety, energy use and mechanical maintenance.
- Extend the capacity of existing primary systems by upgrading constant volume labs to VAV.
- Reduce the potential for chemical exposure in labs by bringing today's aerodynamic design

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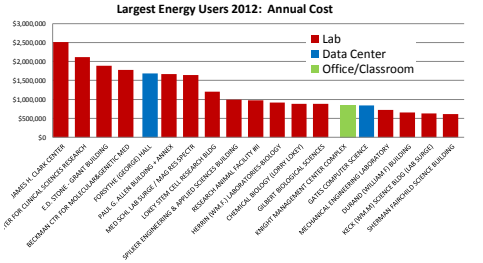
Why focus on labs?



Lab Retrofit process: Three Phases

Initial Assessment

- Benchmarking
- High level audit

Not all high users are good candidates

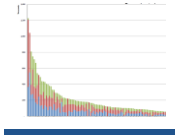
12 buildings use 33% electricity

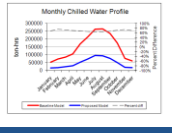
Detailed Study

- Targeted TAB
- As-builts
- Calibrated simulation
- Cost estimate

Implementation

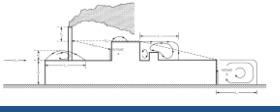
- Construction
- Commissioning
- M&V, Rebates

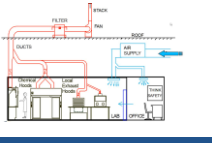




Laboratory Retrofit Opportunities: High Cost

- Medium to High Capital Cost Measures
  - DDC to the Zone
  - Convert systems to VAV (supply, exhaust, hoods)
  - Add heat recovery (often difficult in retrofit)
  - Stack airflow reduction based on wind tunnel analysis
  - Bring non-lab zones up to current energy code standards





Laboratory Retrofit Opportunities: Lower Cost

- Low Capital Cost (RCx Opportunities)
  - Fix economizers
  - Fix AHU controls
  - Fix leaking valves/dampers
  - Rebalance airflows
  - Convert constant flow HW and CHW to variable flow
  - Recalibrate or replace critical control sensors (a.k.a. money sensors)
  - Update sequences if DDC
  - Fault detection & alarming

Completed Projects

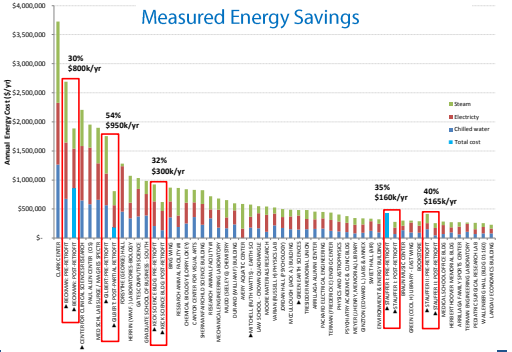
- Start with constant volume labs
  - VAV to the zone
  - Demand based resets: temperature, pressure
  - VAV hoods where it makes sense
  - Fume stack dispersion study and reduced flow
  - VAV fume stack flow where possible
  - RCx and smaller energy measures easily piggyback on a large retrofit project
- Then convert pneumatic VAV labs to DDC
  - DDC control retrofit
  - Demand based resets
  - Fume stack dispersion and reduced flow
  - Re-commissioning

Representative results of CAV to VAV conversion Gilbert Hall

Energy Cost Savings	
Pre-retrofit utility cost	$1,750,000
2012-2013 utility cost	$804,000
Utility Cost Savings	54%

First Costs & Payback	
First Costs	$3,300,000
Utility rebate	$710,000
Net cost	$2,590,000
Simple Payback	2.7 years

Measured Energy Savings

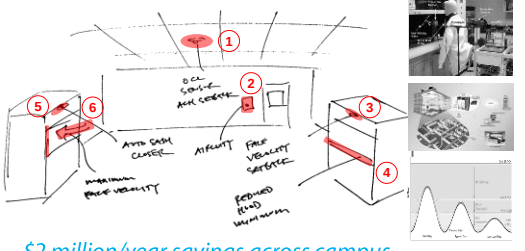


Non-Energy Benefits

- Fume dispersion study identifies issues, particularly with small stacks
- Less noise
- Higher comfort
- Fume hood safety improvements
- Better control of room pressurization
- Feedback and alarming for better management

What is next?

Lab of the future



$2 million/year savings across campus

Lab Of the Future Measures

hood
- Face Velocity Setback
- Face Velocity Limit
- Hood Minimum Reduction
- Auto Sash Closers

room
- Air Change Setback
- Central Demand Controlled Ventilation

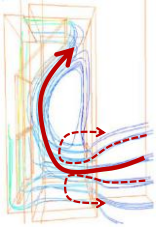
Measure: Face Velocity Setback

- Reduce velocity from 100 to 60 fpm when no users detected
- ASHRAE 110 testing
- Benefits
  - Energy
  - Usage data
  - Safety
- Barriers: None

Measure: Face Velocity Limit

- Limit average face velocity to 120 fpm
- Safety:
  - Turbulence & reduced containment at higher speed
  - Impact on room pressure
- Minimize unnecessary energy use
- Barriers: None

"Higher face velocities do not result in greater protection as might be supposed." -- ACGIH



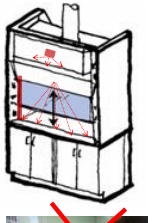
● ANSI/AIHA Z9.5 & NPFA: 80 – 120 fpm ● ACGIH & NRC: 80 – 100 fpm ● UC Guide: 125 fpm max

Measure: Hood Minimum Reduction

- Reduce flow when sash closed
- ANSI Z9.5-2012 LEL/LFL limits
  - Up to 50% reduction over NFPA-45 2004
- LEL/LFF Calculation per hood
- Barriers: None

Measure: Auto Sash Closers

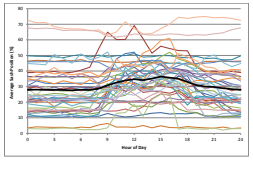
- Automatically close sash when not in use
- Benefits
  - Safety
  - Energy
  - Sound
  - Simplifies fire life safety design
- Barriers: user acceptance, cost



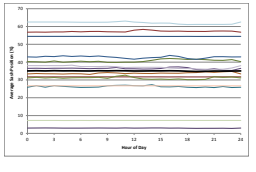
Measure: Auto Sash Closers

- Sash management:

Stauffer I & II



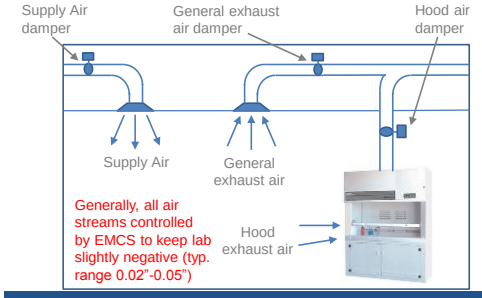
Gilbert



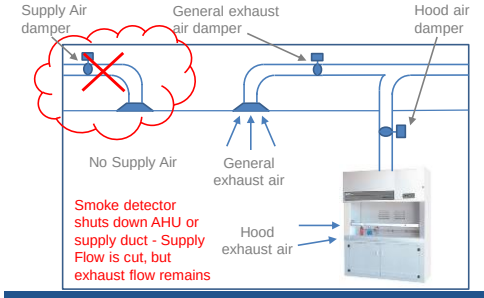
Auto Sash Closers: Life Safety benefit

- Can program sashes to automatically close on a signal from the fire panel
- This reduces the DP across the doors
- It also eliminates (or greatly reduces) the need for MAU
- Better containment of fumes if there is a spill during unoccupied hours (e.g. earthquake)

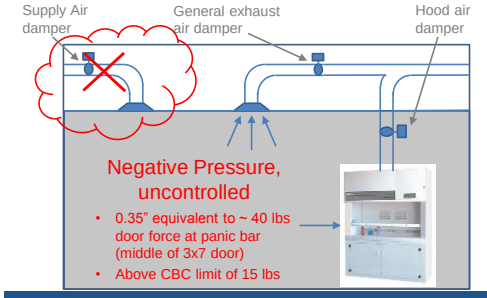
Typical Lab Design



Typical Lab Design – Fire Mode



Typical Lab Design – Fire Mode

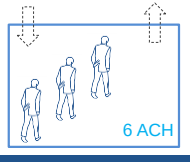


Measure: Air Change Setback

OCCUPIED

Why 6 or higher ACH?

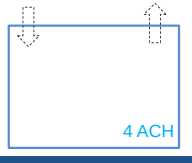
- 6 ACH is common EH&S guideline
- Driven by chemical inventory & spill analysis



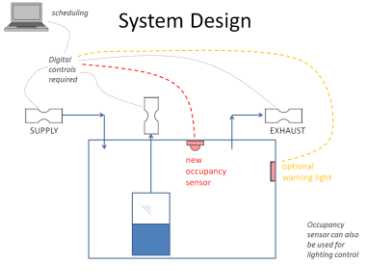
UNOCCUPIED

Why 4 ACH?

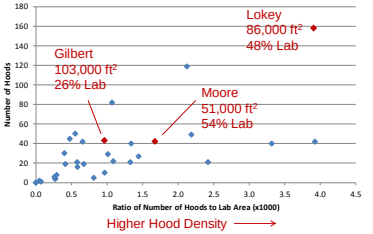
- Minimum per ANSI Z9.5 2012, OSHA 1990, ASHRAE, NFPA-45 2004
- Numerous precedents



Measure: Air Change Setback

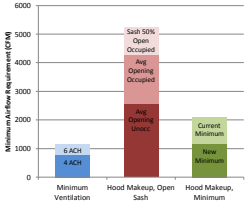


Lab of the Future Study Buildings

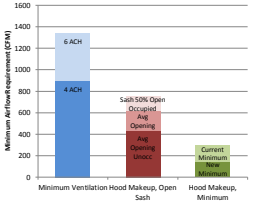


Interactive Effects

Hood Dominated



ACH Dominated



Energy Cost Savings

Measure	Energy Cost Savings ($/yr) Gilbert	Lokey	Moore
Air Change Setback	$14,000	$10,000	$12,000
Auto Sash Closers	$17,000	$263,000	$77,000
Face Velocity Setback	$14,000	$216,000	$64,000
Hood Minimum Reduction	$0	$20,000	$2,000
Face Velocity Limit	$5,000	$22,000	$18,000
All but Face Velocity Setback	**$38,000**	**$301,000**	**$95,000**

Package with largest savings potential

Simple Payback

Measure	Simple Payback (yr) Gilbert	Lokey	Moore
Air Change Setback	3	4	1
Auto Sash Closers	9	3	3
Face Velocity Setback	2	1	1
Hood Minimum Reduction	-	0	1
Face Velocity Limit	1	1	0
All but Face Velocity Setback	**5**	**3**	**3**

Economic Results

Measure	Energy Cost Savings ($/yr) Gilbert	Lokey	Moore	First Cost ($) Gilbert	Lokey	Moore
Air Change Setback	$14,000	$10,000	$12,000	$43,000	$40,000	$18,000
Auto Sash Closers	$17,000	$263,000	$77,000	$149,000	$869,000	$253,000
Face Velocity Setback	$14,000	$216,000	$64,000	$26,000	$150,000	$44,000
Hood Minimum Reduction	$0	$20,000	$2,000	$1,000	$8,000	$2,000
Face Velocity Limit	$5,000	$22,000	$18,000	$6,000	$19,000	$7,000
All but Face Velocity Setback	**$38,000**	**$301,000**	**$95,000**	**$199,000**	**$935,000**	**$280,000**

Measure	Simple Payback (yr) Gilbert	Lokey	Moore	Net Present Value ($) Gilbert	Lokey	Moore	Internal Rate of Return (%) Gilbert	Lokey	Moore
Air Change Setback	3	4	1	$87,000	$51,000	$89,000	32%	23%	67%
Auto Sash Closers	9	3	3	$8,000	$1,527,000	$447,000	4%	29%	29%
Face Velocity Setback	2	1	1	$102,000	$1,818,000	$538,000	55%	145%	147%
Hood Minimum Reduction	-	0	1	-$1,000	$170,000	$17,000	-	249%	92%
Face Velocity Limit	1	1	0	$41,000	$180,000	$160,000	85%	118%	272%
All but Face Velocity Setback	**5**	**3**	**3**	**$149,000**	**$1,807,000**	**$581,000**	**15%**	**31%**	**33%**

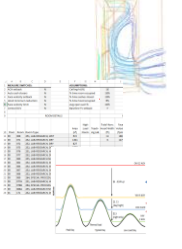
What if we remove Air Change Setback?

Measure	Energy Cost Savings ($/yr) Gilbert	Lokey	Moore
~~Air Change Setback~~	~~$14,000~~	~~$10,000~~	~~$12,000~~
Auto Sash Closers	$17,000	$263,000	$77,000
Face Velocity Setback	$14,000	$216,000	$64,000
Hood Minimum Reduction	$0	$20,000	$2,000
Face Velocity Limit	$5,000	$22,000	$18,000
~~**All but Face Velocity Setback**~~	~~**$38,000**~~	~~**$301,000**~~	~~**$95,000**~~
	$19,000	$0	$82,000

Gilbert: 50% reduction in potential savings

Conclusions & Summary

- CV to VAV Conversions
  - 30-55% energy savings
  - Improved: Safety, comfort, acoustics
- Advanced Airflow controls
  - $0.40-$3.00/ft²savings above VAV lab (5-36%)
  - 3-5 year payback
  - Improved safety



Questions

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