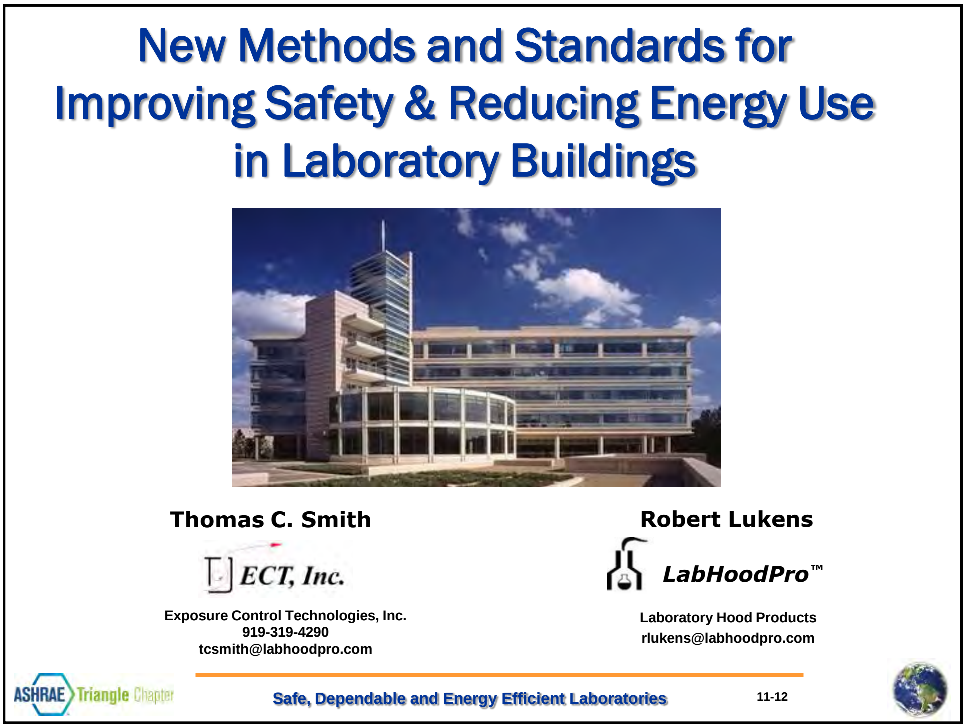

New Methods and Standards for Improving Safety & Reducing Energy Use in Laboratory Buildings

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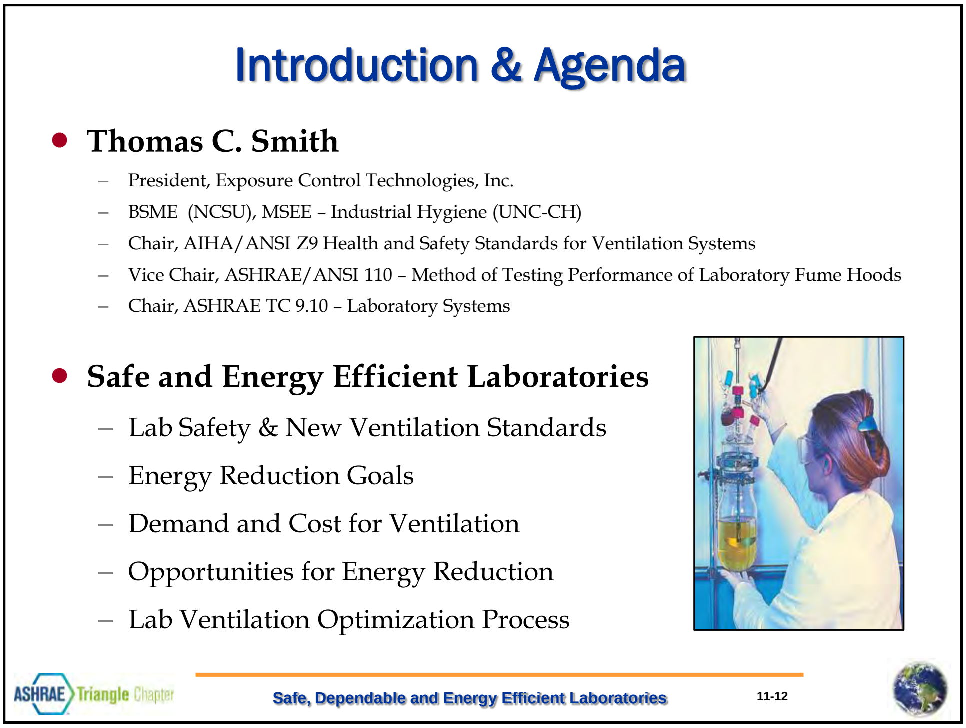


Introduction & Agenda

- **Thomas C. Smith**
  - President, Exposure Control Technologies, Inc.
  - BSME (NCSU), MSEE – Industrial Hygiene (UNC-CH)
  - Chair, AIHA/ANSI Z9 Health and Safety Standards for Ventilation Systems
  - Vice Chair, ASHRAE/ANSI 110 – Method of Testing Performance of Laboratory Fume Hoods
  - Chair, ASHRAE TC 9.10 – Laboratory Systems
- **Safe and Energy Efficient Laboratories**
  - Lab Safety & New Ventilation Standards
  - Energy Reduction Goals
  - Demand and Cost for Ventilation
  - Opportunities for Energy Reduction
  - Lab Ventilation Optimization Process

ECT, Inc.

Exposure Control Technologies, Inc.

Safety and Energy Services for R&D Facilities

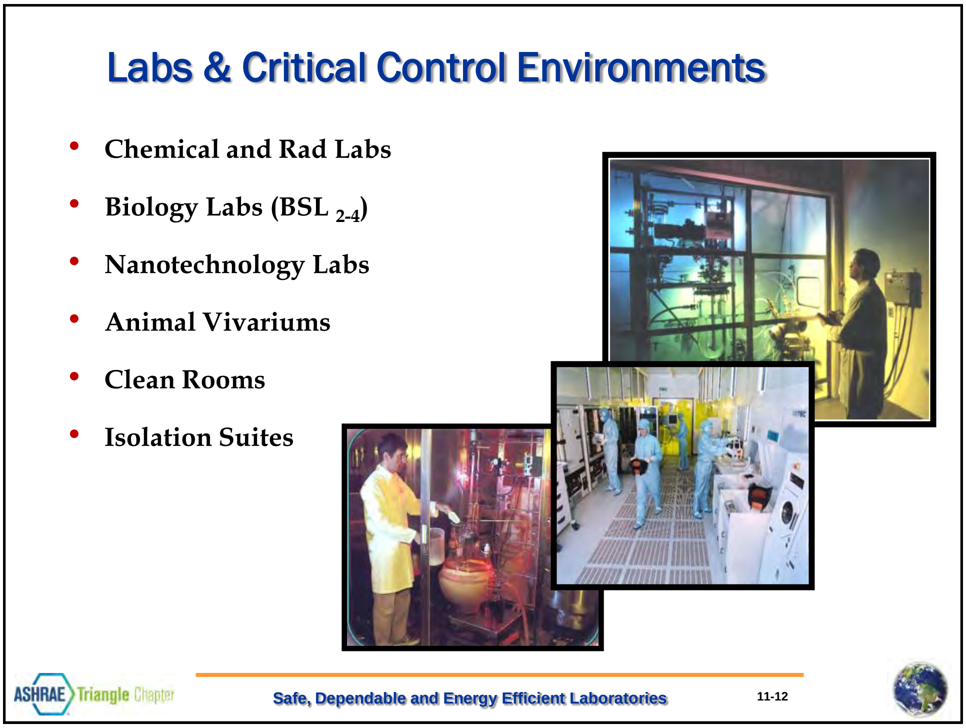
- Industrial Hygiene and Ventilation Consulting
- Energy and CO_2 Reduction
- Commissioning & ASHRAE 110 Tests
- Lab Ventilation Management

LabHoodPro

Laboratory Hood Products

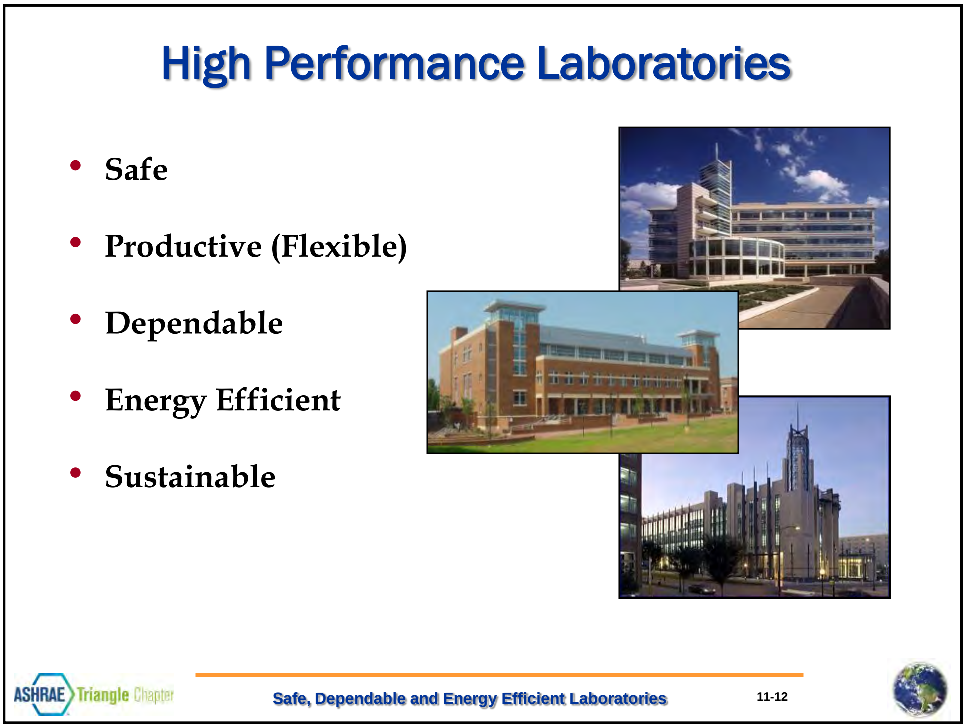
A Division of ECT, Inc.

- Fume Hood Upgrades
- Hood Testing Equipment
- Testing Software



Labs & Critical Control Environments

- Chemical and Rad Labs
- Biology Labs (BSL $_{2\text{-}4}$)
- Nanotechnology Labs
- Animal Vivariums
- Clean Rooms
- Isolation Suites



High Performance Laboratories

- Safe
- Productive (Flexible)
- Dependable
- Energy Efficient
- Sustainable

ASHRAE Triangle Chapter

Safe, Dependable and Energy Efficient Laboratories

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Primary Objective:

Lab Safety
and
Personnel Protection

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Safe, Dependable and Energy Efficient Laboratories

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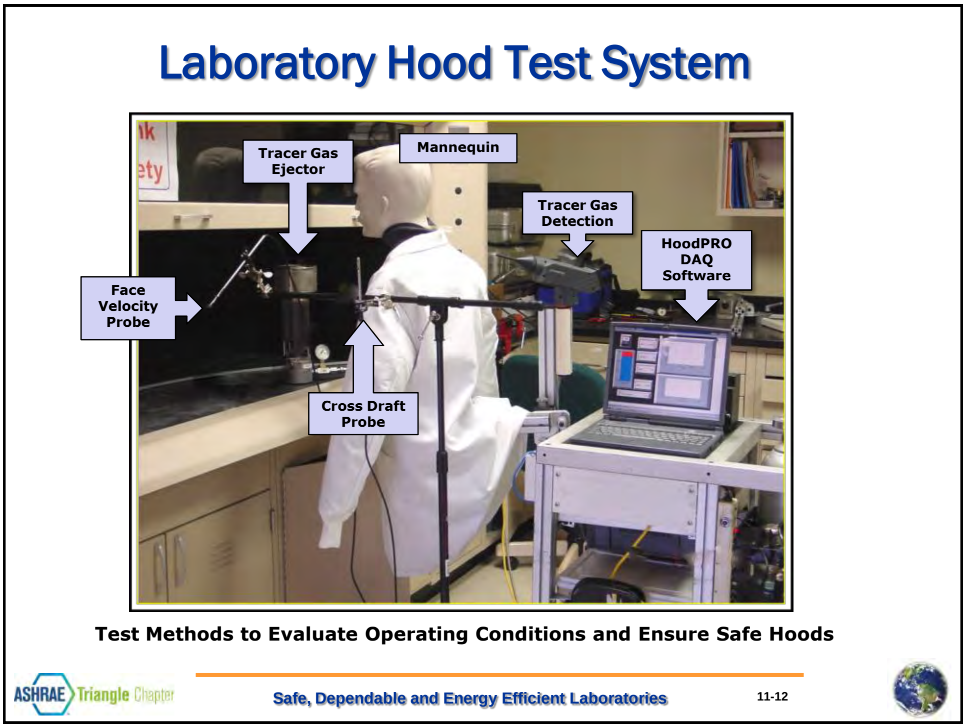
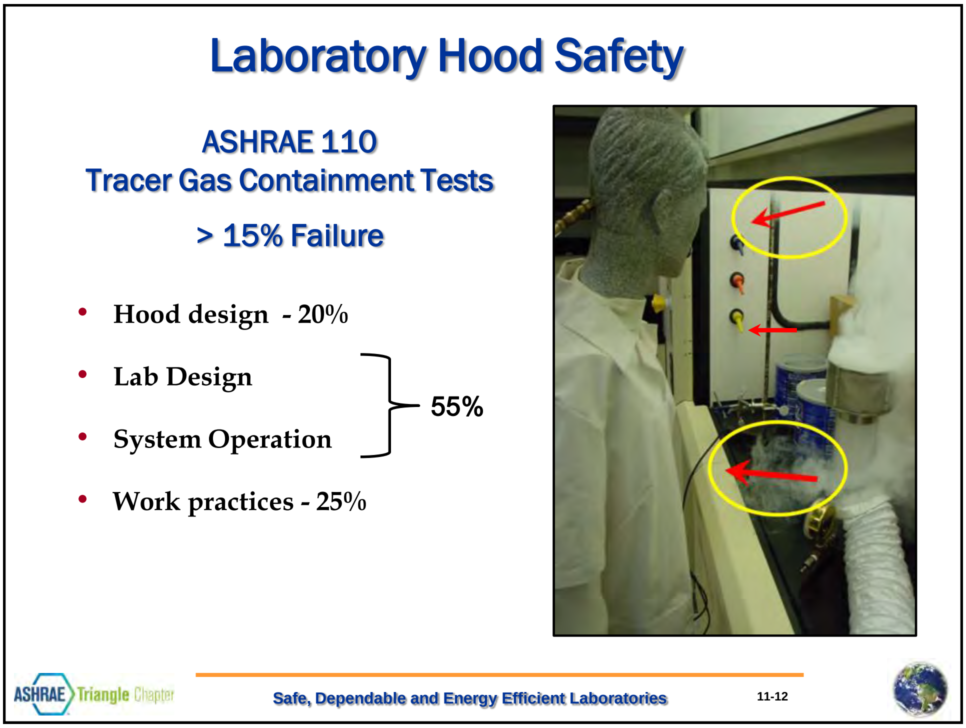


Laboratory Hood Test System

Test Methods to Evaluate Operating Conditions and Ensure Safe Hoods



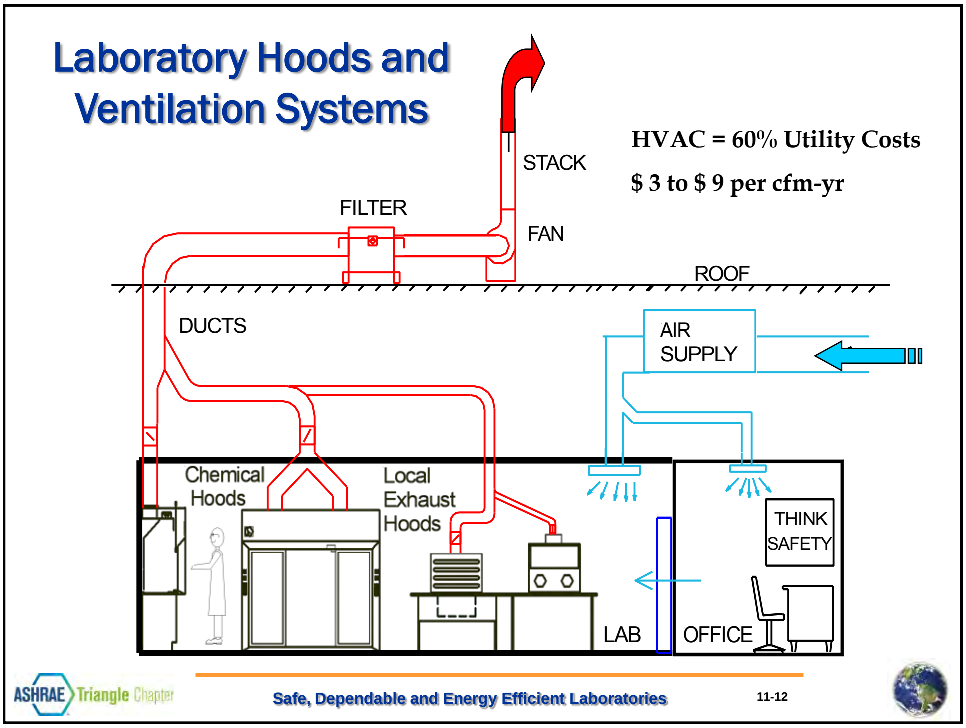
Laboratory Hood Safety

ASHRAE 110
Tracer Gas Containment Tests

> 15% Failure

- Hood design - 20%
- Lab Design
- System Operation
- Work practices - 25%

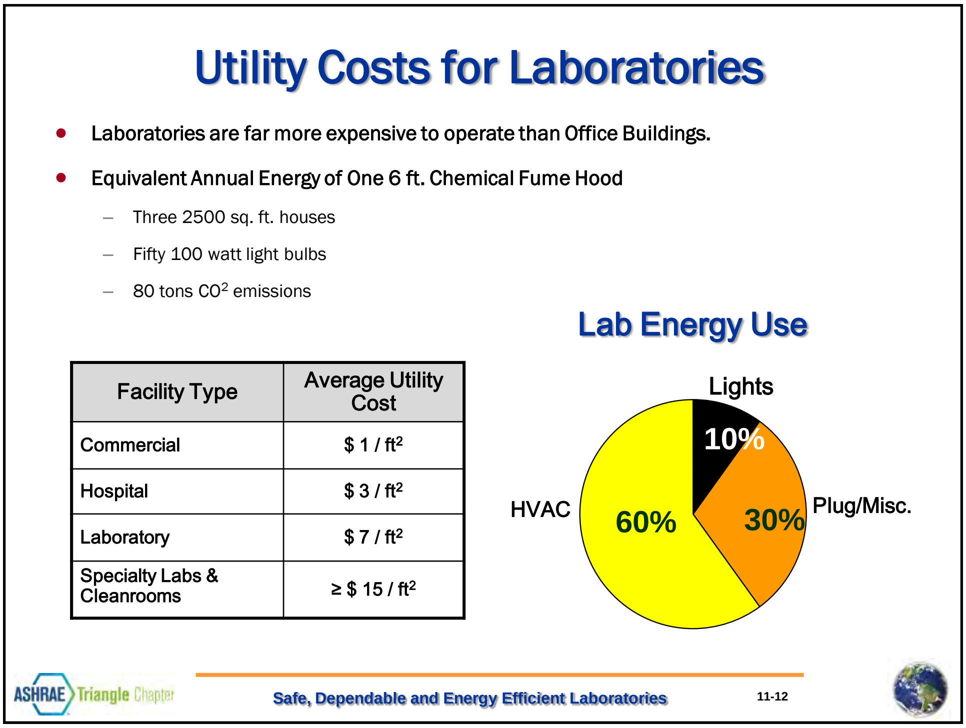
55%



Laboratory Hoods and Ventilation Systems

HVAC = 60% Utility Costs

$ 3 to $ 9 per cfm-yr

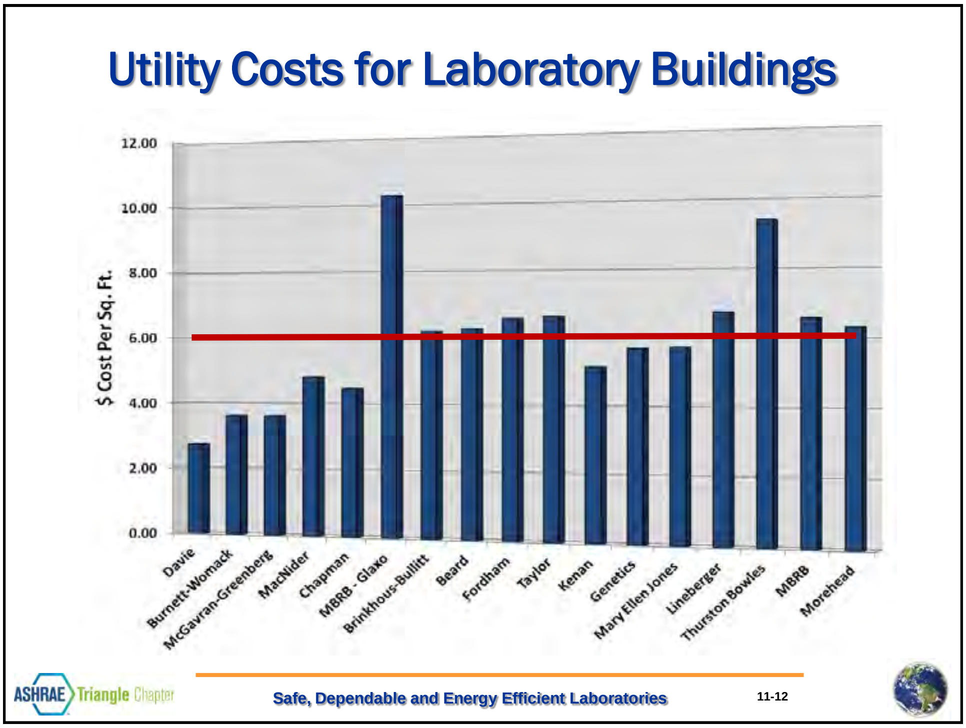


Utility Costs for Laboratories

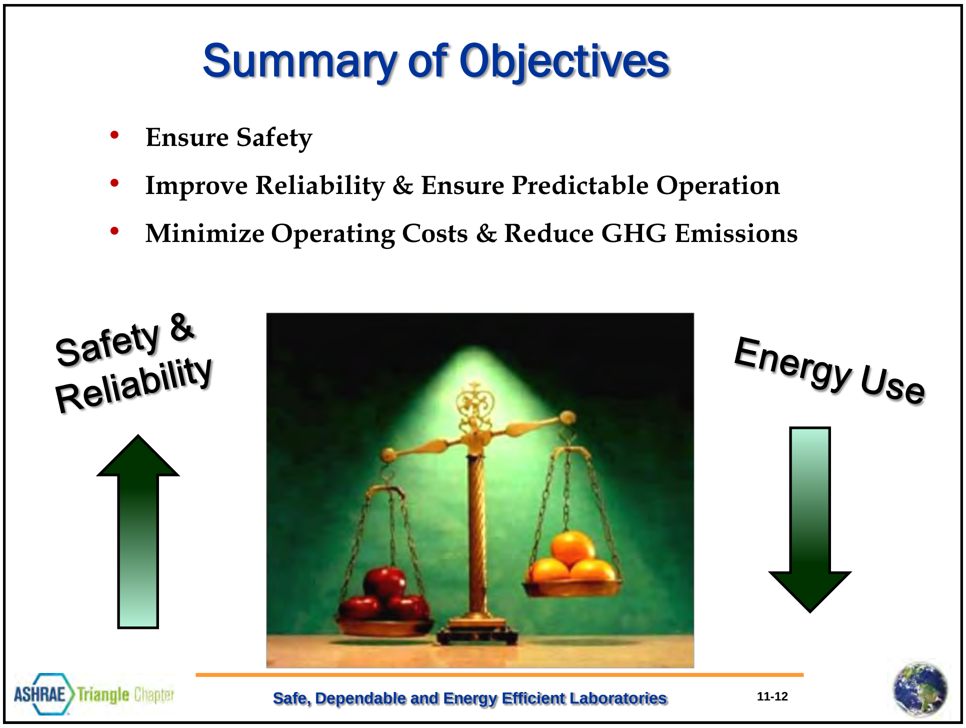
- Laboratories are far more expensive to operate than Office Buildings.
- Equivalent Annual Energy of One 6 ft. Chemical Fume Hood
  - Three 2500 sq. ft. houses
  - Fifty 100 watt light bulbs
  - 80 tons CO^2 emissions

Facility Type	Average Utility Cost
Commercial	\$ 1 / ft^2
Hospital	\$ 3 / ft^2
Laboratory	\$ 7 / ft^2
Specialty Labs & Cleanrooms	≥ \$ 15 / ft^2

Lab Energy Use



Utility Costs for Laboratory Buildings

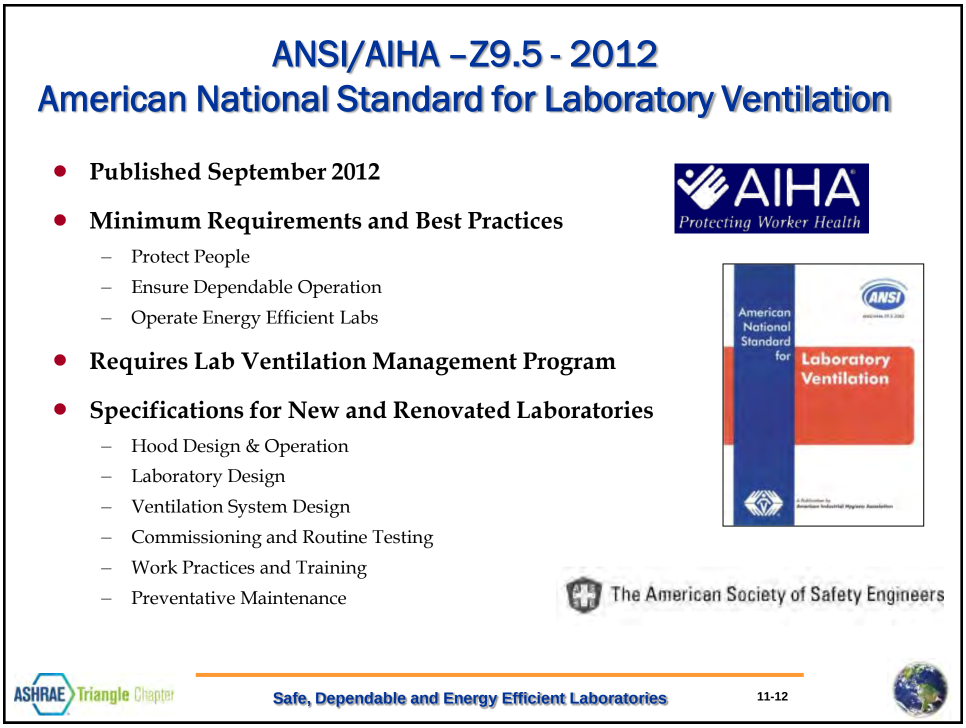


Summary of Objectives

- Ensure Safety
- Improve Reliability & Ensure Predictable Operation
- Minimize Operating Costs & Reduce GHG Emissions

Site Strategic Plans & Goals

- Facility Mission
- Building Asset & Function
- Energy Consumption Level & Goal
- GHG Emission Level & Goal
- Time Frame & Lifecycle
- Available Funds & Budgets
- ROI & Sustainability
- Health and Safety Requirements



ANSI/AIHA –Z9.5 - 2012
American National Standard for Laboratory Ventilation

- Published September 2012
- Minimum Requirements and Best Practices
  - Protect People
  - Ensure Dependable Operation
  - Operate Energy Efficient Labs
- Requires Lab Ventilation Management Program
- Specifications for New and Renovated Laboratories
  - Hood Design & Operation
  - Laboratory Design
  - Ventilation System Design
  - Commissioning and Routine Testing
  - Work Practices and Training
  - Preventative Maintenance

Specifications for Safe & Energy Efficient Labs

- **Laboratory Hood Design & Operation**
  - Selection, Specifications & Performance Criteria
- **Monitors & VAV Controls**
  - Types and Operating Modes
- **Laboratory Design & Operation**
  - ACH & Air Change Effectiveness
  - Pressurization
- **Ventilation Design & Operation**
  - Duct Velocity
  - Stack Discharge
  - Recirculation & Energy Recovery
- **Commissioning and Routine Tests**
  - ANSI / ASHRAE 110 "Method of Testing Performance of Laboratory Fume Hoods"

Demand Based Optimization

Improve safety and reduce energy by meeting the demand for ventilation

Demand for Ventilation

- **Safety**
  - Hood Exhaust Requirements
  - Laboratory Pressurization
  - Laboratory Airflow (Dilution)
- **Comfort (IAQ)**
  - Temperature
  - Humidity
- **Occupancy / Utilization**

Demand Based Optimization

Opportunities to Improve Safety and Reduce Energy

Modify Systems to Meet Demand

- Remove or Hibernate Unnecessary Hoods
- Install High Performance Fume Hoods
- Retrofit & Upgrade Traditional Fume Hoods
- Upgrade CAV & VAV Controls
- Optimize Temperature & Humidity Controls
- Reduce / Reset System Static Pressure
- Install Demand Control Ventilation
- Install Energy Recovery Systems

Modify Inefficient Hoods

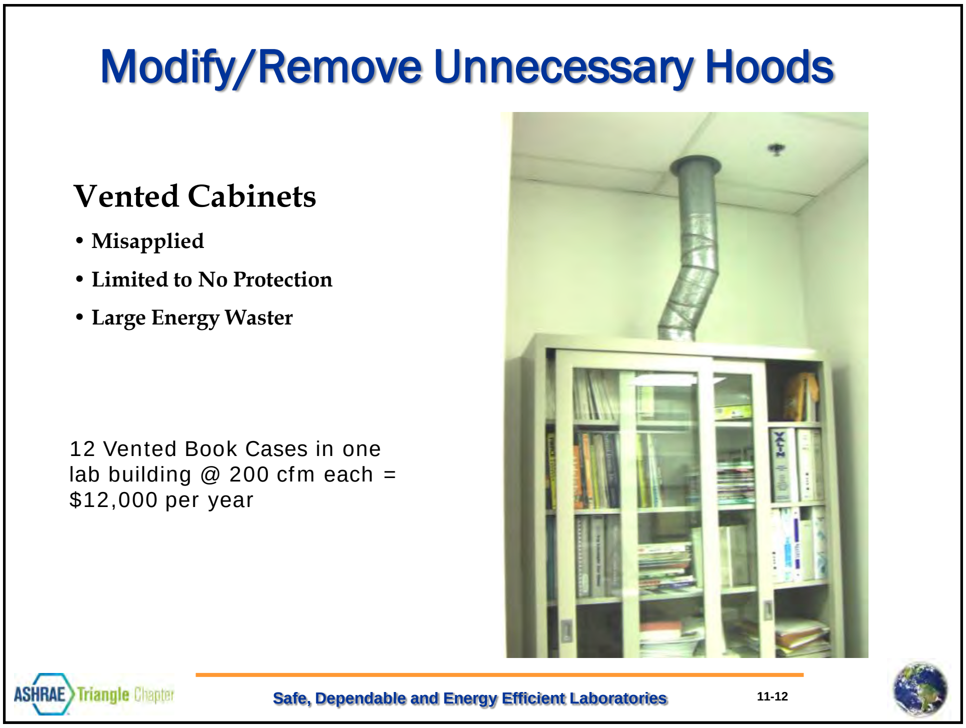
Glass Wash / Sterilizer Canopies

- Poorly designed
- Ineffective capture
- Typically Operate Continuously
- Large Energy Waster

Modify/Remove Unnecessary Hoods

Operating Cost = $250 - $500 per year

Recent project removed 325 unused snorkels saving $81,250 per year.

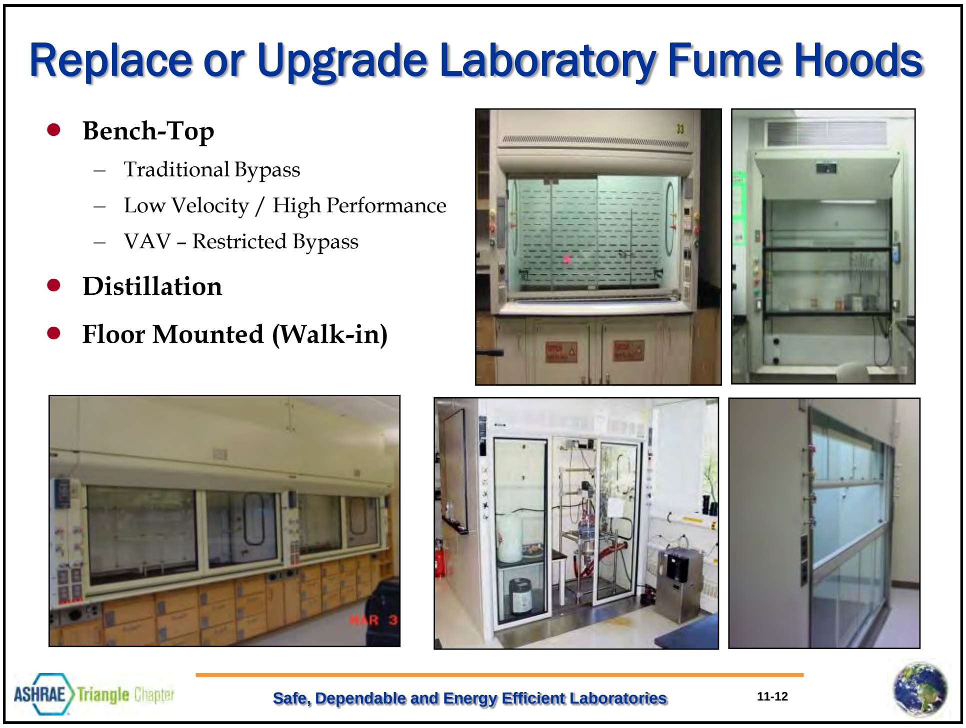


Modify/Remove Unnecessary Hoods

Vented Cabinets

- **Misapplied**
- **Limited to No Protection**
- **Large Energy Waster**

12 Vented Book Cases in one lab building @ 200 cfm each = $12,000 per year



Replace or Upgrade Laboratory Fume Hoods

- **Bench-Top**
  - Traditional Bypass
  - Low Velocity / High Performance
  - VAV – Restricted Bypass
- **Distillation**
- **Floor Mounted (Walk-in)**

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Safe, Dependable and Energy Efficient Laboratories

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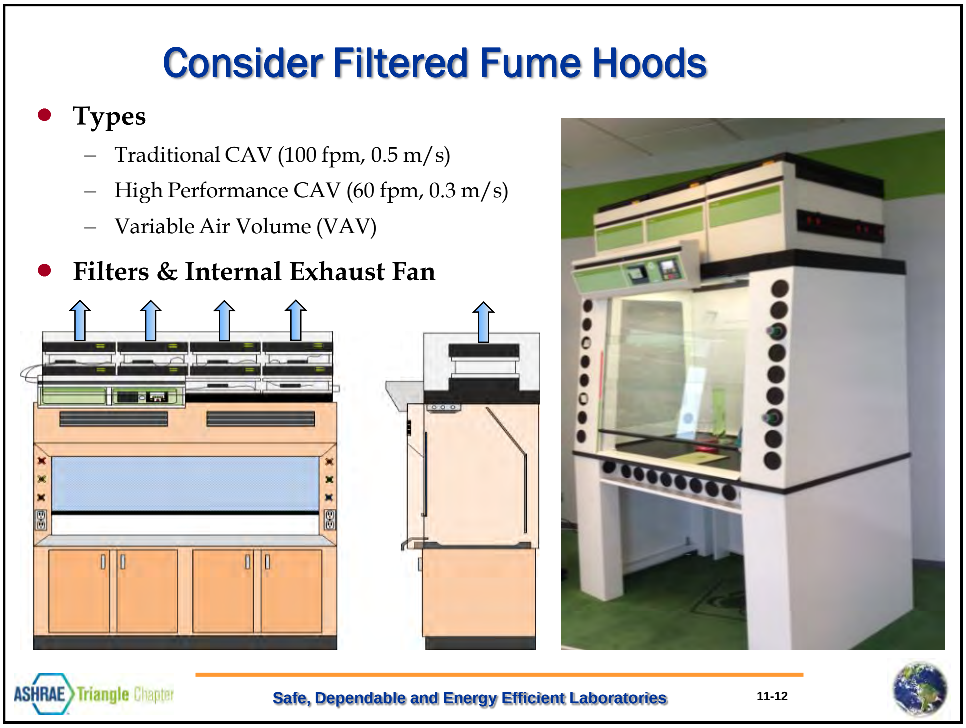

Consider Filtered Fume Hoods

- **Types**
  - Traditional CAV (100 fpm, 0.5 m/s)
  - High Performance CAV (60 fpm, 0.3 m/s)
  - Variable Air Volume (VAV)
- **Filters & Internal Exhaust Fan**

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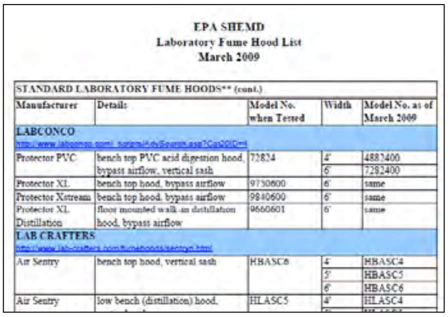
Install High Performance Fume Hoods

- DuPont Stnd – 60 fpm
- Hood Manufacturers
  - Lab Crafters
  - Fisher Hamilton
  - Kewaunee Scientific
  - Labconco
  - Air Master
- EPA Approved Hood List

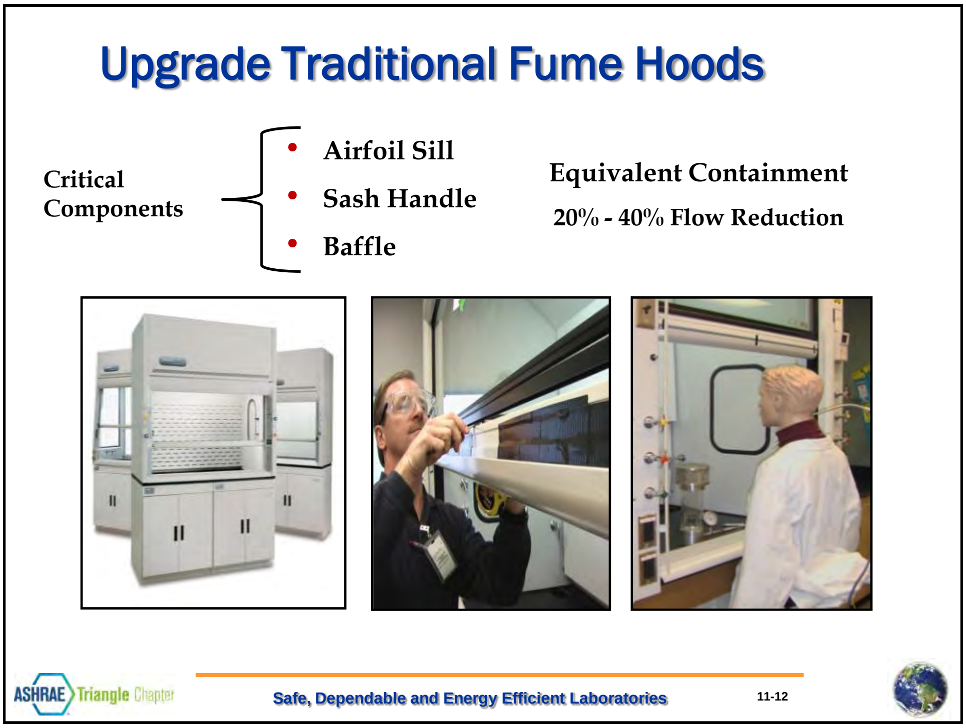


EPA SHEMD
Laboratory Fume Hood List
March 2009

STANDARD LABORATORY FUME HOODS** (cont.)				
Manufacturer	Details	Model No. when Tested	Width	Model No. as of March 2009
LABCONCO [illegible]				
Protector PVC	bench top PVC acid digestion hood, bypass airflow, vertical sash	72824	4'	4882400
			6'	7282400
Protector XL	bench top hood, bypass airflow	9730600	6'	same
Protector Xstream	bench top hood, bypass airflow	9840600	6'	same
Protector XL Distillation	floor mounted walk-in distillation hood, bypass airflow	9660601	6'	same
LAB CRAFTERS [illegible]				
Air Sentry	bench top hood, vertical sash	HBASC6	4'	HBASC4
			5'	HBASC5
			6'	HBASC6
Air Sentry	low bench (distillation) hood,	HLASC5	4'	HLASC4

ECTI - Evaluation of HP Fume Hoods

- Manufacturer Prototype Tests
- Factory Acceptance Tests
  - As Manufactured
  - EPA, NIH, GSK, Merck, UNC, Duke, etc.
- Extensive Field Tests
  - UCI Low Flow Hood Study
  - State of Wisconsin Equivalent Hood Study



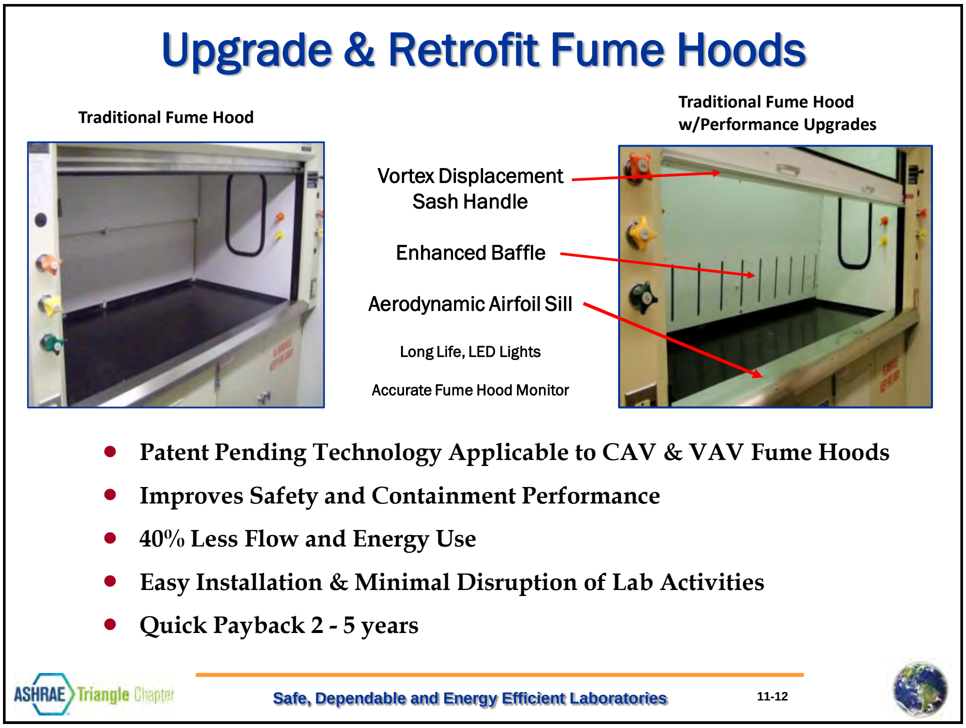
Upgrade Traditional Fume Hoods

Critical Components

- Airfoil Sill
- Sash Handle
- Baffle

Equivalent Containment

20% - 40% Flow Reduction



Upgrade & Retrofit Fume Hoods

Traditional Fume Hood

Traditional Fume Hood w/Performance Upgrades

Vortex Displacement Sash Handle

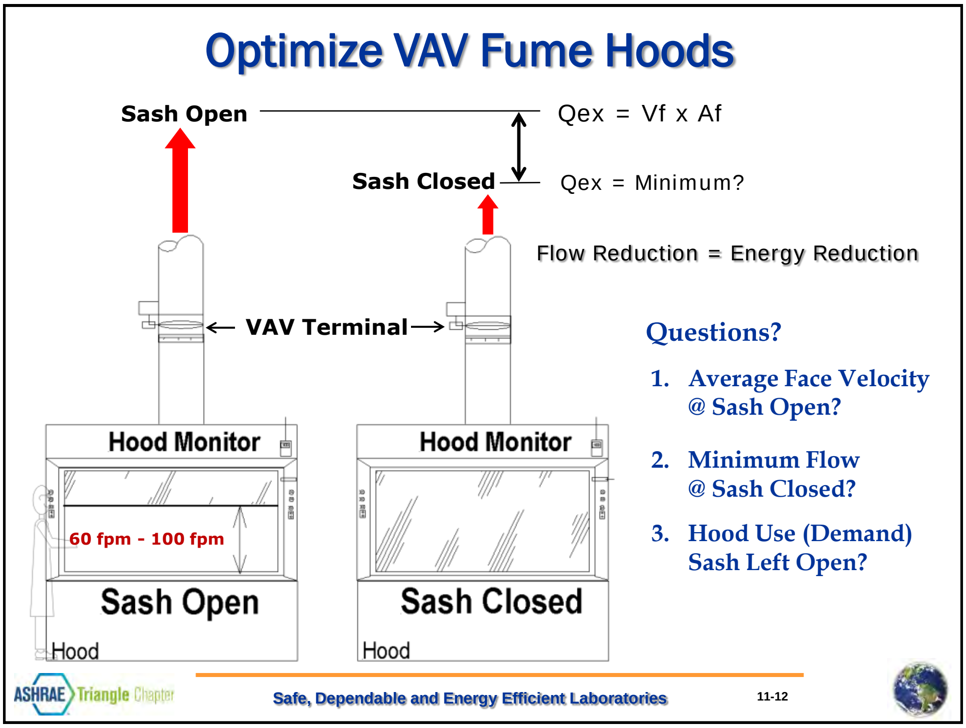
Enhanced Baffle

Aerodynamic Airfoil Sill

Long Life, LED Lights

Accurate Fume Hood Monitor

- Patent Pending Technology Applicable to CAV & VAV Fume Hoods
- Improves Safety and Containment Performance
- 40% Less Flow and Energy Use
- Easy Installation & Minimal Disruption of Lab Activities
- Quick Payback 2 - 5 years



Optimize VAV Fume Hoods

Flow Reduction = Energy Reduction

Questions?

1. Average Face Velocity @ Sash Open?
2. Minimum Flow @ Sash Closed?
3. Hood Use (Demand) Sash Left Open?

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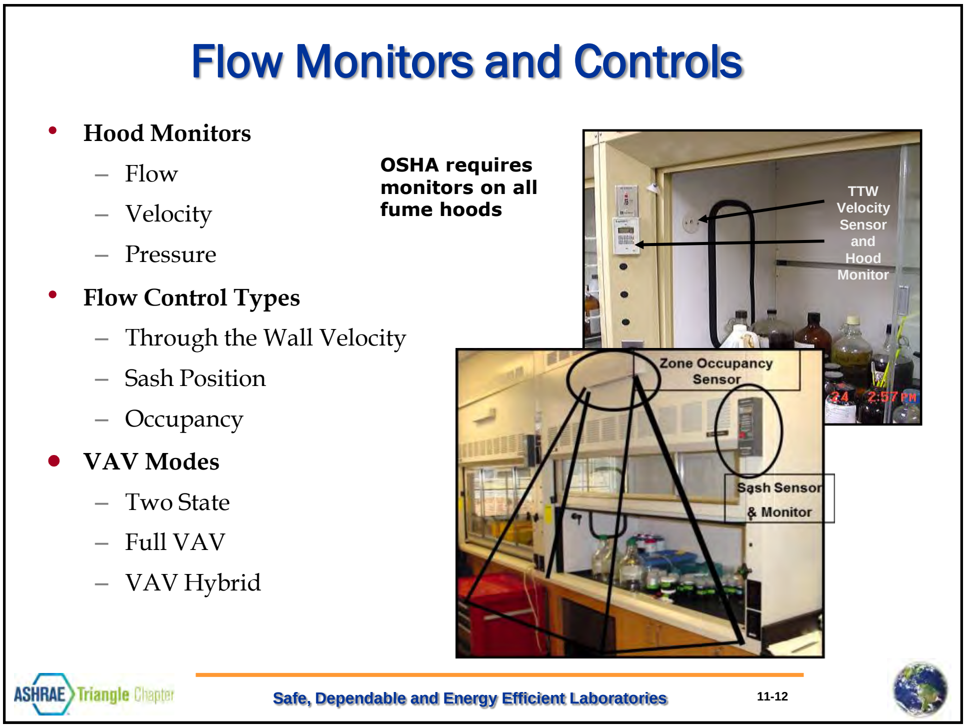

Flow Monitors and Controls

- **Hood Monitors**
  - Flow
  - Velocity
  - Pressure
- **Flow Control Types**
  - Through the Wall Velocity
  - Sash Position
  - Occupancy
- **VAV Modes**
  - Two State
  - Full VAV
  - VAV Hybrid

OSHA requires monitors on all fume hoods

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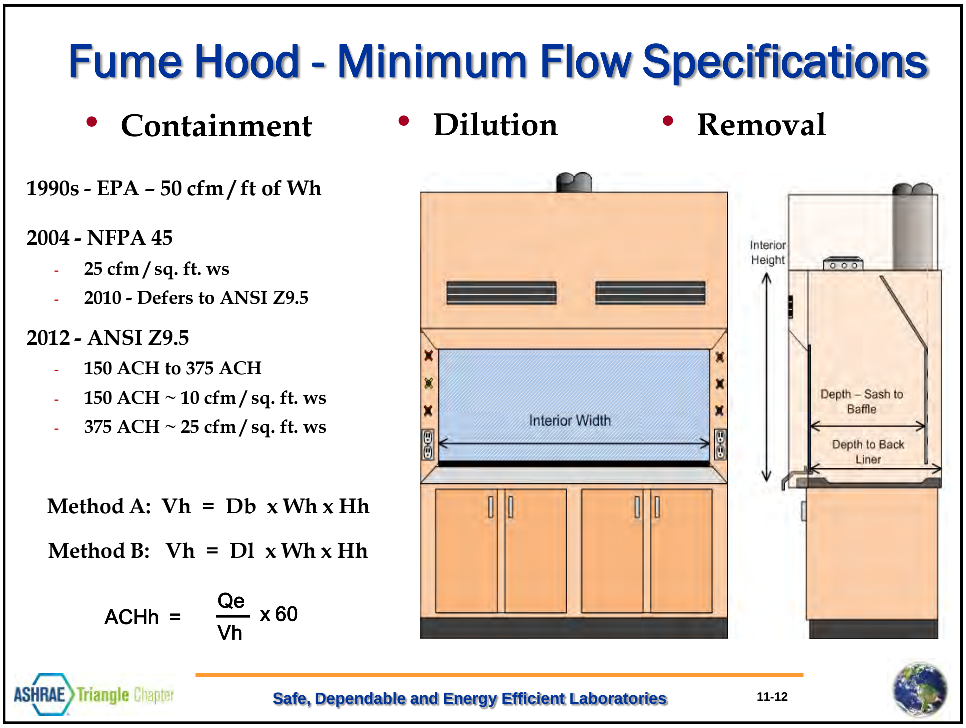

Fume Hood - Minimum Flow Specifications

- Containment
- Dilution
- Removal

1990s - EPA – 50 cfm / ft of Wh

2004 - NFPA 45
  - 25 cfm / sq. ft. ws
  - 2010 - Defers to ANSI Z9.5

2012 - ANSI Z9.5
  - 150 ACH to 375 ACH
  - 150 ACH ~ 10 cfm / sq. ft. ws
  - 375 ACH ~ 25 cfm / sq. ft. ws

Method A: Vh = Db x Wh x Hh

Method B: Vh = Dl x Wh x Hh

$$ACHh = \frac{Qe}{Vh} \times 60$$

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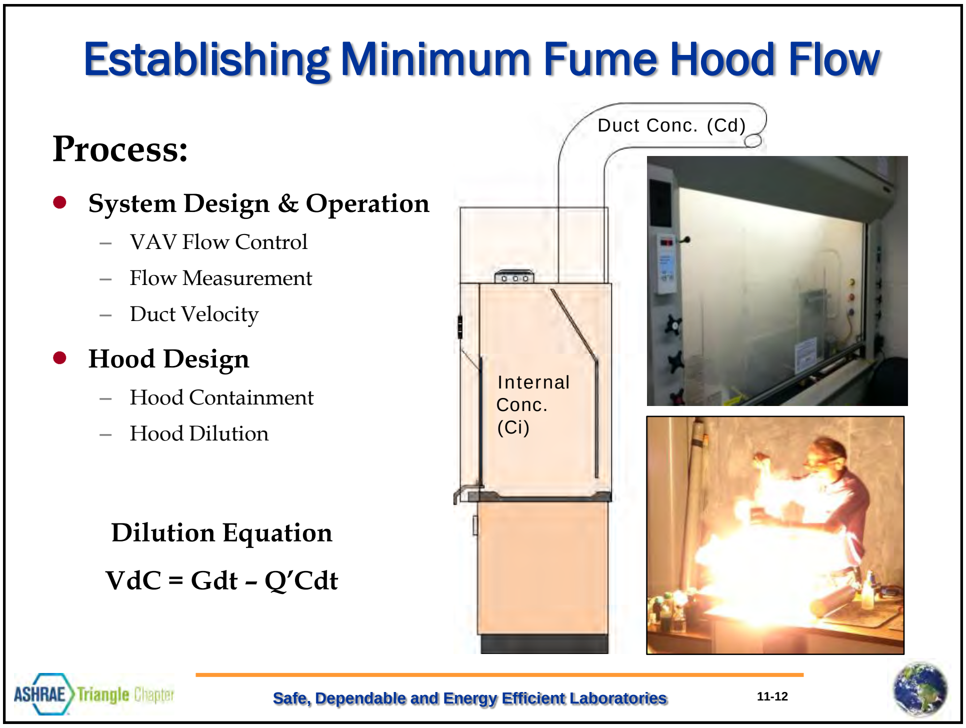

Establishing Minimum Fume Hood Flow

Process:

- System Design & Operation
  - VAV Flow Control
  - Flow Measurement
  - Duct Velocity
- Hood Design
  - Hood Containment
  - Hood Dilution

Dilution Equation

VdC = Gdt – Q'Cdt

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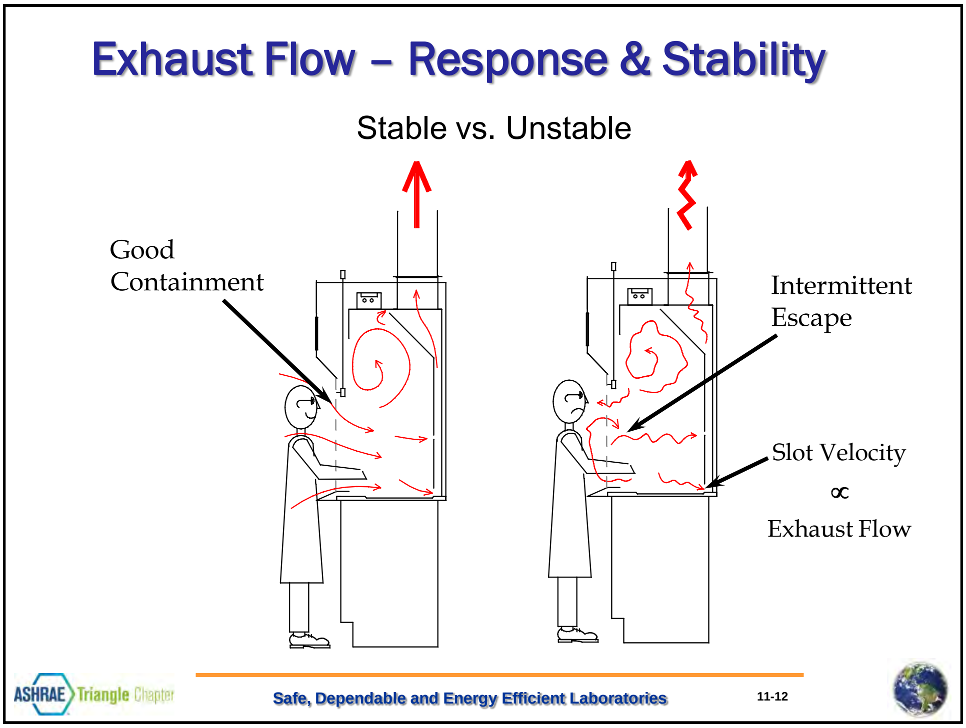

Exhaust Flow – Response & Stability

Stable vs. Unstable

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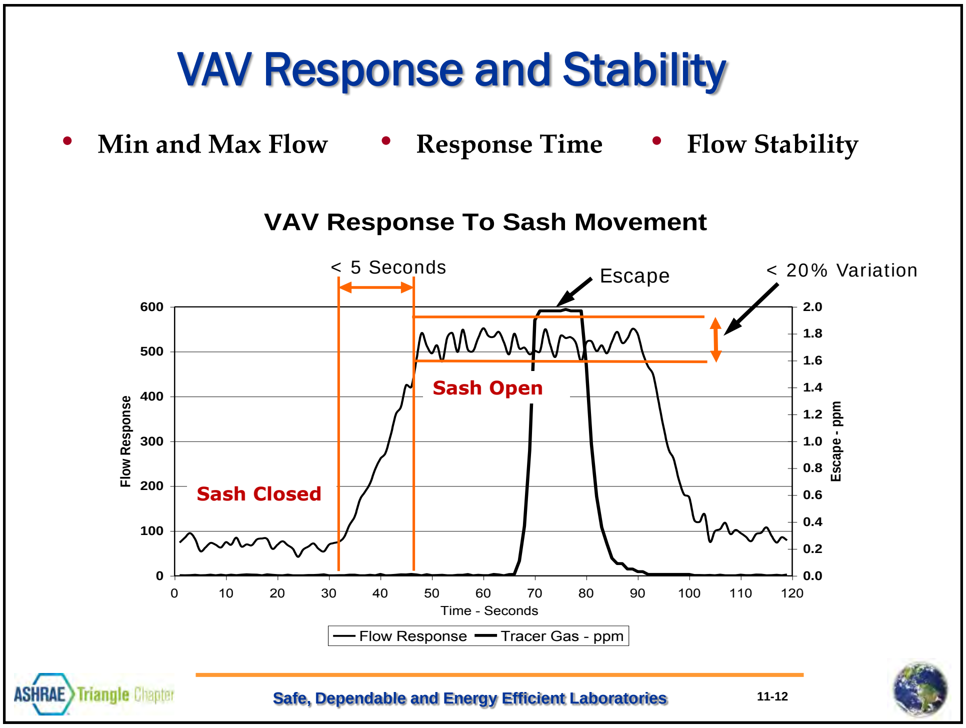

VAV Response and Stability

- Min and Max Flow
- Response Time
- Flow Stability

VAV Response To Sash Movement

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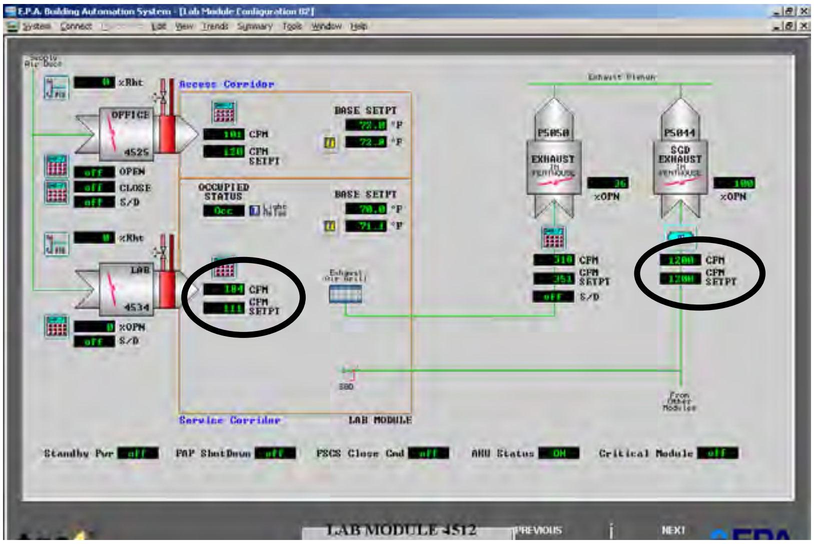
Controls & Building Automation System (BAS)



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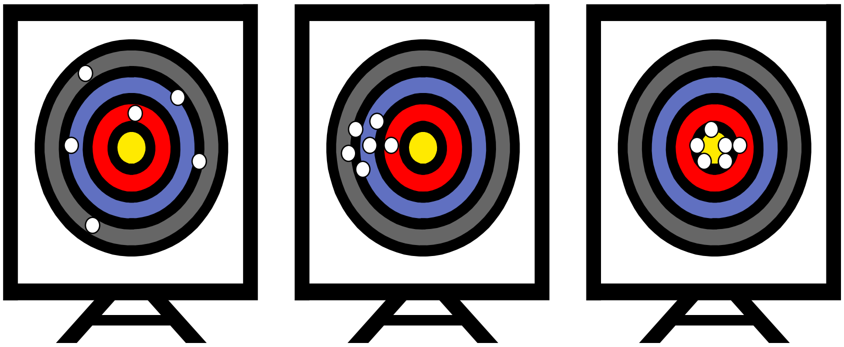
Quality Data - Accuracy and Precision



Not Accurate and Not Precise

Precise but not Accurate

Accurate and Precise

<u>EPA RTP</u> Flow Sensors (Pre LVOP) = 20% to 65% Error

Flow Sensors (Post LVOP) = 5% Error

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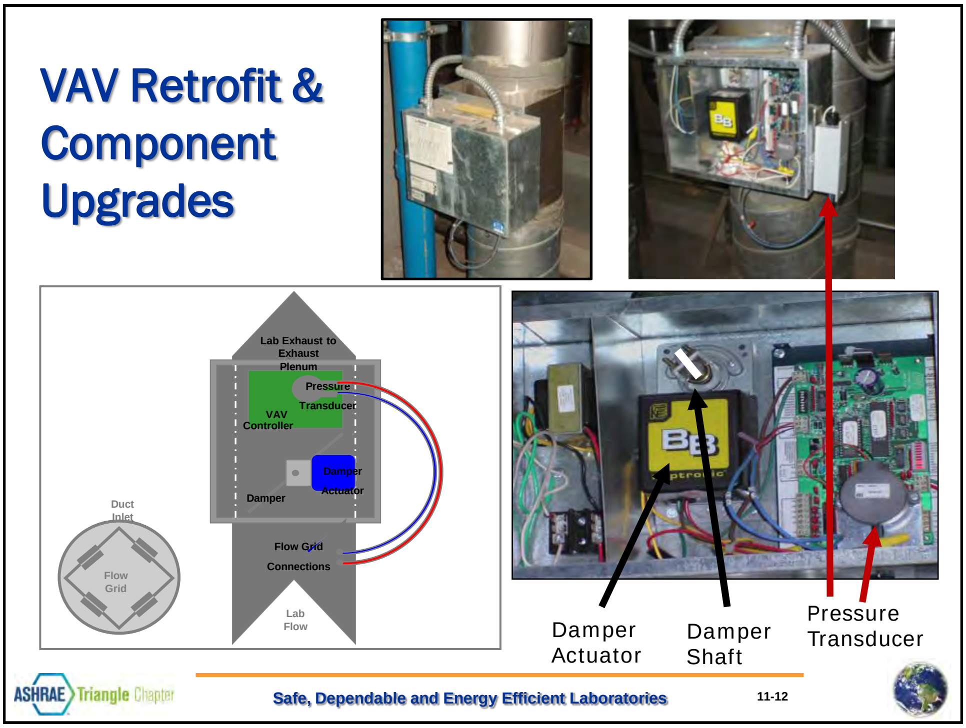
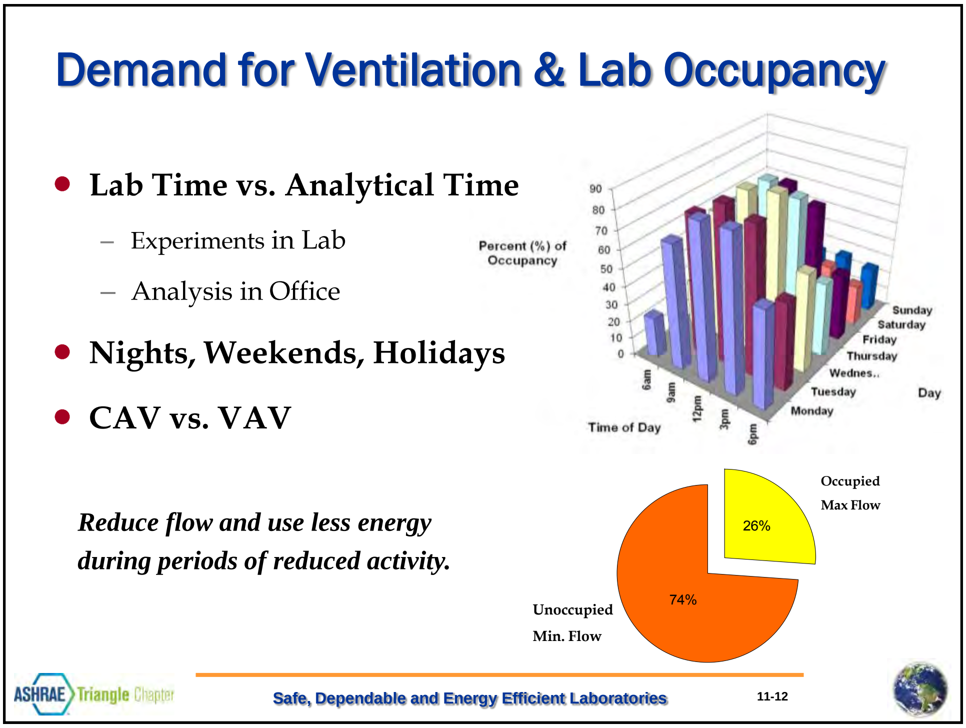


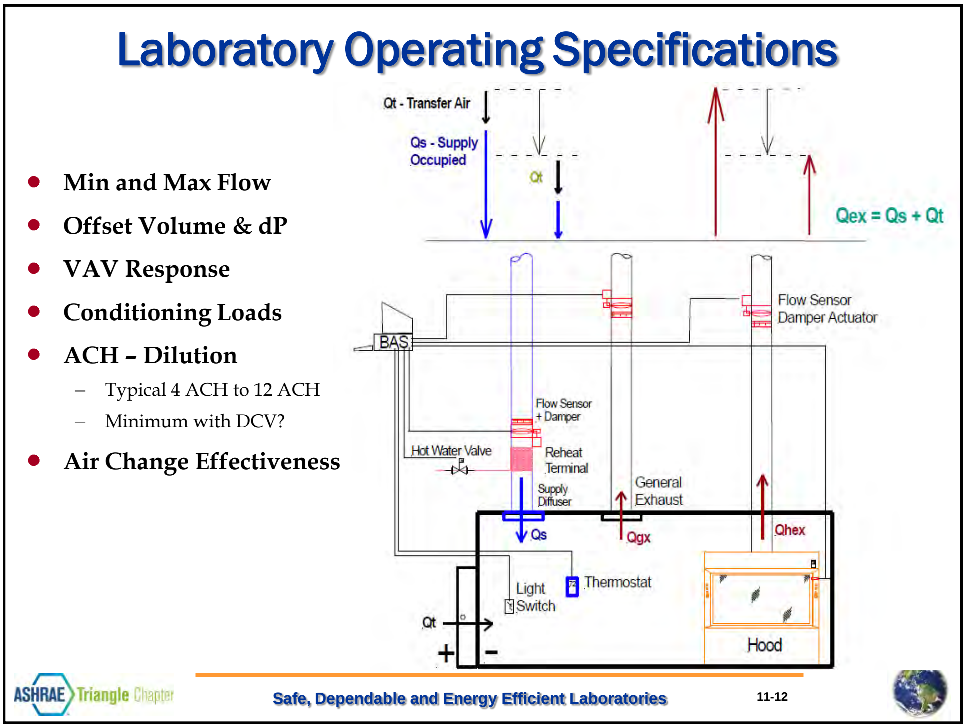
VAV Retrofit & Component Upgrades



Demand for Ventilation & Lab Occupancy

- Lab Time vs. Analytical Time
  - Experiments in Lab
  - Analysis in Office
- Nights, Weekends, Holidays
- CAV vs. VAV

Reduce flow and use less energy during periods of reduced activity.



Laboratory Operating Specifications

- **Min and Max Flow**
- **Offset Volume & dP**
- **VAV Response**
- **Conditioning Loads**
- **ACH – Dilution**
  - Typical 4 ACH to 12 ACH
  - Minimum with DCV?
- **Air Change Effectiveness**

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Safe, Dependable and Energy Efficient Laboratories

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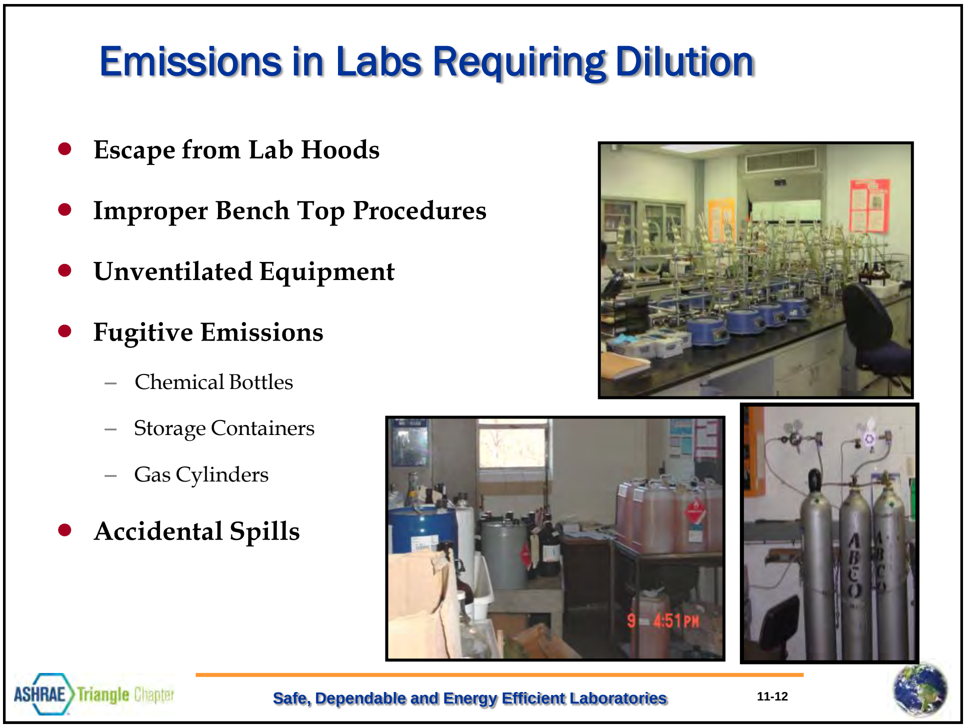

Emissions in Labs Requiring Dilution

- **Escape from Lab Hoods**
- **Improper Bench Top Procedures**
- **Unventilated Equipment**
- **Fugitive Emissions**
  - Chemical Bottles
  - Storage Containers
  - Gas Cylinders
- **Accidental Spills**

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Typical ACH Guidelines

Agency	Ventilation Rate
OSHA 29 CFR Part 1910.1450	**4-12 ACH**
ASHRAE Lab Guides	**4-12 ACH**
UBC – 1997	**1 cfm/ft2**
IBC – 2003	**1 cfm /ft2**
IMC – 2003	**1 cfm/ft2**
U.S. EPA	**4 ACH Unoccupied Lab** **8 ACH Occupied Lab**
AIA	**4-12 ACH**
NFPA-45-2004	**4 ACH Unoccupied Lab** **8 ACH Occupied Lab**
NRC Prudent Practices	**4-12 ACH**
ANSI/AIHA Z9.5	**ACH is not appropriate.** **Rate shall be established by the owner.**
ACGIH 24th Edition, 2001	**Ventilation depends on the generation rate and toxicity of the contaminant and not the size of the room.**

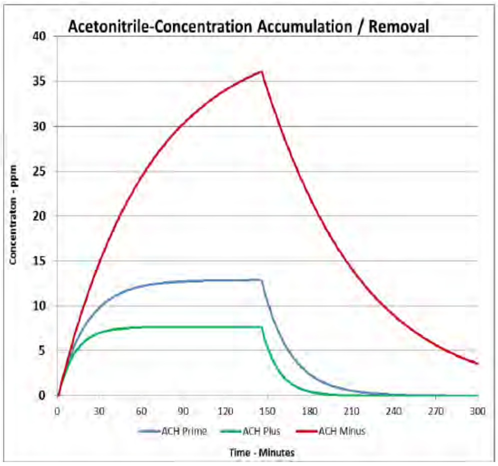
ECT's ChemGen Lab Dilution Calculator

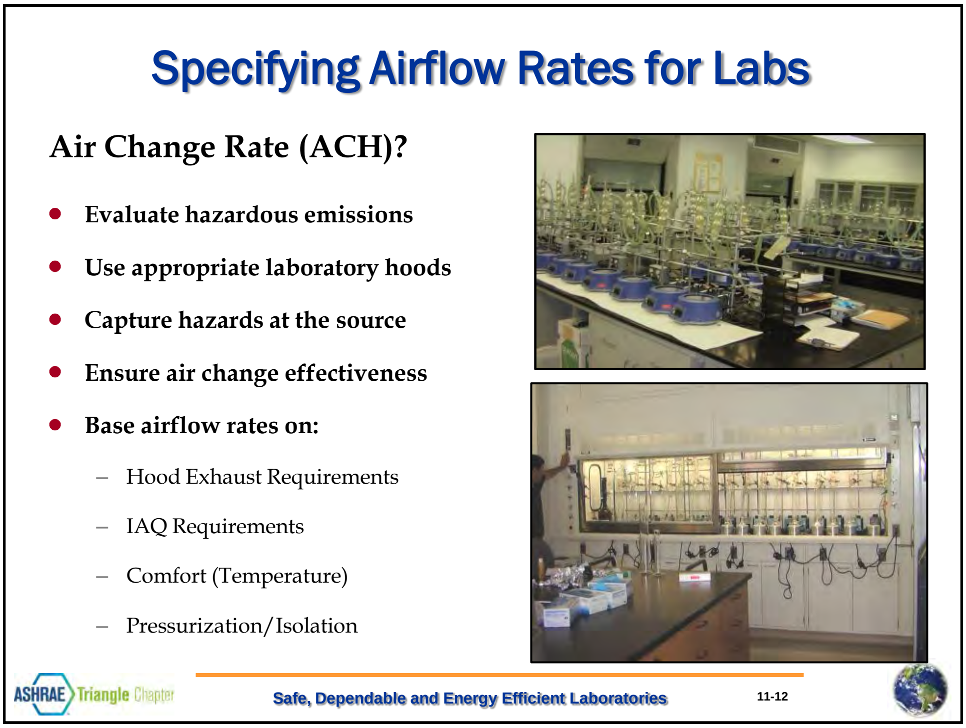
Rate of Accumulation = Generation Rate – Removal Rate

VdC = Gdt – Q'Cdt

- Multiple Hazards
- Varied Emission Scenarios
- Lab Size & Configurations
- Air Change Effectiveness
- Accumulation & Decay at Different ACH

$$C = \frac{G\left[1 - e^{\frac{(-Q'\Delta t)}{V}}\right]}{Q'} \times 10^{6}$$





Specifying Airflow Rates for Labs

Air Change Rate (ACH)?

- Evaluate hazardous emissions
- Use appropriate laboratory hoods
- Capture hazards at the source
- Ensure air change effectiveness
- Base airflow rates on:
  - Hood Exhaust Requirements
  - IAQ Requirements
  - Comfort (Temperature)
  - Pressurization/Isolation

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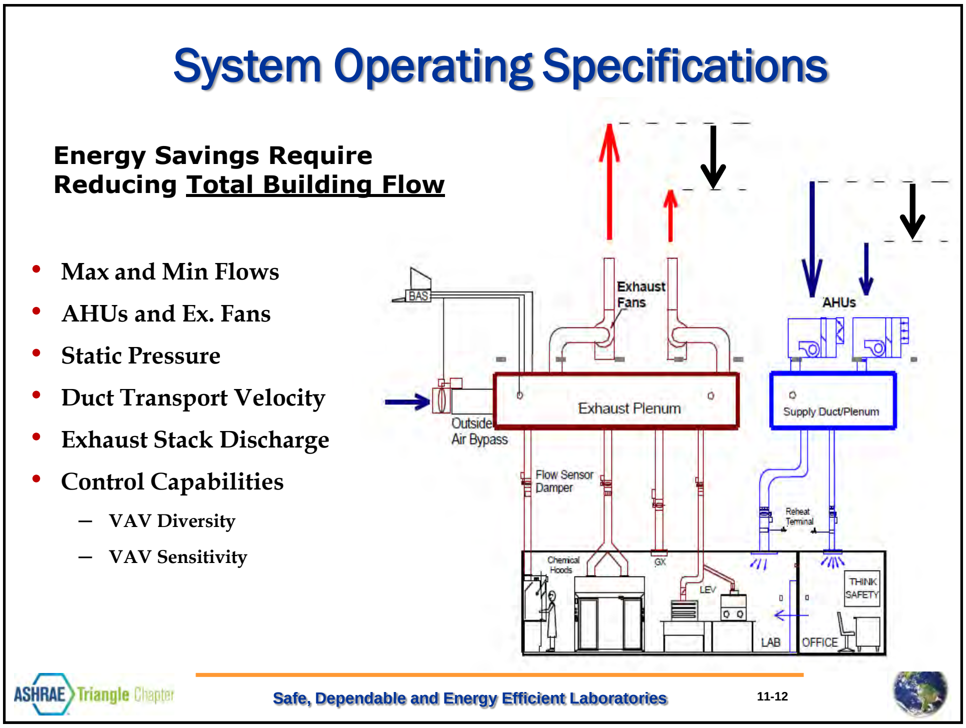

System Operating Specifications

Energy Savings Require
Reducing Total Building Flow

- Max and Min Flows
- AHUs and Ex. Fans
- Static Pressure
- Duct Transport Velocity
- Exhaust Stack Discharge
- Control Capabilities
  - VAV Diversity
  - VAV Sensitivity

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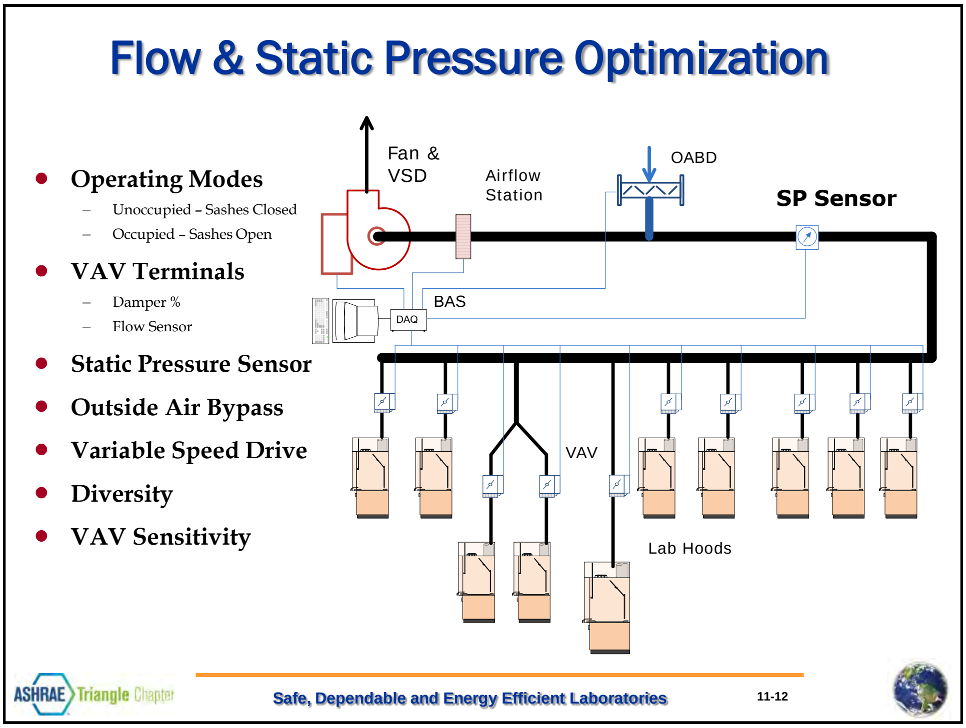

Flow & Static Pressure Optimization

- **Operating Modes**
  - Unoccupied – Sashes Closed
  - Occupied – Sashes Open
- **VAV Terminals**
  - Damper %
  - Flow Sensor
- **Static Pressure Sensor**
- **Outside Air Bypass**
- **Variable Speed Drive**
- **Diversity**
- **VAV Sensitivity**

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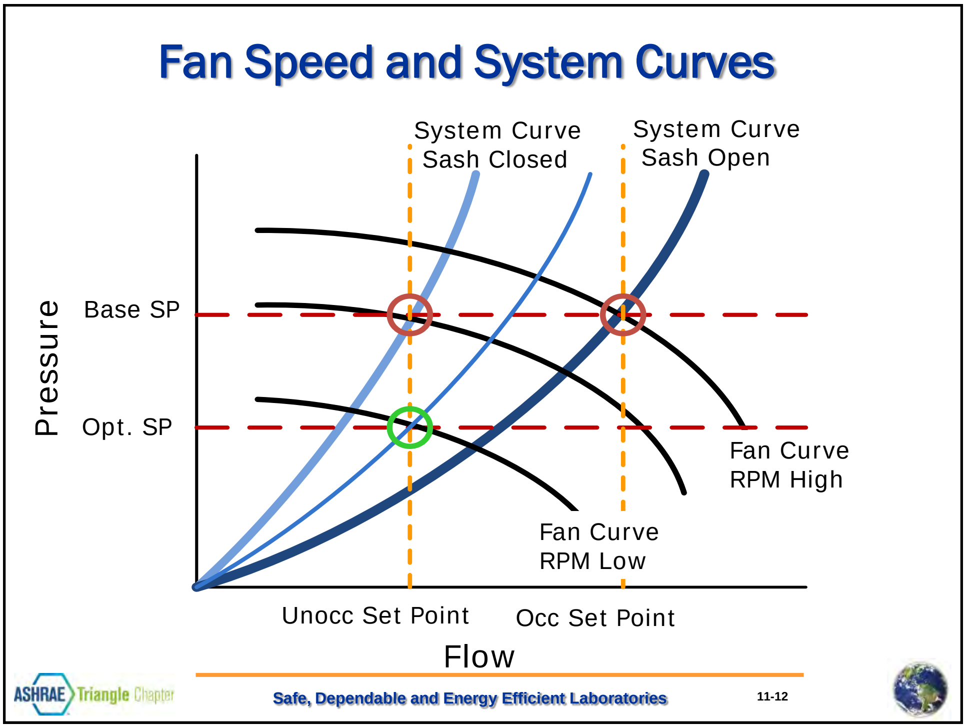

Fan Speed and System Curves

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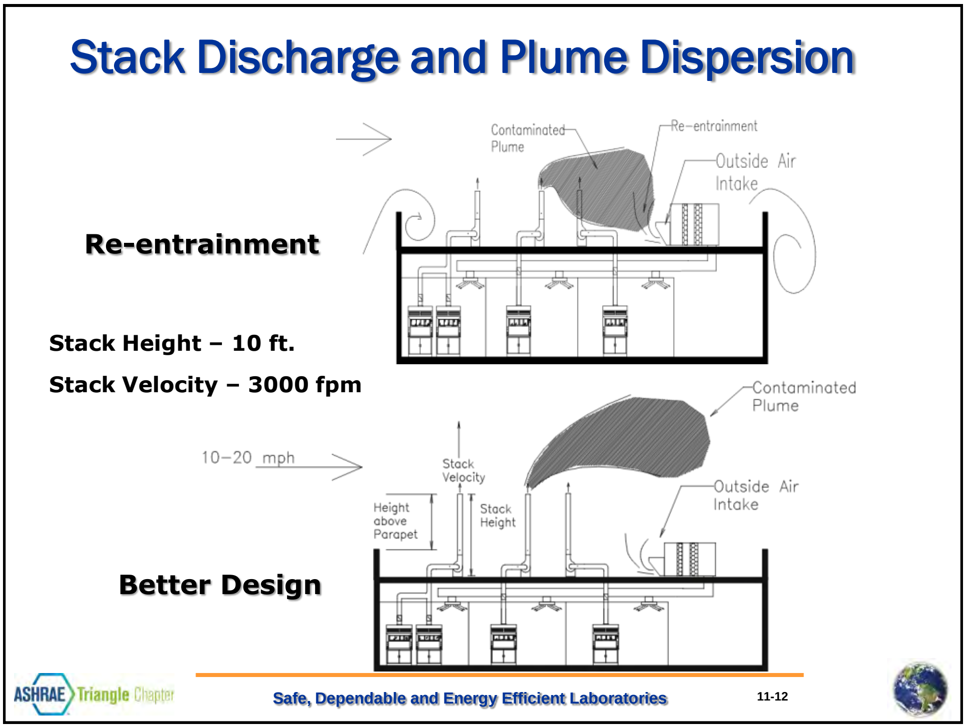


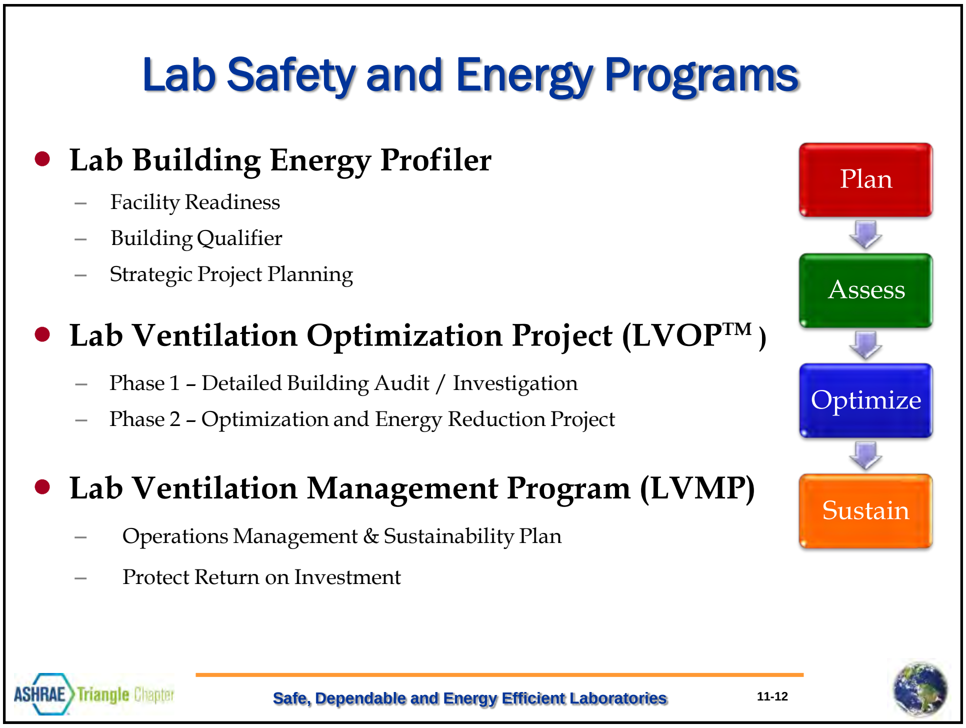
Stack Discharge and Plume Dispersion

Re-entrainment

Stack Height – 10 ft.

Stack Velocity – 3000 fpm

Better Design



Lab Safety and Energy Programs

- **Lab Building Energy Profiler**
  - Facility Readiness
  - Building Qualifier
  - Strategic Project Planning
- **Lab Ventilation Optimization Project (LVOP™)**
  - Phase 1 – Detailed Building Audit / Investigation
  - Phase 2 – Optimization and Energy Reduction Project
- **Lab Ventilation Management Program (LVMP)**
  - Operations Management & Sustainability Plan
  - Protect Return on Investment

Plan

Assess

Optimize

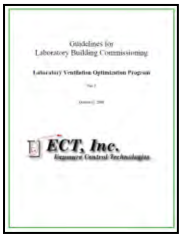
Sustain

Building Rank & Energy Project Prioritization

Rank	Building	Total Annual Utility Cost	% Utility Reduction	Annual Savings $	Investment to Realize Savings $	Conservative Payback Period
1	Bldg D	$2,000,000	18	$345,000	$1,030,000	3
2	Bldg E	$1,000,000	13	$140,000	$700,000	5
3	Bldg A	$800,000	14	$102,000	$405,000	4
4	Bldg F	$600,000	8	$50,000	$190,000	4
5	Bldg B	$450,000	7	$33,000	$165,000	5
6	Bldg C	$300,000	7	$22,000	$130,000	6
	Totals	$5,150,000		$692,000	$2,620,000	

Lab Ventilation Optimization Project (LVOP™)

- **Phase 1 – Safety and Energy Assessment**
  - – Evaluate Demand for Ventilation
  - – Establish Safety and Health Specifications
  - – Analyze Utilities & Operating Costs
  - – Propose Energy Conservation Measures (ECMs)
- **Phase 2 A&B – Energy Reduction Project**
  - 2 A - Scope of Work & Engineering
  - 2 B – Project to Implement Selected ECMs
    - Verify Performance and Energy Savings



Guidelines for
Laboratory Building Commissioning

Laboratory Ventilation Optimization Program

ECT, Inc.
Exposure Control Technologies

Overview of LVOP™
Form and Field Application

ECT, Inc.

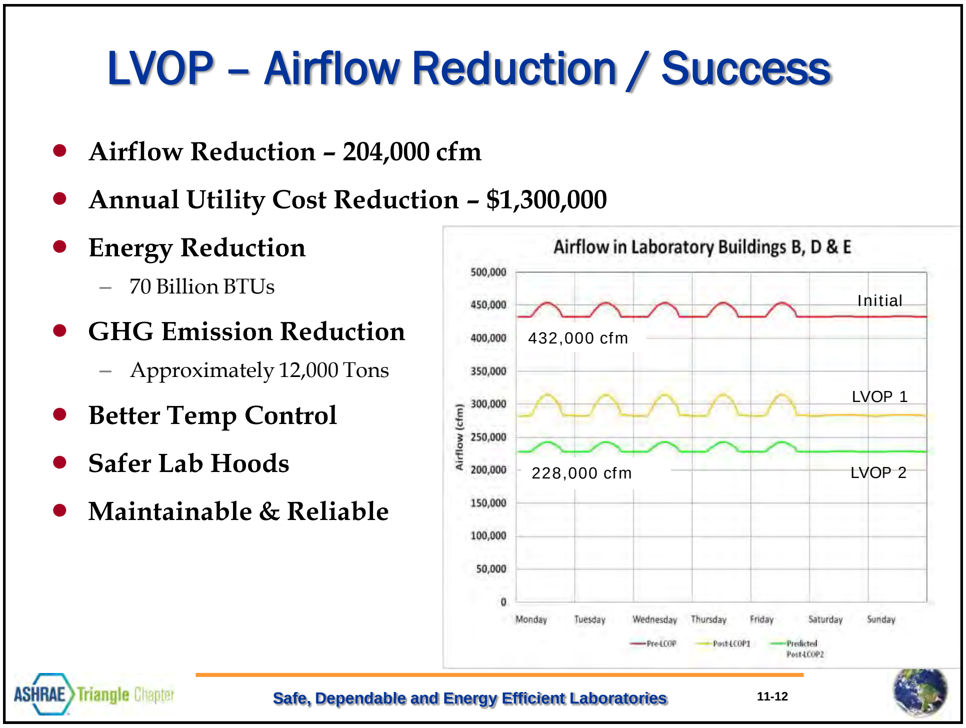
LVOP™ – Coordinated Team Effort

- **Site Project Manager**
- **Team Development (In-house and Contractors)**
  - Facilities and Energy Engineers
  - Environmental Health and Safety
  - Lab Staff Representatives
  - HVAC Systems Engineer
  - Laboratory Hood Specialist
  - Building Controls Operator
  - TAB Contractor
  - Commissioning Agent
  - Mechanical Maintenance Technician

ASHRAE Triangle Chapter

Safe, Dependable and Energy Efficient Laboratories

11-12



LVOP – Airflow Reduction / Success

- **Airflow Reduction – 204,000 cfm**
- **Annual Utility Cost Reduction – $1,300,000**
- **Energy Reduction**
  - 70 Billion BTUs
- **GHG Emission Reduction**
  - Approximately 12,000 Tons
- **Better Temp Control**
- **Safer Lab Hoods**
- **Maintainable & Reliable**

Airflow in Laboratory Buildings B, D & E

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Safe, Dependable and Energy Efficient Laboratories

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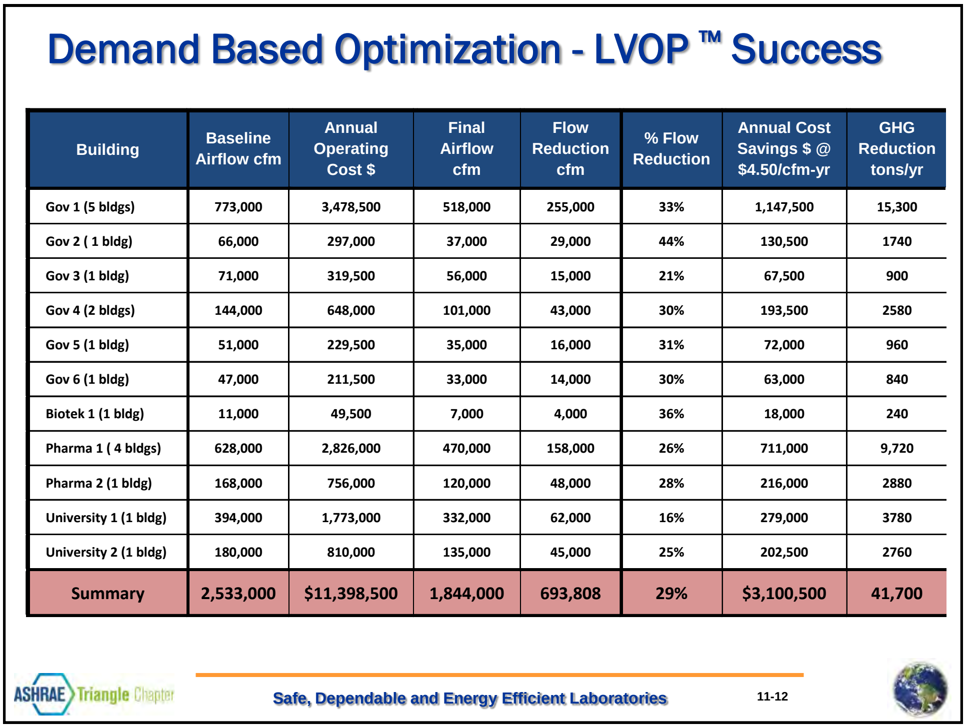

Demand Based Optimization - LVOP ™ Success

Building	Baseline Airflow cfm	Annual Operating Cost $	Final Airflow cfm	Flow Reduction cfm	% Flow Reduction	Annual Cost Savings $ @ $4.50/cfm-yr	GHG Reduction tons/yr
Gov 1 (5 bldgs)	773,000	3,478,500	518,000	255,000	33%	1,147,500	15,300
Gov 2 (1 bldg)	66,000	297,000	37,000	29,000	44%	130,500	1740
Gov 3 (1 bldg)	71,000	319,500	56,000	15,000	21%	67,500	900
Gov 4 (2 bldgs)	144,000	648,000	101,000	43,000	30%	193,500	2580
Gov 5 (1 bldg)	51,000	229,500	35,000	16,000	31%	72,000	960
Gov 6 (1 bldg)	47,000	211,500	33,000	14,000	30%	63,000	840
Biotek 1 (1 bldg)	11,000	49,500	7,000	4,000	36%	18,000	240
Pharma 1 (4 bldgs)	628,000	2,826,000	470,000	158,000	26%	711,000	9,720
Pharma 2 (1 bldg)	168,000	756,000	120,000	48,000	28%	216,000	2880
University 1 (1 bldg)	394,000	1,773,000	332,000	62,000	16%	279,000	3780
University 2 (1 bldg)	180,000	810,000	135,000	45,000	25%	202,500	2760
Summary	2,533,000	$11,398,500	1,844,000	693,808	29%	$3,100,500	41,700

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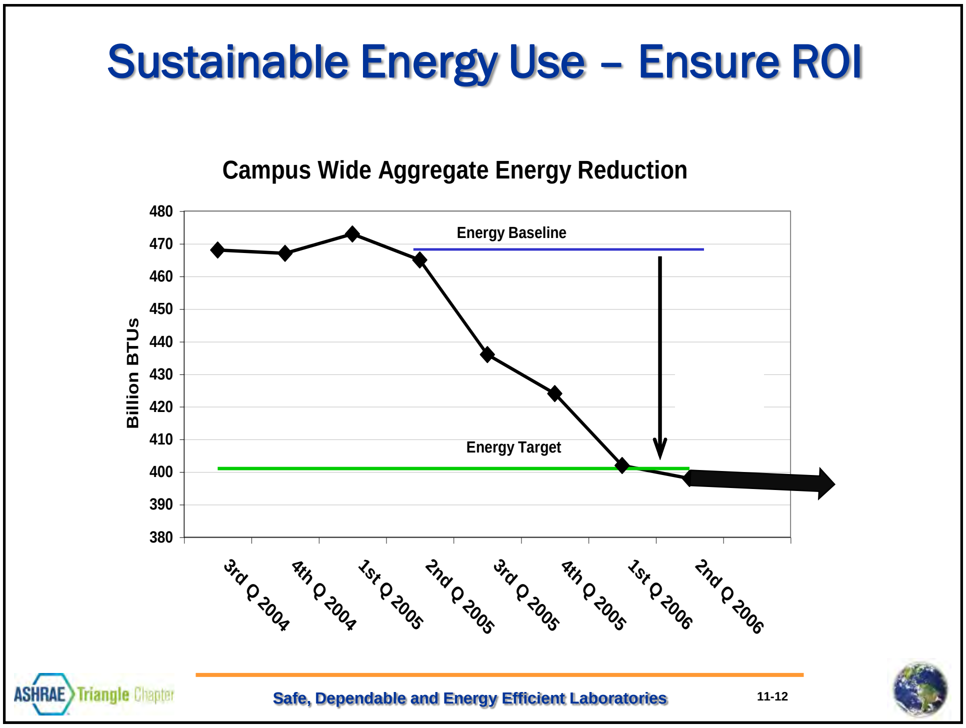

Sustainable Energy Use – Ensure ROI

Campus Wide Aggregate Energy Reduction

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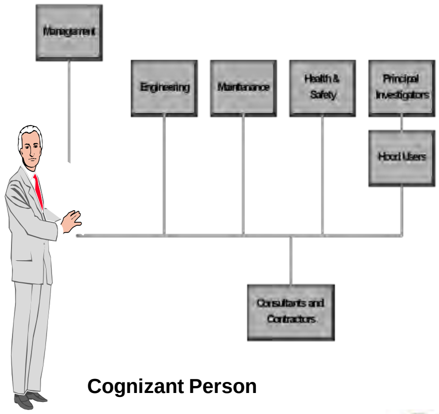
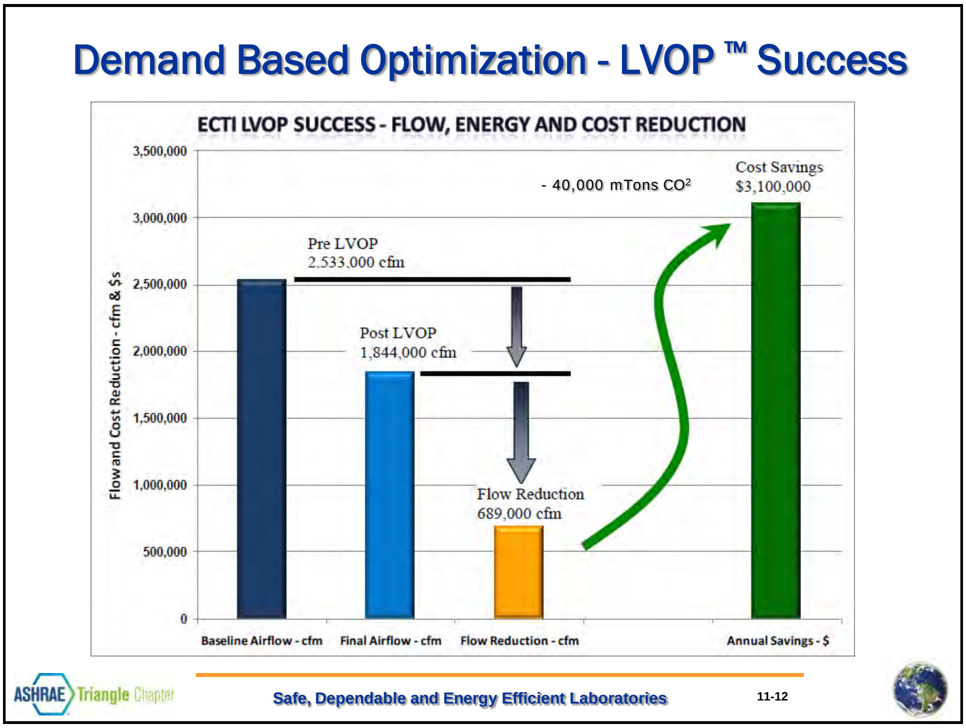
Laboratory Ventilation Management Program (LVMP)

- **System Management and Sustainability Plan**
  - Organization and Responsibilities
  - Effective Collaboration/Integration
  - SOP's for Testing and Maintenance
  - Metrics and Monitoring
  - BAS Utilization
- **Management of Change**
- **Personnel Training**



LVMP – Personnel Training

- **Hood Users and Lab Managers**
- **Maintenance Personnel**
- **Facility Engineers**
- **Building Operators**
- **Management**



Demand Based Optimization - LVOP ™ Success

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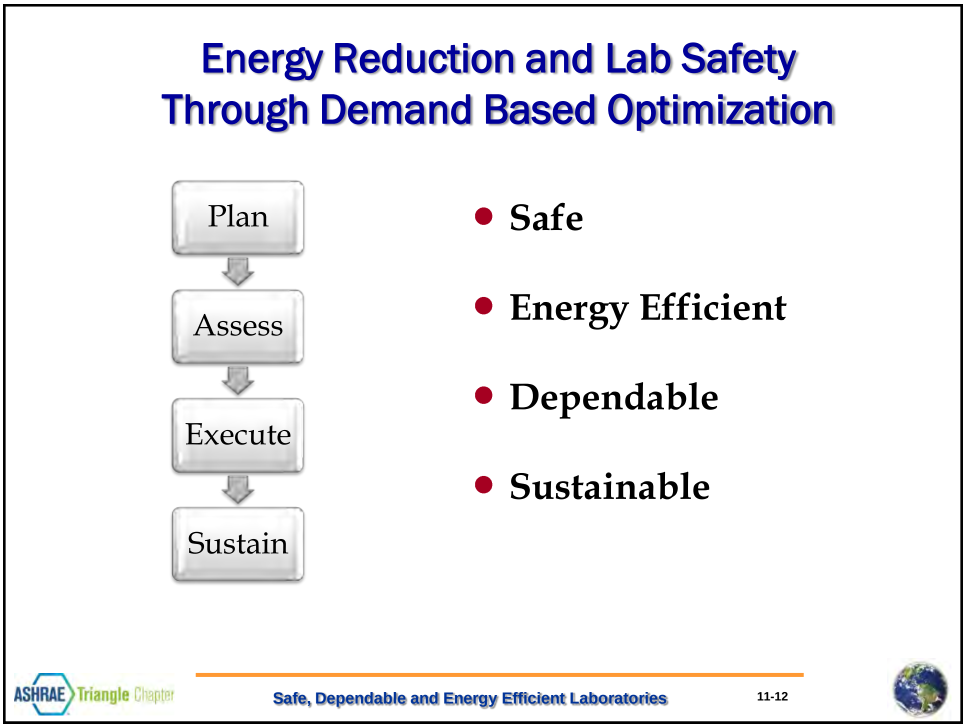

Energy Reduction and Lab Safety Through Demand Based Optimization

- **Safe**
- **Energy Efficient**
- **Dependable**
- **Sustainable**

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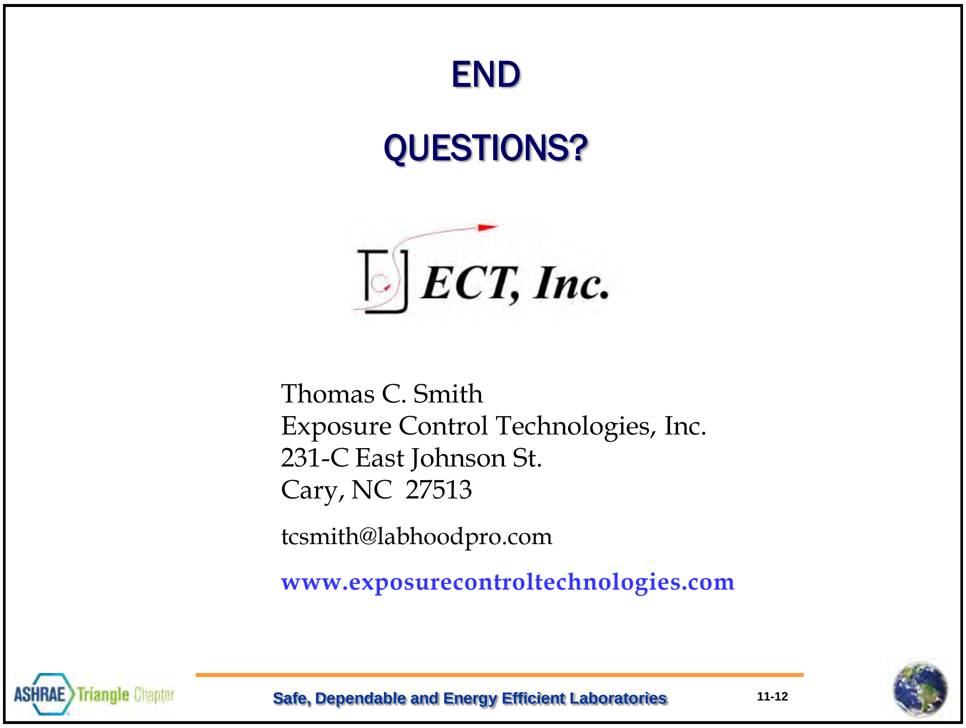

END

QUESTIONS?

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