Reducing Minimum Exhaust Flow for Laboratory Fume Hoods at the University of California, Irvine: A Case Study

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Introduction and Agenda

- Study Goals
- ANSI Z9.5 background information
- Study methodology/description of tests conducted
- Results
- Savings
- Implementation

Minimum Fume Hood Flow Study Goals

- **UC Irvine desires to reduce energy use in labs by minimizing the exhaust flow through VAV fume hoods when the sash is closed**
- **Evaluate whether exhaust flow can be reduced below current design specifications and determine the min recommended exhaust flow for VAV hoods located throughout the UCI campus**
- **Development of Criteria for Implementing new flow set points**

AIHA/ANSI Z9.5 Laboratory Standard

- **Current design min flow is determined by AIHA/ ANSI Z9.5 that requires a minimum flow of 25 cfm/ft^2 of work surface**
- **The new ANSI Z9.5 Standard is still in draft and under review, but it recommends basing the minimum flow on the internal volume of the fume hood and internal air change per hour(ACH) where a range of 375 ACH to as low as 150 ACH is proposed**
- **375 ACH is roughly equivalent to 25 cfm/ft^2 and150 ACH is roughly equivalent to 10 cfm/ft^2**

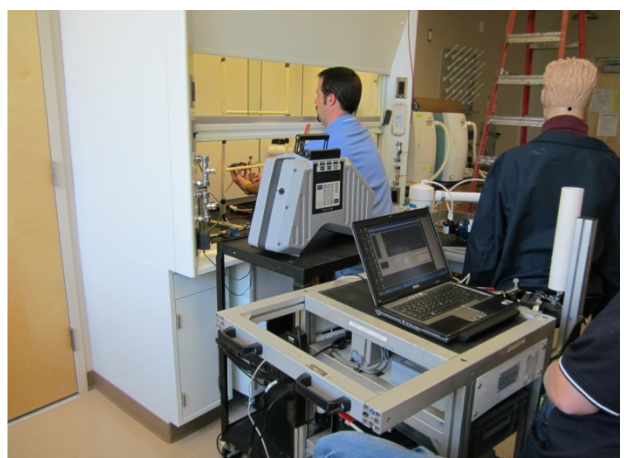
AIHA/ANSI Z9.5 Laboratory Standard cont

- **The processes and materials generated within the hoods**
- **Hood containment and dilution of hazardous concentrations within the hood**
- **Potential for increased corrosion**
- **The ability to measure and control flow**
- **Affect on duct transport and stack discharge velocities**

Two types of test conducted

- **Solvent Evaporation Test**

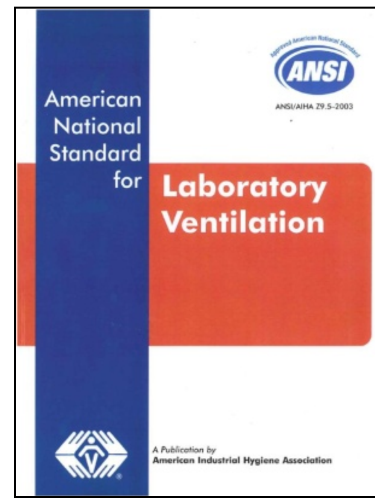
- **Dilution Test**



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

AIHA Protecting Worker Health

- **Publication Expected September 2012**
- **Minimum Requirements and Best Practices**
- **Supports OSHA Chemical Hygiene Plan and Hazard Assessment**
- **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



The American Society of Safety Engineers

Fume Hood - Minimum Flow Specifications

- Containment
- Dilution
- Removal

EPA – 50 cfm / ft of Wh

NFPA 45 – 2004

- 25 cfm / sq. ft. ws
- 2010 - Defers to AIHA Z9.5

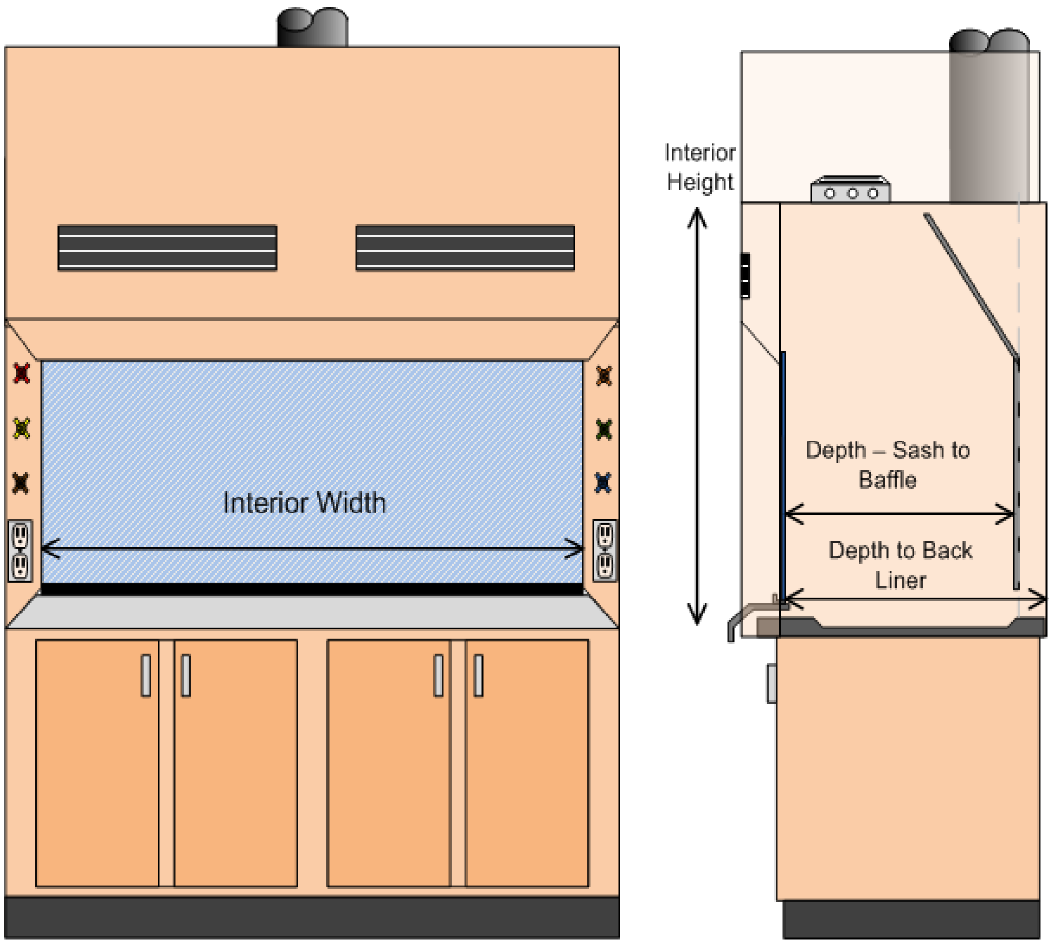
AIHA Z9.5 - 2012

- 150 – 375 ACH
- 150 ACH ~ 10 cfm / sq. ft. ws
- 375 ACH ~ 25 cfm / sq. ft. ws

Method A: Vh = Db x Wh x Hh

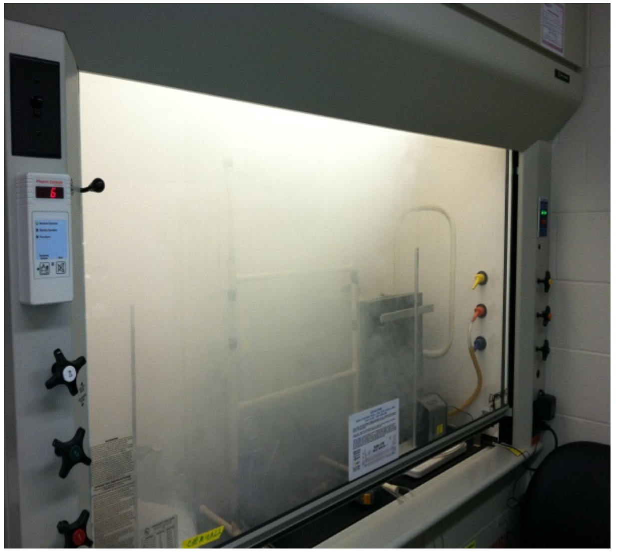
Method B: Vh = Dl x Wh x Hh

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



Establishing Minimum Fume Hood Flow

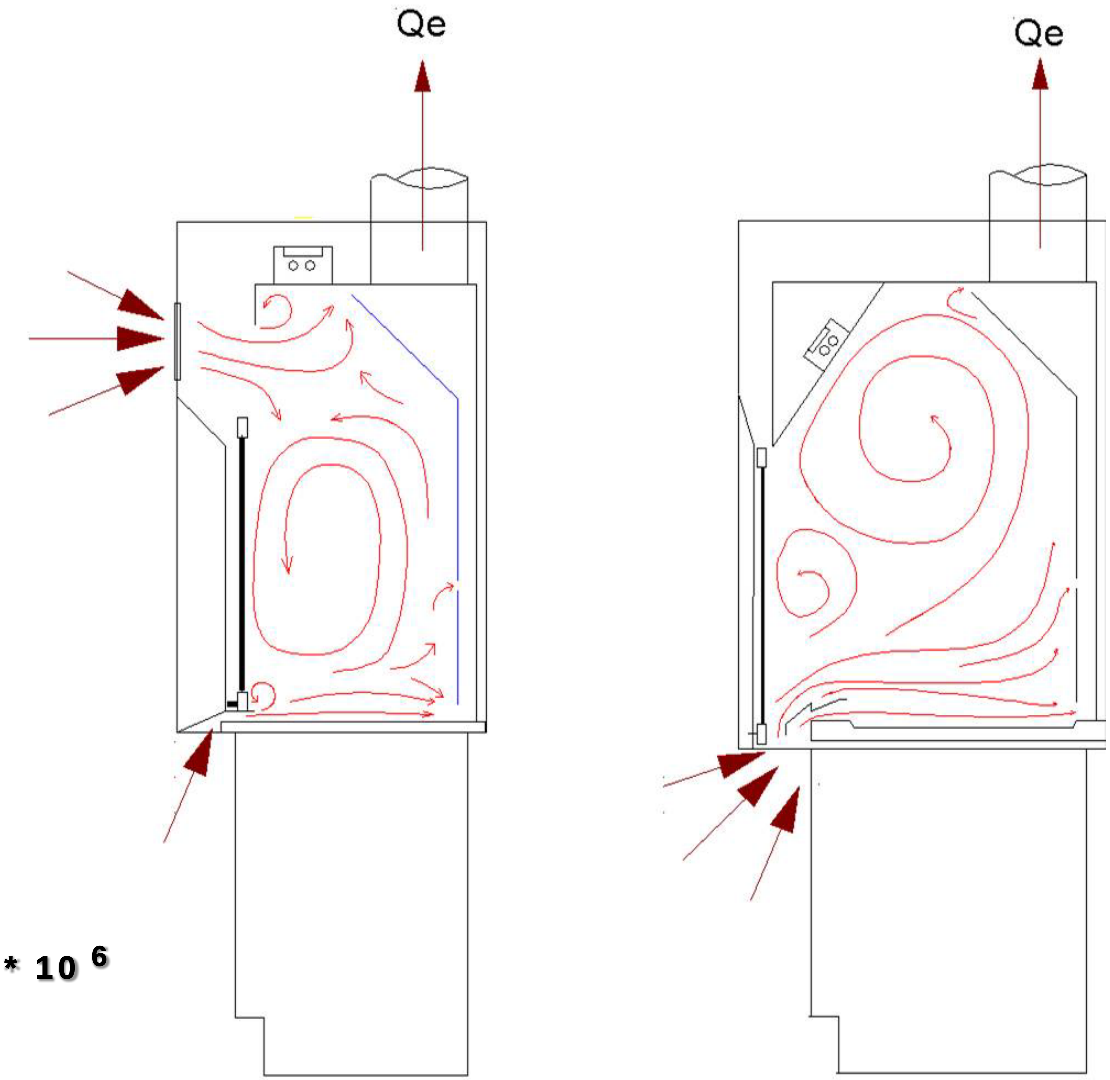
- **System Design & Operation**
  - VAV Flow Controls
  - Flow Measurement
  - Duct Transport Velocity
- **Fume Hood Design**
  - Hood Containment
    - Sash Closed
    - Sash Movement
  - Hood Dilution
- **Application**
  - Chemical Properties / Hazards
  - Generation Rates



Fume Hood Airflow Patterns & Concentration Accumulation

- **Hood Design**
  - Internal Volume - V
  - Bypass Design
  - Aerodynamic Design
- **Exhaust Flow - Qe**
- **Generation Rate – G**
- **Dilution Factor – Df**
- **Concentration - C**

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



Contaminant Accumulation and Dilution

Accumulation = Generation – Removal

$$VdC = Gdt - Q'Cdt$$

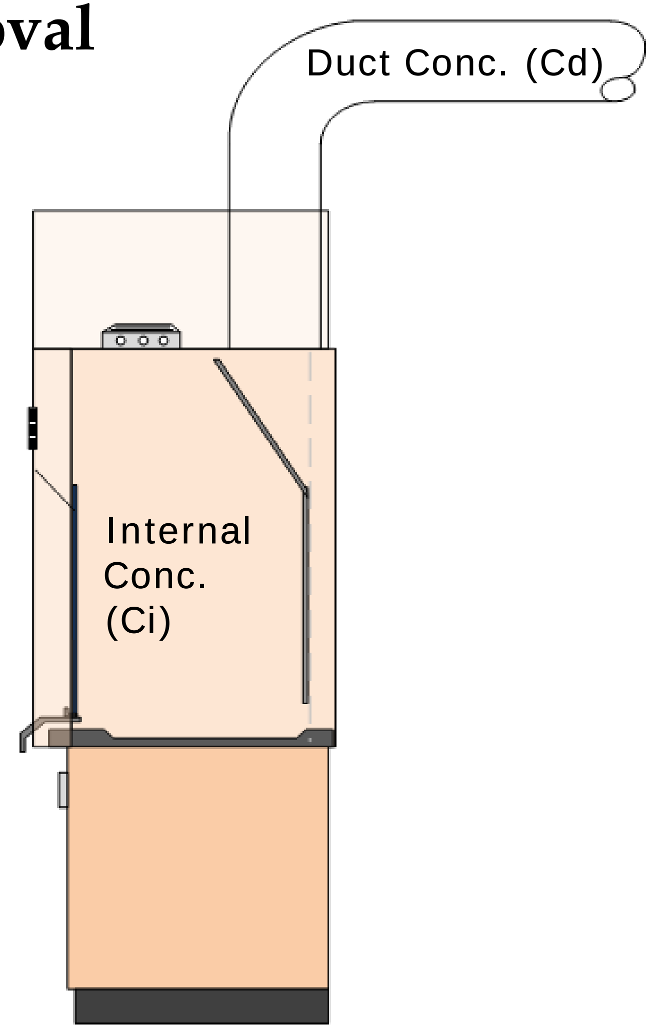
V = Volume of Room
G = Rate of Generation
Qe = Total Exhaust Flow
Q' = Effective Exhaust Flow
C = Concentration of Gas
t = Time

At Steady State:

$$Cd = G / Qe$$

$$Q' = Qe / Df$$

$$Ci = G / Q'$$



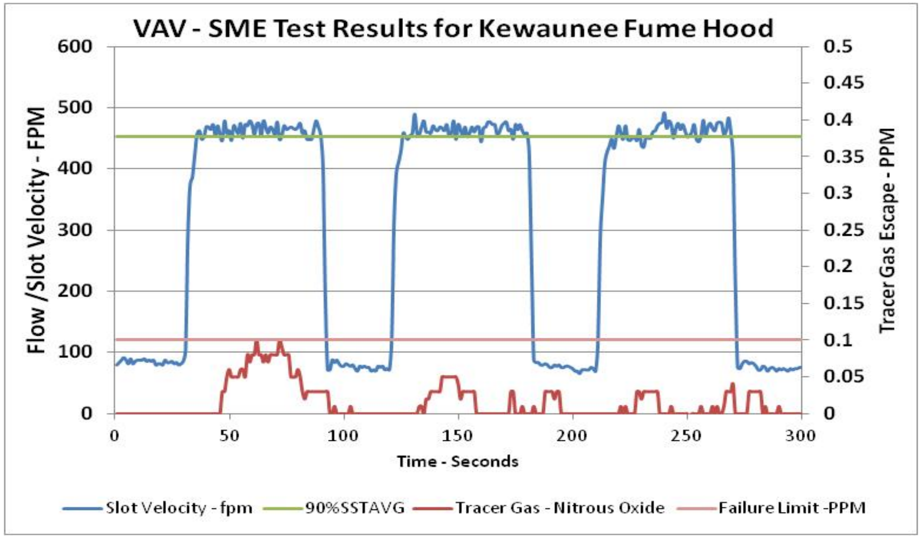
Laboratory Fume Hood Dimensions

- Six Fume Hoods Tested in Study
  - 2 – 6 ft. Labconco Bench-top Fume Hoods
  - 1 – 5 ft. Jamestown Bench-top Fume Hood
  - 1 – 5 ft. Kewaunee Bench-top Fume Hood
  - 2 – Fisher Hamilton Bench-top Fume Hoods

Laboratory Hood	Hood Size	Int. Width ft	Int. Height ft	Depth (A) ft	Depth (B) ft	Internal Volume (A) ft3	Internal Volume (B) Ft3
Labconco Protector	6’	5.21	4	2.38	2.66	49.5	55.4
Jamestown Isolator	5’	4.33	4	2.08	2.33	36.0	40.4
Kewaunee Supreme Air	5’	4.33	4	2.16	2.42	37.4	41.9
Fisher Hamilton Safeaire	6’	5.21	4	2.0	2.25	41.7	46.9

Fume Hood Exhaust Flow & ACH

- Minimum Exhaust Flow
- VAV Response & Stability
- Duct Velocity
- ACH Method A & B



Laboratory Hoods	Hood Size	Exhaust Flow cfm	Duct Velocity fpm	ACHh (A)	ACHh (B)	Cfm / ft² (A)	Cfm / ft² (B)
Labconco Protector	6’	129	164	156	139	10.4	9.3
Labconco Protector	6’	135	172	224	200	10.9	9.7
Jamestown Isolator	5’	127	162	203	181	14.1	12.6
Kewaunee Supreme Air	5’	103	131	165	147	11.0	9.8
Fisher Hamilton Safeaire	6’	131	167	188	167	12.6	11.2
Fisher Hamilton Safeaire	6’	130	166	187	166	12.5	11.1

Fume Hood Containment

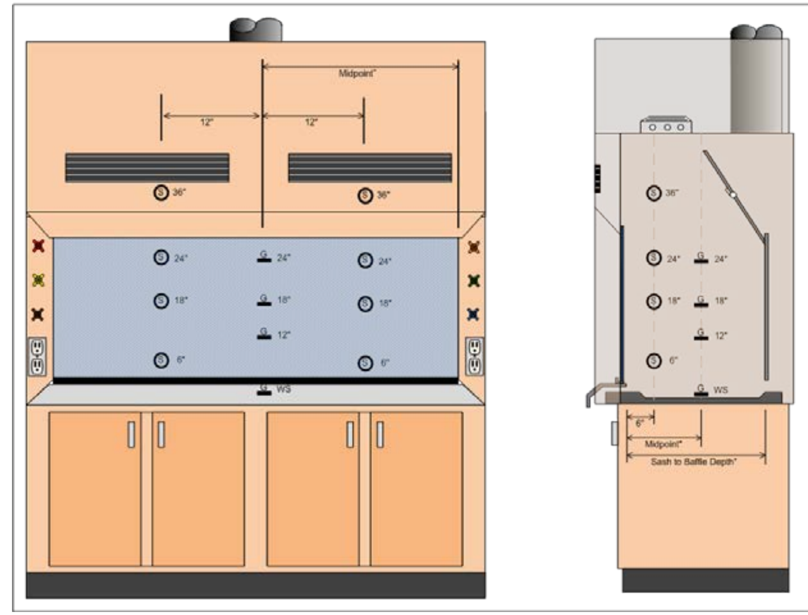
- ASHRAE 110 – Tracer Gas Tests
  - Sash Movement Effect Test (SME)
  - Perimeter Scan
- Nitrous Oxide
- Criteria: 4 lpm AU < 0.1 ppm

Laboratory Hoods	SME	Perim. Scan
Labconco Protector	BDL	BDL
Labconco Protector	0.03	BDL
Jamestown Isolator	BDL	BDL
Kewaunee Supreme Air	BDL	BDL
Fisher Hamilton Safeaire	BDL	BDL
Fisher Hamilton Safeaire	BDL	BDL

BDL = Below Detection Limit

Fume Hood Dilution Factor

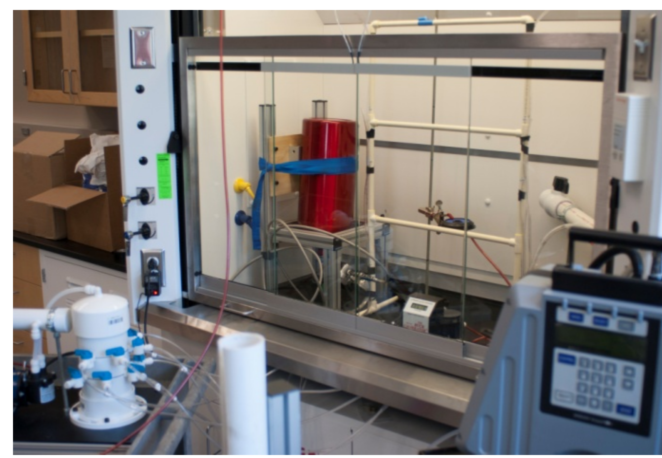
Laboratory Hoods	Exhaust Flow cfm	ACHh (A)	Dilution Factor
Labconco Protector	129	156	2.95
Labconco Protector	135	224	2.53
Jamestown Isolator	127	203	1.92
Kewaunee Supreme Air	103	165	6.6
Fisher Hamilton Safeaire	131	188	1.25
Fisher Hamilton Safeaire	130	187	2.7



$$Q' = Qe / Df$$

$$C\ lel = G / Q'$$

$$Clel = 25\%\ \text{of LEL}\ @1\%$$

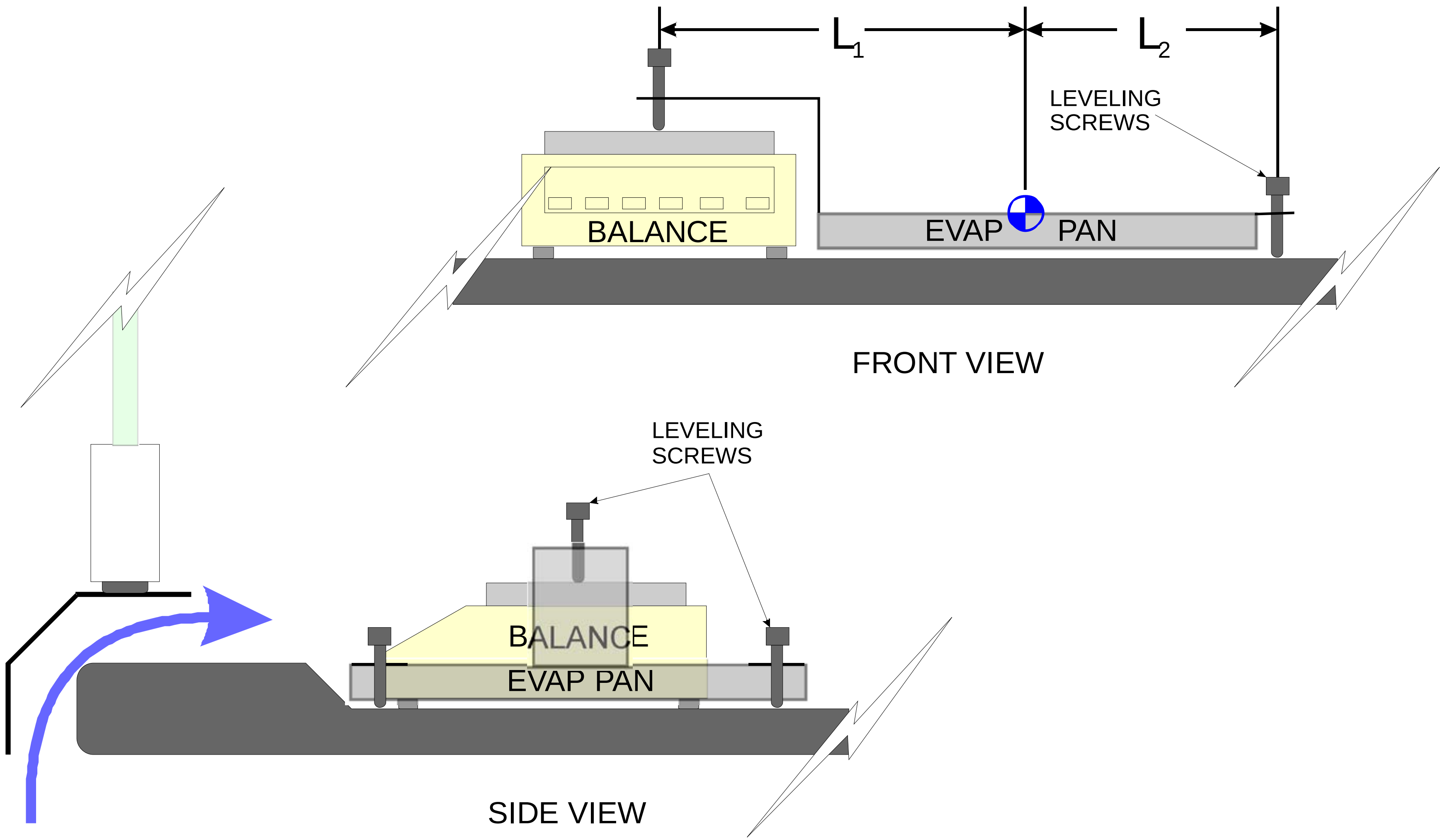


Test Results - Containment & Dilution

- Minimum Flow For Containment – Qmin
- Minimum ACH for Containment – ACHmin
- Fume Hood Dilution Factor - DF
- Maximum Flammable Gas Generation Rate at Qmin & ACHmin to Prevent Concentrations Less than 25% of LEL (1%) – Gmax
- Flow Reduction from Design @ 25 cfm/ft^2 of work surface

	6 ft - Labconco	5 ft - Jamestown	6 ft - Fisher Hamilton	5 ft - Kewaunee
Qmin - cfm	140	150	130	135
ACH Min	165	230	200	220
DF	3	3	3	6.6
Gmax - lpm	3.30	3.60	3.10	1.50
Flow Reduction - cfm	170	75	130	100

Solvent Evaporation Testing




Xylol
Xylene
Xileno
Toluene
0.00 g.
ON:OFF
CAL
MODE
SAMPLE
PRINT
RE-ZERO
FX-3000i

TESTING PROCEDURE

- **Level Evap Pan**
- **Measure Solvent ($M_{0\text{-}act}$)**
- **Zero Balance**
- **Pour Solvent Into Evap Pan**
- **Record Apparent Mass ($M_{0\text{-}bal}$)**
- **Activate Balance Transmit**
- **Close the Hood**
- **Computer reads the balance and does all the math…**

$$M_{t-act} = \frac{M_{0-act}}{M_{0-bal}} M_{t-bal}$$

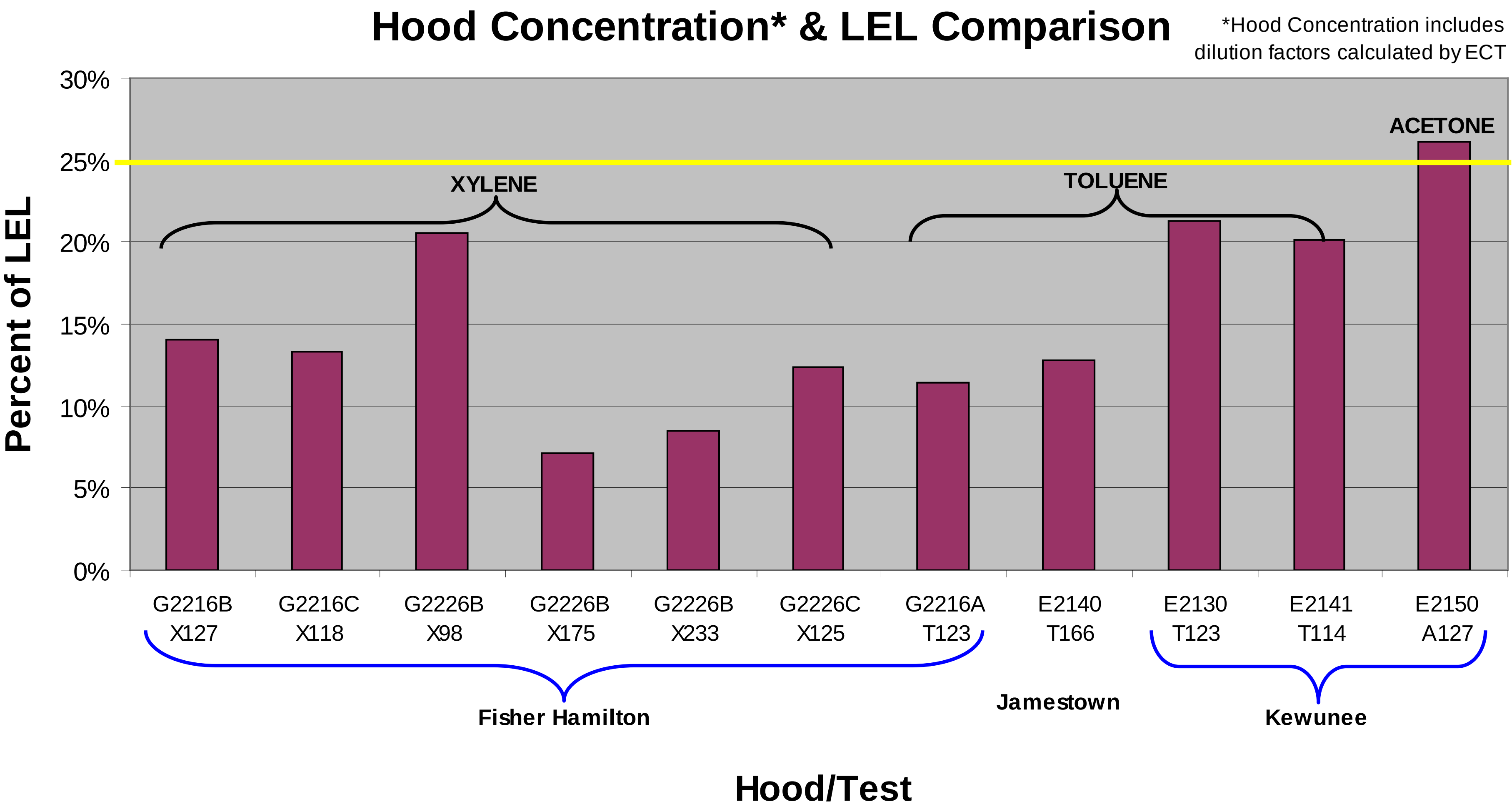
M_{t-act} = Mass at time t

M_{0-act} = Mass at time 0

M_{0-bal} = Balance Mass at time 0

M_{t-bal} = Balance Mass at time t

TESTING RESULTS



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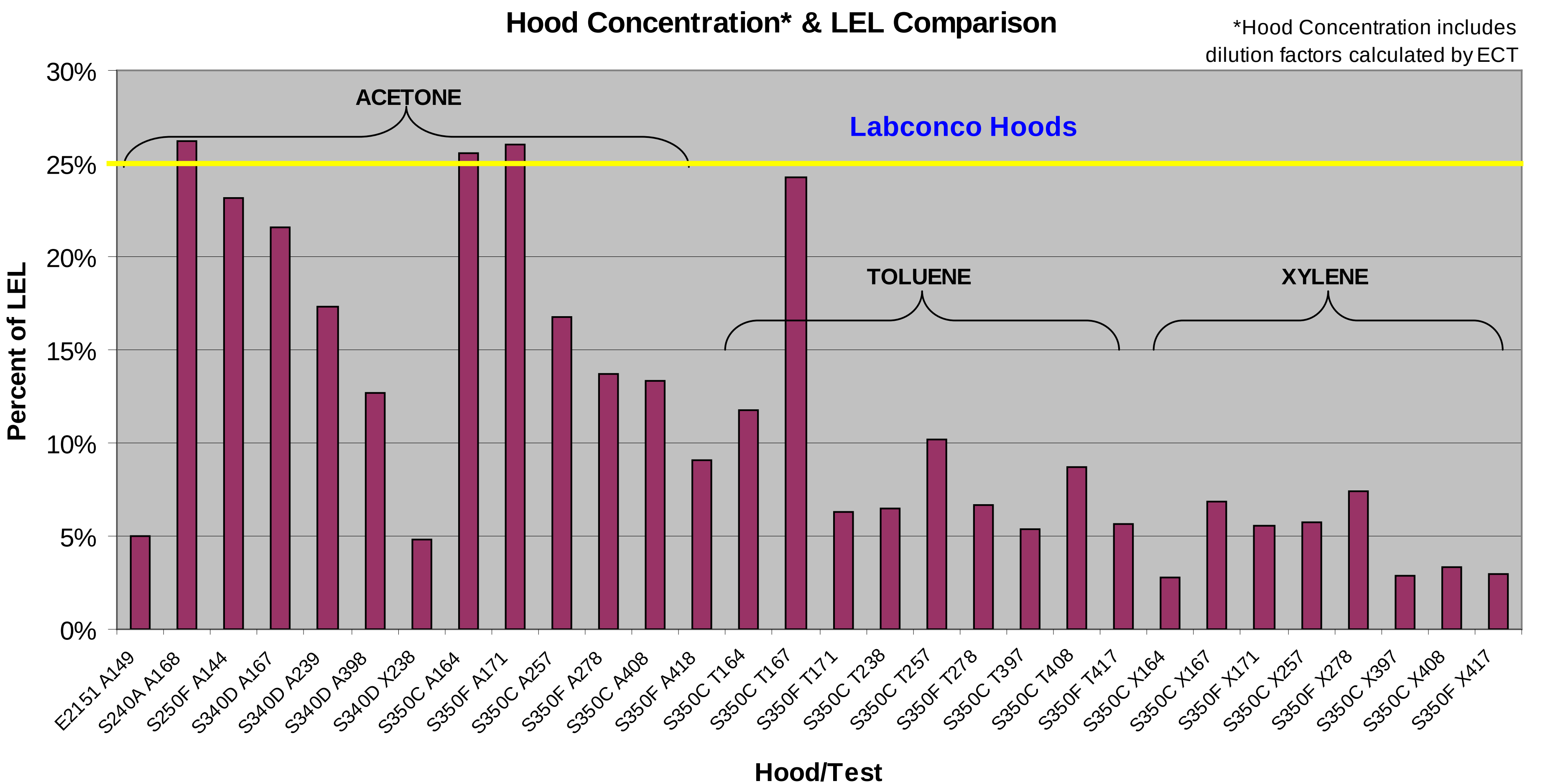
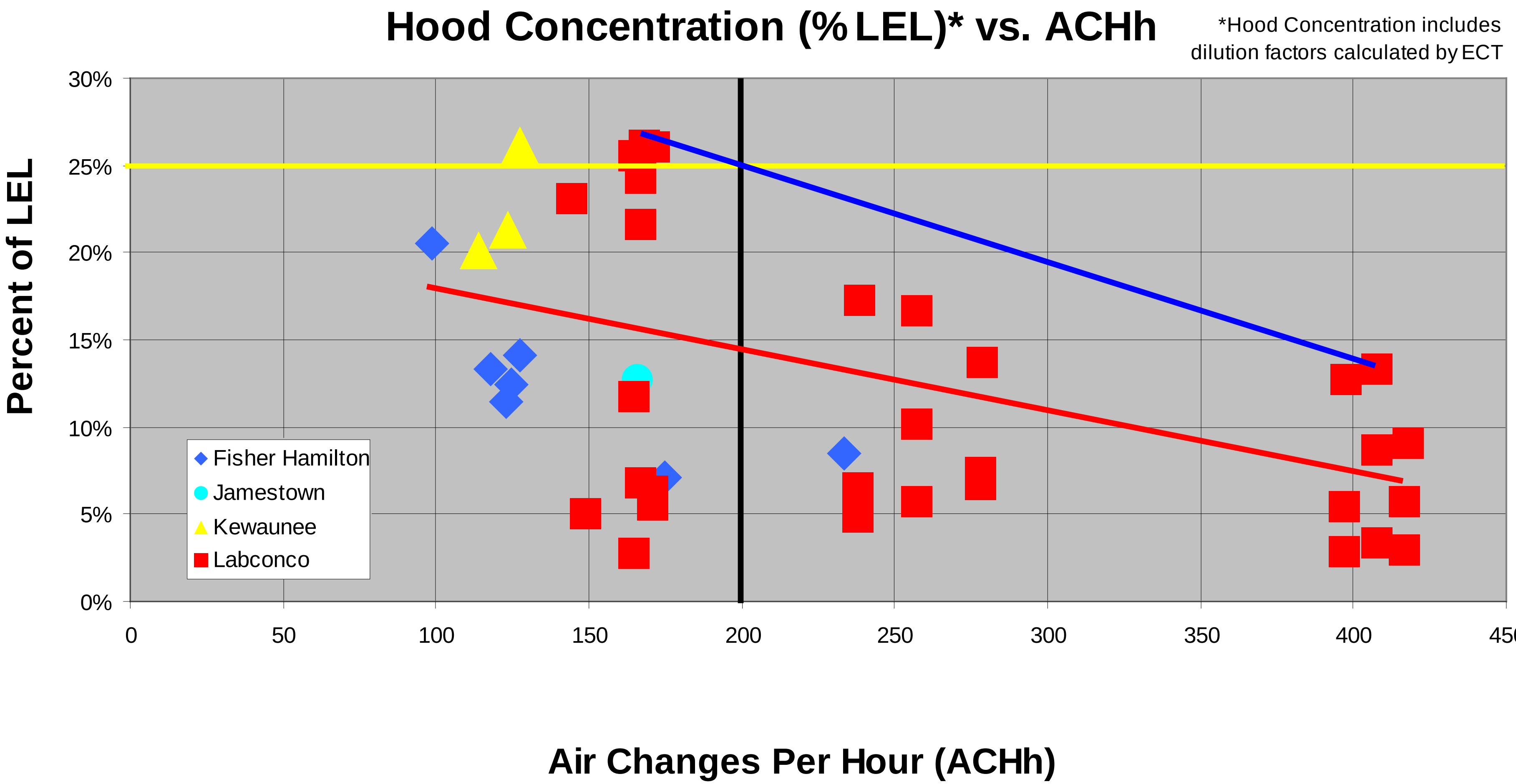


TESTING RESULTS



Conclusions and Recommendations

- Define your terms (A vs. B volume)
- Flow measurement is challenging
- UCI Hoods are capable of operating at lower minimum flow rates
- Recommend 200 – 250 ACHh
- Represents a significant cost/energy savings

Conclusions and Recommendations

Energy/Co$t Savings Potential

	Status Quo	Aggressive Model	Conservative Model
Hood Volume (ft^3)*	50		
Energy Cost ($/cfm•yr)	$7.50		
Minimum Flow (ACHh)	375	200	250
Minimum Flow (cfm)	313	167	208
Annual Cost	$2,344	$1,250	$1,563
Annual Savings	-	$1,094	$781

*6-ft. Fume Hood

END

QUESTIONS?

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