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Fume Hood Performance

It is all about containment and seeing is believing.

Friday, October 27, 2023

9:45a – 11:15a

Chip Albright
Fume Hood Certified, LLC

For 40 years I have been designing and manufacturing fume hoods. This has put me into thousands of labs around the world. I have seen the good, the bad, and the ugly. What I recognized was that the people working in front of a fume hood have no good way to know if that fume hood is working or not.



ASHRAE

LEED AP

Creative Solutions

SEFA MEMBER

My mission is to make labs safer, one fume hood at a time.

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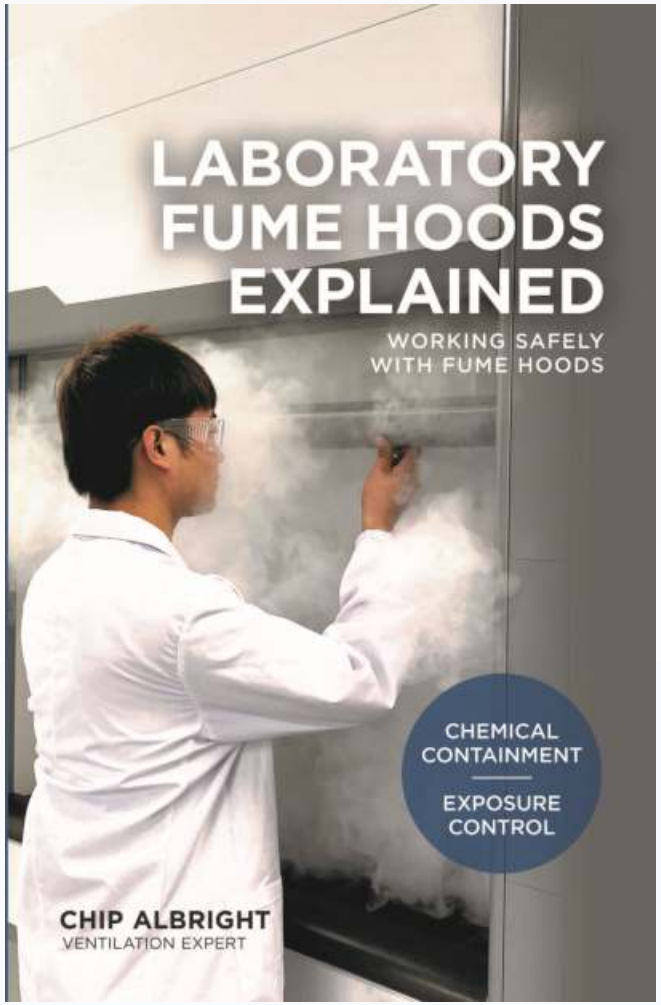
Learning Objectives

Explore the issues of containment and the users role in fume hood performance

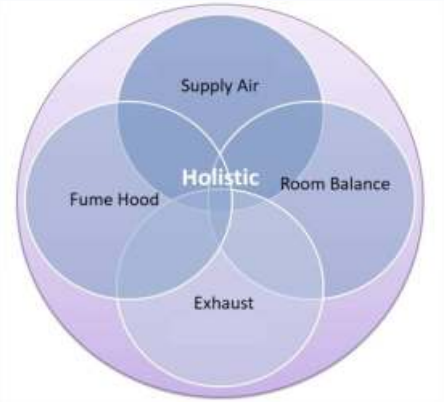
- Containment vs. Face Velocity – Why Face Velocity alone is not an indication of containment
- What comprises the laboratory ventilation system
- Why a hood with adequate face velocity could still have unsafe loss of containment
- Why Containment Testing is the only way to know if the hood is performing safely
- How the users work practices impact performance. We have to alert the users that their actions in and around the hood have an impact on performance.
- Why training is critical.
- The need for record keeping and the liabilities of testing
- The role of the fume hood tester
- An overview of standards that relate to fume hoods and testing



During my 40 plus years in the fume hood industry I have been, designing fume hoods, manufacturing fume hoods, installing fume hoods and testing fume hoods.

This extensive experience has given me a lot of insight into the subject matter.

In 2020 I wrote this book, which is a very holistic approach to laboratory ventilation; written in simple language that anyone can understand.



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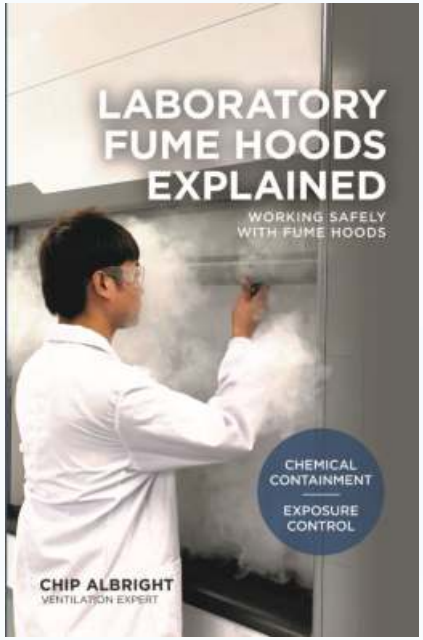

We converted the book…

No, not into a movie, which would be cool, but into a free online course

Check it out - we want everyone who is a fume hood stakeholder to have access to this information at no cost.

fumehoodonlinecourse.com



Today we are going to take a holistic look a fume hood performance

Unless you look at all these factors you will not have a safely performing fume hood

- Fume Hood And Lab Design Issues
- Laboratory Ventilation Systems
- User Training And Work Practices

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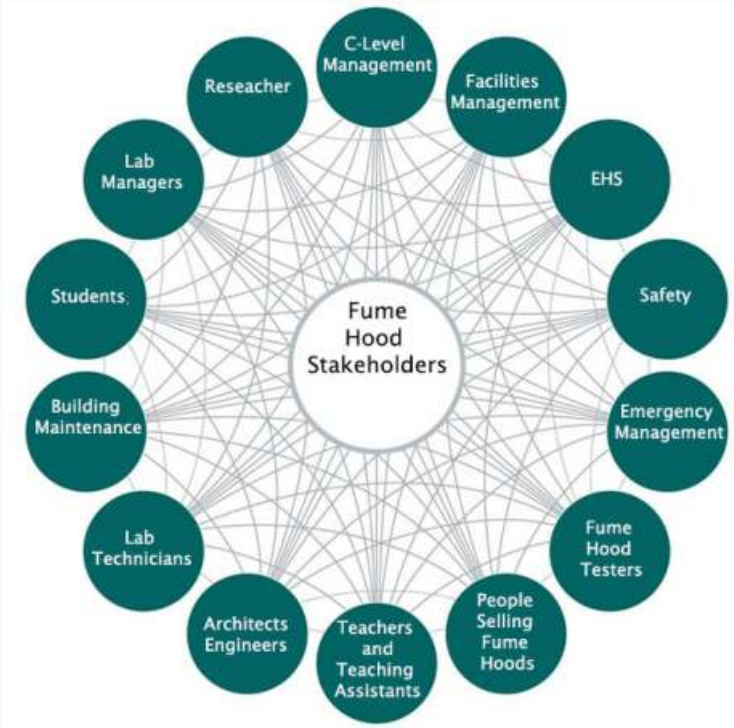

Making labs and fume hoods safer involves many stakeholders.

Each group has a role to play.

This is not a one size fits all situation. Each situation is unique, and different approaches are required to optimize the safety.

There is a movement towards "Risk –Based" safety strategies.

Not all labs have the same level of potential danger.

A more holistic view of fume safety is required.

The day of one size fits all is over. We have to look at each situation and consider the risk of exposure and the consequences of exposure.

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Fume hoods are often thought to be a standalone device, but not even the best fume hood in the world can do anything until it is connected to a properly designed and maintained laboratory ventilation system.

A fume hood is the interface between user and the mechanical ventilation system.



What does **"Is your fume hood working"** really mean?



Its about Containment Not Face Velocity

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What does a properly functioning fume hood do?

- **Capture**

The first task for a fume hood is to capture the bad stuff inside the fume chamber.

- **Contain**

After the chemicals have been captured, the hood's primary function is to contain them in the fume chamber until they can be diluted and exhausted.

- **Dilute**

Using room air, the fume hood should dilute the chemicals to a safe level so they can safely be exhausted outside.

- **Exhaust**

Finally, the fume hood is designed to exhaust the chemicals, getting them outside and away from people and at safe concentrations.

The principle function of a fume hood is to capture and contain potentially hazardous chemicals within the fume chamber and then exhaust them.

A fume hood is an **Exposure Control Device**

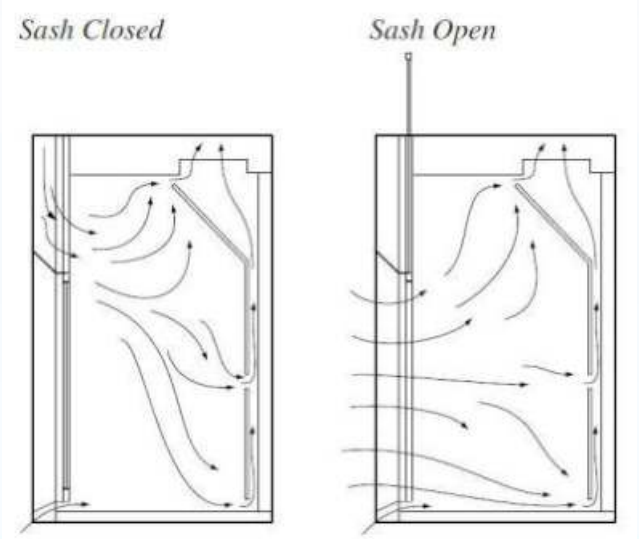
When we ask, **"Is your fume hood working?"** we are asking if it is capturing and containing. Loss of containment and the escape of fugitive substances into the room air is a failure of the hood to safely perform.

Velocity and Turbulence

We, as the fume hood industry, have done users a disservice with a strong emphasis on face velocity

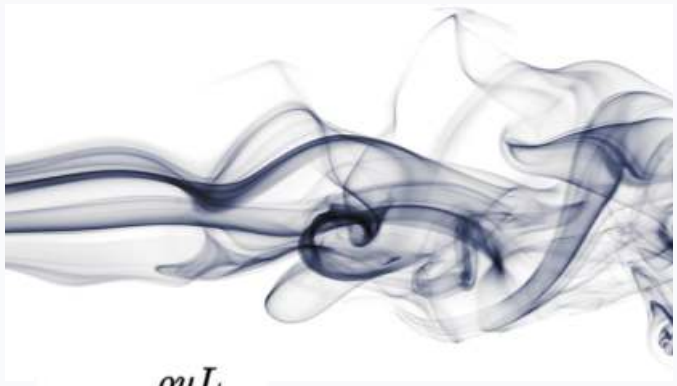


This airflow diagram is very misleading. The airflow in a fume hood is very turbulent

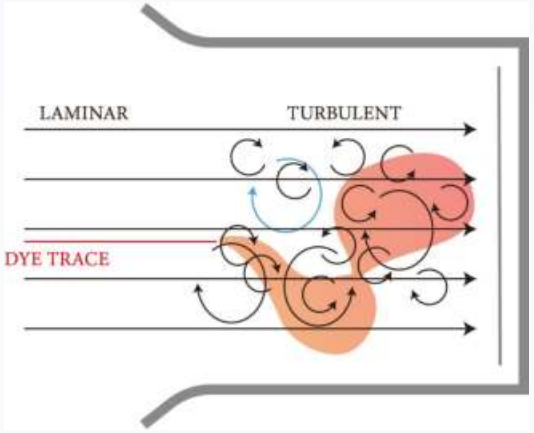


Based on the Reynolds Number most fume hoods are very turbulent

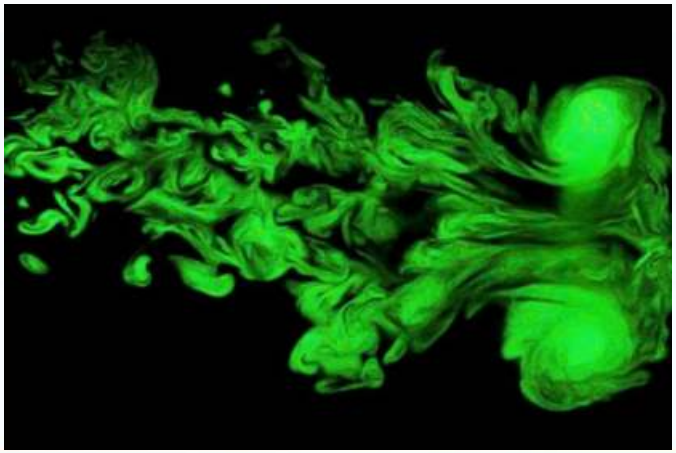




$$Re = \frac{\rho u L}{\mu}$$



the flow is considered to be turbulent when Re > 3500





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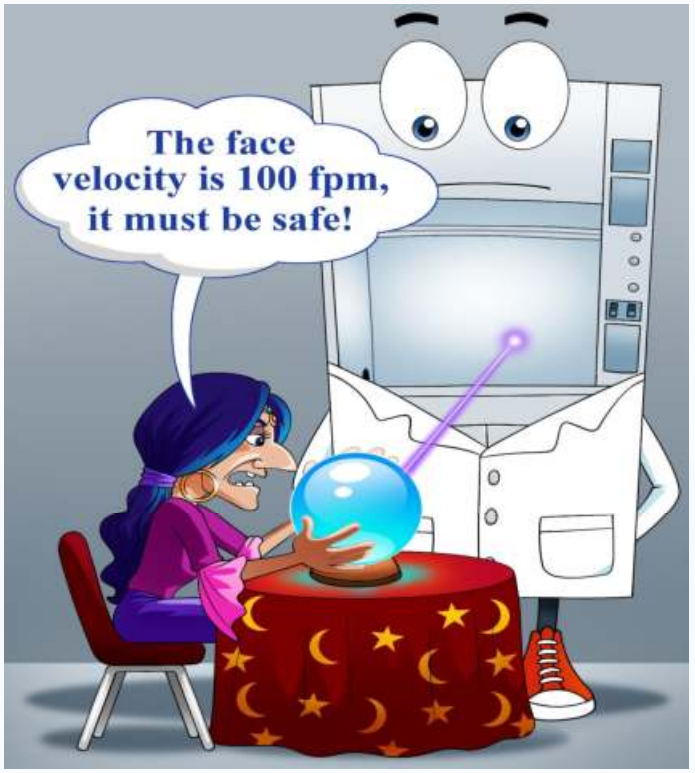
Something we can relate to is a roaring campfire





The flames dance around and the smoke is influenced by the wind. Just like fume hoods, most fires are very turbulent. If you took a photo every 30 seconds you would see very different images. This image like much testing is just a **snapshot** of what is happening over time.

About 20 years ago, **The Myth of Face Velocities** in Fume Hoods was published. Yet today, little has changed. The misunderstanding about using face velocity to judge containment has actually grown. (Reference *The Significance of Laboratory Fume Hood Face Velocities,* Caoimhín P. Connell)



www.forensic-applications.com/hoods/face.html

FHC FUME HOOD CERTIFIED



The Myth of Face Velocity Reloaded

January 29, 2023, Chip Albright

About 20 years ago, **The Myth of Face Velocities** in Fume Hoods was published. Yet today, little has changed. The misunderstanding about using face velocity to judge containment has actually grown.

The complete article can be downloaded at www.fumehoodcertified.com/myth

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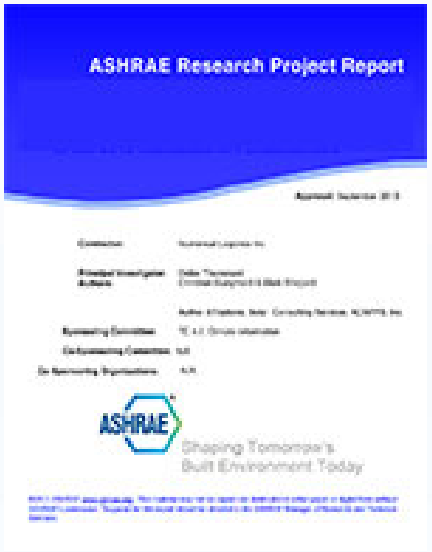
The subject of the relationship, or lack of relationship, between Face Velocity and Containment is now coming around again for public discussion. In the June 2022 ASHRAE Journal, a technical article was published on this subject.

"*Factors Influencing Face Velocity for Fume Hood Containment*" by Kang Chen.


TECHNICAL FEATURE

Factors Influencing Face Velocity for Fume Hood Containment



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Many lab personnel erroneously believe that face velocities are an indication of how well a fume hood works. In other words, many believe that the prescribed face velocity equals containment.

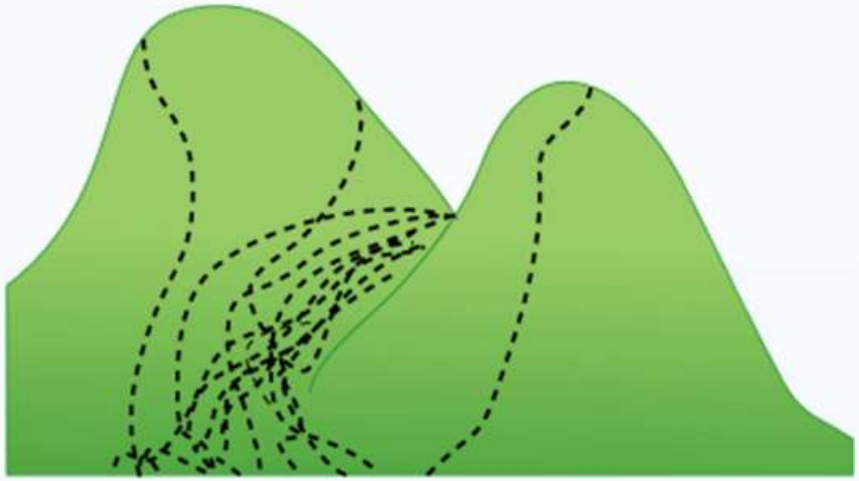
In this video we have a face velocity between 90 and 102 fpm and yet we have a massive loss of containment.

There is no direct correlation between average face velocity and containment.

Given **air is a fluid**, much like water, air will flow from high pressure areas to low pressure areas much like water flows downhill.. Face Velocity just tells us how fast the air is flowing.



Air is lazy, it is going to take the path of least resistance.



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Let's examine face velocity more holistically:

Considering the fact that air is a fluid; it follows the same physical laws (fluid dynamics) as does water. Just like water in a river, it can be calm or turbulent. While the water flowing downstream has a speed, it is the combination of speed and underwater obstacles that create turbulence and determines if we have a smooth flowing river or turbulent rapids.



VS



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The conversation needs to change
from Face Velocity to Containment

When a hood isn't properly containing, it isn't working, regardless of the face velocity

The majority of hoods that failed to contain at acceptable levels, have an acceptable average face velocity.



I have been involved in the testing of countless hood over the past 40 years.

I would estimate that at least 75% of those with poor containment, had acceptable average face velocities (80fpm – 120fpm).

Average Face Velocity is a poor metric for determining safe fume hood performance.

"Although there is a growing consensus that face velocity cannot be applied as a sole evaluation indicator of fume hood containment performance…"



How did we get here?

Differential Pressure is more indictive of a fume hood's ability to contain, but because of the turbulence and the ever changing pressure, it is difficult for us to give user guidance on whether the hood is working or not.

In the mid-1990s, the first LED Fume Hood Airflow Monitors were introduced. At that time, there were more one-hood/one-fan installations than manifolded installations. The primary purpose of the monitor was to indicate if the fan was operating and there was any Face Velocity. It was not intended as an indication of safety (containment).

Why does such a misunderstanding exist today?

For the last 20 plus years, Airflow Monitors have become a standard on most fume hoods. While this is better than nothing, it became assumed if the face velocity was in an acceptable range of 80fpm -120fmp that the hood was safe. Since there was good money in selling and servicing fume hood monitors, the industry allowed the misconception about face velocity and safety to continue. As more knowledge is gained on hood performance, the whole purpose of the monitor should be reevaluated.

Magnehelic® Gage

Differential Pressure Gage



Face Velocity Monitors











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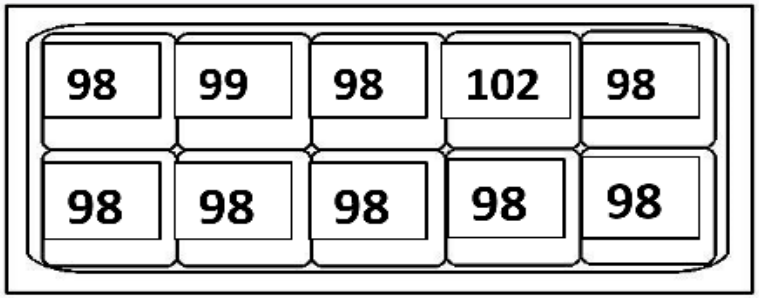
What does Average Face Velocity tell us?

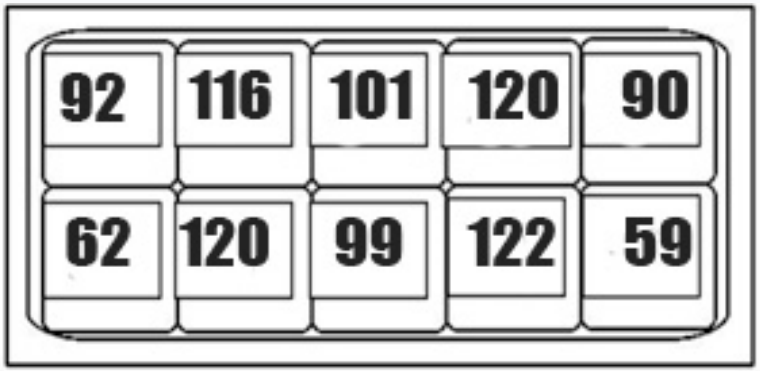


Let's do a deep dive into Face Velocity.

Let's look at a couple of face velocity profiles:



98 ft per minute average



98 ft per minute average

Which one of these is performing better?

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Fume Hood "A"

Half/Design Opening

59	104	88	114	60
52	92	74	102	56

Average Face Velocity: 80

Fume Hood "B"

Half/Design Opening

80	82	84	82	82
79	81	76	79	78

Average Face Velocity: 80

Both hood "A" and "B" have an average face velocity of 80 fpm, but which one will perform better?

Fume Hood "A"

Half/Design Opening

59	104	88	114	60
52	92	74	102	56

Average Face Velocity	80

Fume Hood "B"

Half/Design Opening

80	82	84	82	82
79	81	76	79	78

Average Face Velocity	80

Hood "A", the airflow is very turbulent and would likely fail containment testing.

Whereas "B", is much more laminar and will have more robust containment.

If you do no other testing,
you should perform the best face velocity profile you can.
The results will give you a strong indication of containment.

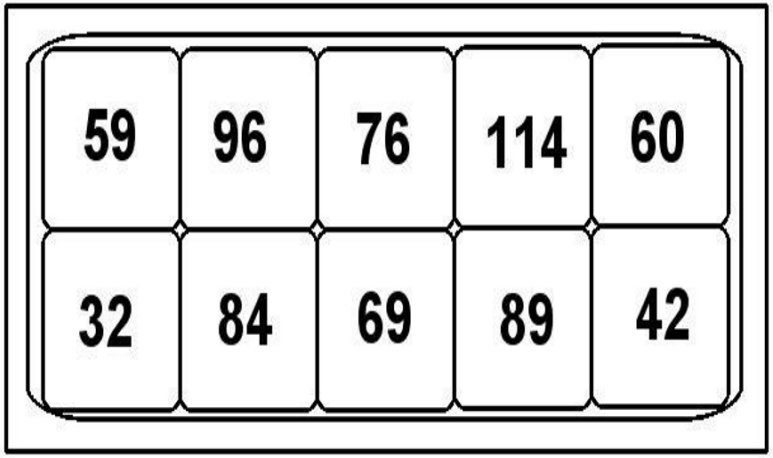
Half/Design Opening

80	82	84	82	82
79	81	76	79	78

Average Face Velocity		80
Acceptable Range - +10% -10%	76	84
Higest Reading		84
Lowest Reading		76

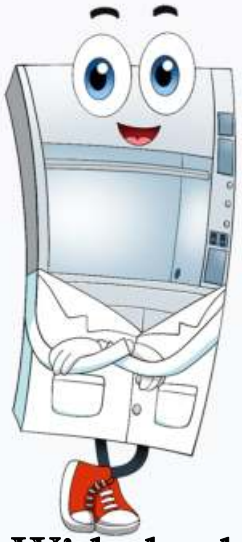
An acceptable range for a face velocity profile is +10% to -10% of the average.
As the numbers become more similar to the average the more laminar the flow will be.

When the face velocity profile shows a lot of variation, it is an indication of turbulence.



From my experience, this hood is likely not to perform well on a containment test.

There is a direct relationship between turbulence and containment.
The more turbulence, the less containment.



The real question is, "Is the hood performing safely?"

From this face velocity profile can you certify the hood is containing?

59	96	76	114	60
32	84	69	89	42

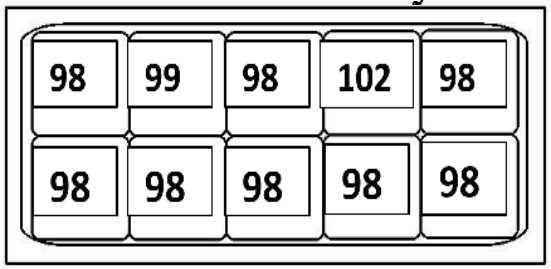
With the data from this profile, how can you possibly believe that a single point average velocity is telling you anything?

If I were testing this hood and got these numbers, my next conversation would be with the **TAB** (Test, Adjust, Balance) people. The problem is clearly with the room conditions.

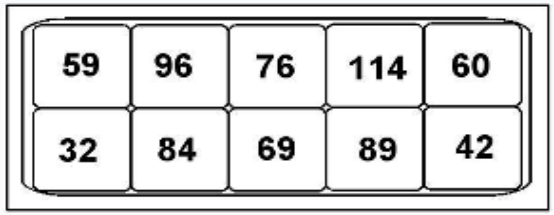
While many people know how to perform the ASHRAE 110 Testing Protocol, few really understand the significance of the data and how to use it to improve performance.

Troubleshooting is a critical part of testing. When a fume hood is not performing well, the tester should be able to offer actionable advice on how to improve performance.

What other ways can we use the ASHRAE 110 Face Velocity Profile?



This profile is from a fume hood test room **(As Manufactured - AM)** with near perfect room conditions. Note the consistency of the velocities.

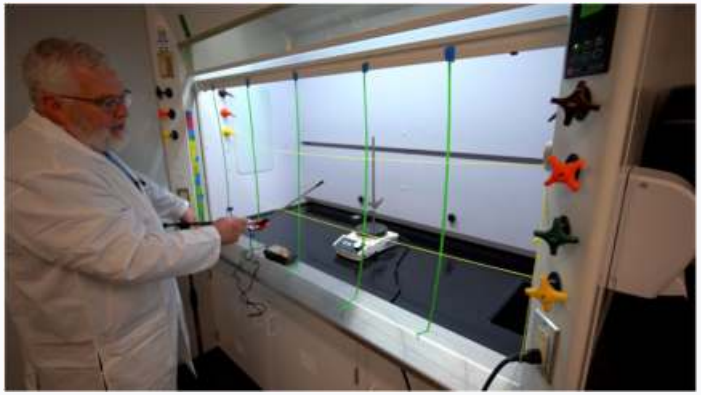


This is the same hood's profile but tested **As Installed (AI).** The numbers are nowhere near the same. What can be determined from this AI profile versus the AM profile above?

The hood didn't change, so the differences in the numbers indicate problems between the interface between the hood and the room conditions.

If you are doing AI Testing, you should have a copy of the AM report as a reference.

Face Velocity Profile: *What are we testing and why?*



There is a huge difference between an average face velocity and a face velocity profile.

The average face velocity is just an indication to how fast air is passing through the sash opening. But has little to do with containment. In fact, the reading is not directional. A hotwire does not understand direction.

A face velocity profile is intended to help us visualize the amount of turbulence. This turbulence is a primary cause of loss of containment



If you wanted to measure the velocity and direction of the flow, where would you take your reading?

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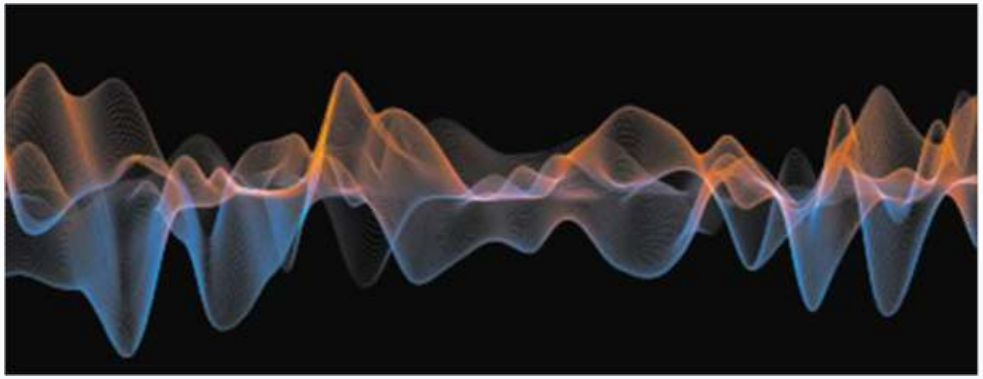
Telegraphing of turbulence and instability

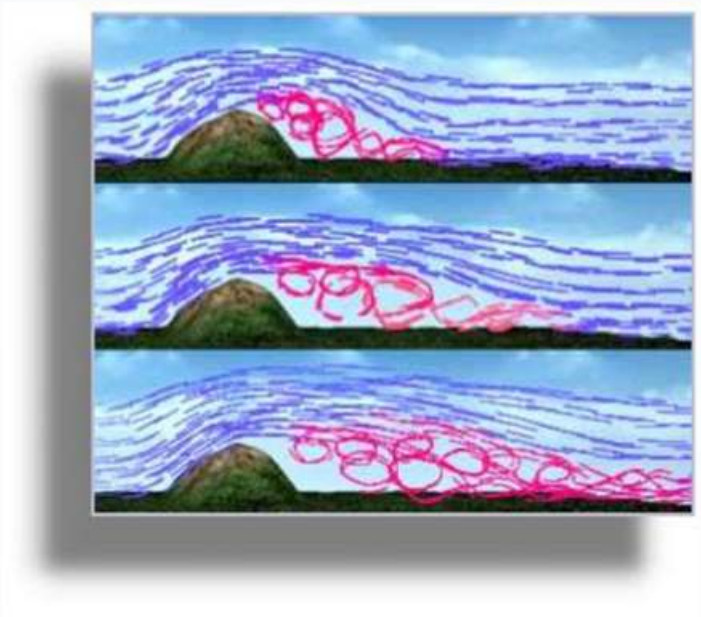
When there is excessive turbulence and instability in the duct system, those fluctuations will telegraph into the hood's plenum and through the hood into the face velocity profile.

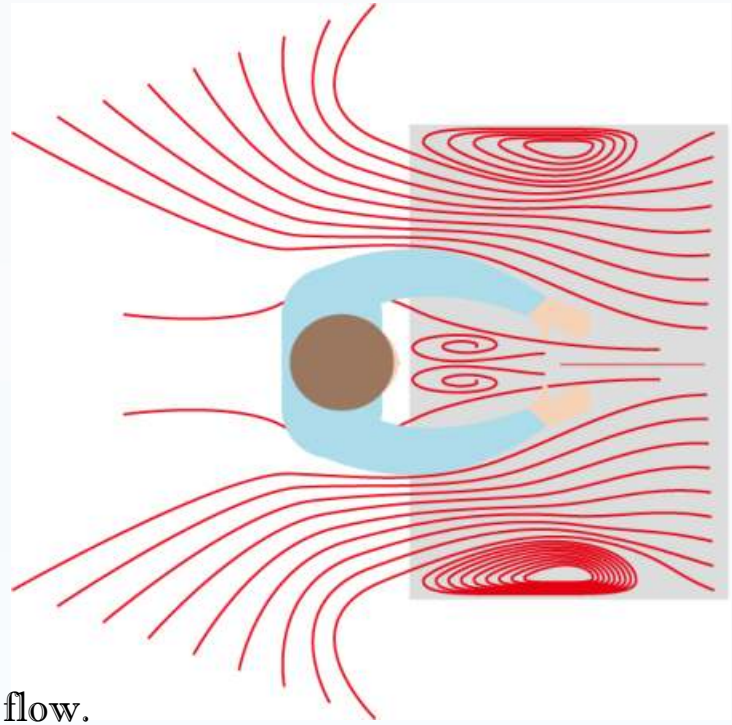


The instability of room air supply not balanced with exhaust, cross drafts, temperature gradients, and a door opening and closing are just a few examples of what can cause instability in a room. Any disturbance or instability in front of the hood will also telegraph into the face velocity profile.

Turbulence is one of the main causes of loss of containment

Turbulence (or turbulent flow) is characterized by chaotic, random property changes and rapid variation of pressure and velocity in space and time. In turbulent flow, unsteady vortices appear on many scales and interact with each other.

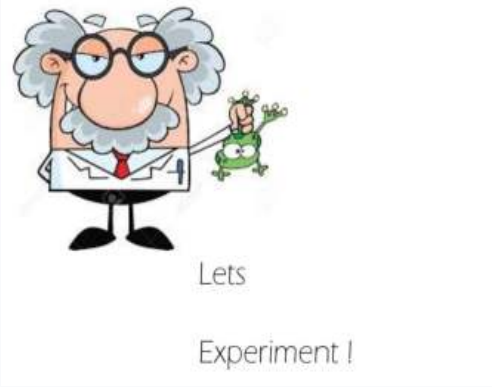




A flow that is not turbulent is known as laminar flow.



What you are seeing here is the vortex is becoming unstable (turbulence), you can see it collapse causing loss of containment.



Since we are talking about science, let's do a little experiment.

With the sash at operating height, determine a single 12" x 12" grid in the center of the sash opening and place two probes (one positioned vertically and one positioned horizontally) within the grid. Connect both probes to our data logger. We will capture readings from each probe at the rate of one per second for a full 24 hours.

During this time, normal lab activities continue; people walk by, lab doors open and close many times, and other hoods have their sashes opened and closed as people work.

After 24 hours of recording, we have 86,400 data points from each probe. Upon analysis, we determine the average velocity is 96 fpm, but we have readings that deviate as much as 40 fpm from the average. Possibly more notable is the fact that the reading is constantly changing. Any single face velocity reading is just a snapshot.

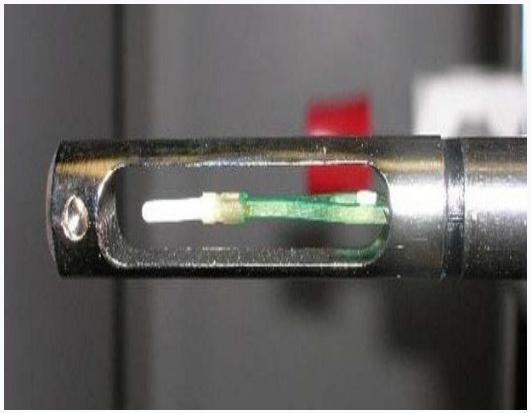


In this photo of an everyday interstate, we cannot determine the speed of the traffic. It is just a snapshot of the speeding vehicles. An average face velocity reading is not much different. Average face velocity readings are a snapshot at the moment but do little to show us performance over time.

Snapshots of dynamic processes are not good indicators of what is happening over time.

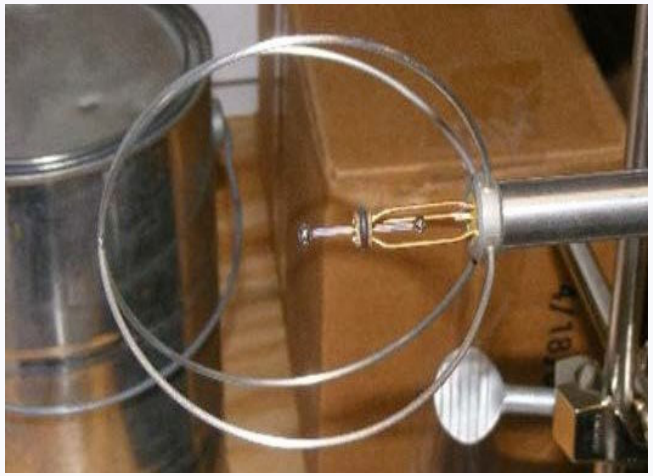
But when it comes to fume hood face velocity, getting good data becomes even more difficult.

This is a typical probe. The hot wire sensor is shielded with a protective shroud to minimize damage.



But the shield can cause turbulence when the airflow is coming in from a high or low angle. So getting a good reading can be difficult because of the turbulence just beyond the probe caused by the air entering the from steep angles creates resistance that distorts the velocity reading.

This photo shows a research grade omnidirectional probe.



With this probe, we can capture 10 readings per second. We will also reduce the grid size to a maximum of 6 inches square. With these changes, the face velocity profile will look very different. This is similar to the testing protocol developed by the NIH (National Institutes of Health). This profile will better illustrate the turbulence present at the sash opening and will be a very good predictor of containment.

The limitations of hot wire anemometer:





- Hot wires don't detect the direction of the airflow.
- Shrouds cause turbulence when the air is not flowing directly into it.
- Only measures accurately when air is coming in parallel with the shroud opening.

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What are the take aways about face velocity?

- Average face velocity is indictive of air moment and has no direct relationship to containment and safe hood performance.

- Face velocity readings are merely a snapshot, they do not provide a good indication of what is happening over time.

- Simple face velocity readings are meaningless as a basis of determining a fume hood's safe performance level.

- Face velocities are a useful diagnostic indicator in the event that the hood does not perform well, but face velocity should not be used as the method of determining how well a hood contains.

- Face velocity is only one component of containment.

- In the ASHRAE 110 Fume Hood Testing protocol, we perform a simple face velocity profile.

- A face velocity profile is a more forensic evaluation of face velocity. This profile reflects the level of turbulence across the face of the hood.

- Average face velocity alone is just an indication that air is moving through the hood.

There is a group of testers that the more elite testers call **“lick’em stick’em”** testers.



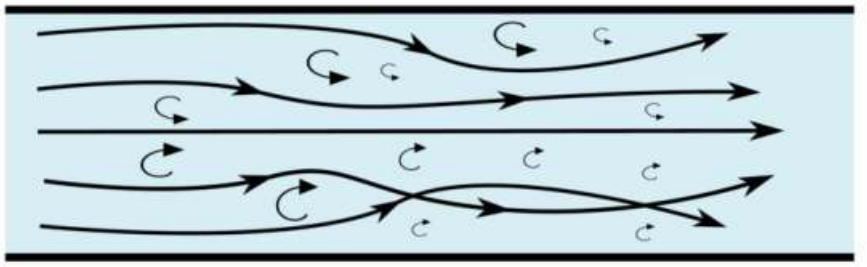
These testers come in an do a couple face velocity readings, maybe use a little local smoke, and then they slap a safety certificate label on the hood saying the hood is safe.

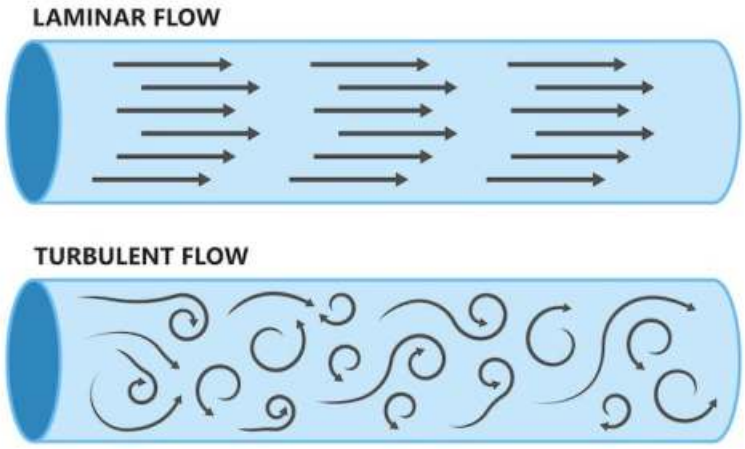
This type of testing is basically useless and is doing the hood users a disservice.

Turbulence

Given the impact turbulence has on containment, we need to focus much more on turbulence both internal and external to the hood









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The surfaces that define the sash opening act very similar to an airplane wing.

This is what turbulence looks like just inside the opening.



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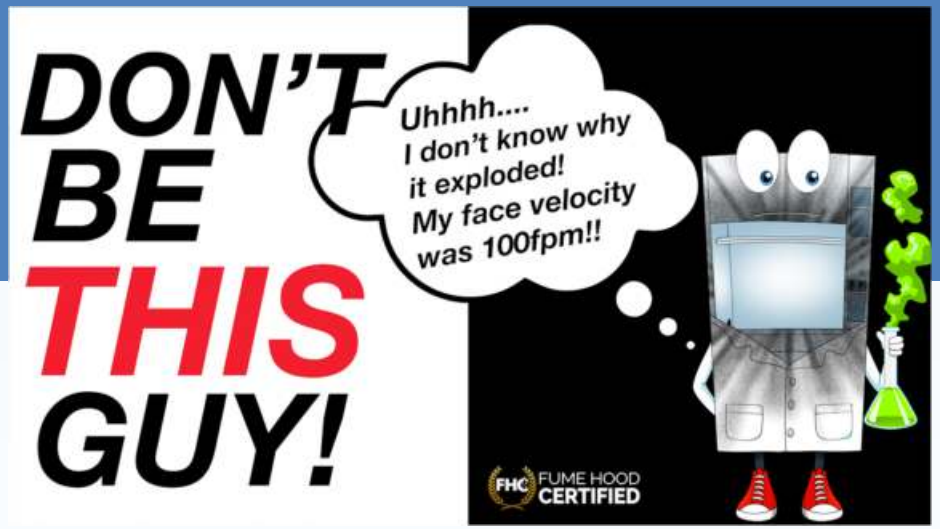
Common Misconception

Face velocity alone is not an indication of containment

Over 70% of fume hoods that are failing to safely contain have an acceptable face velocity





Containment is all about turbulence in and around the hood.









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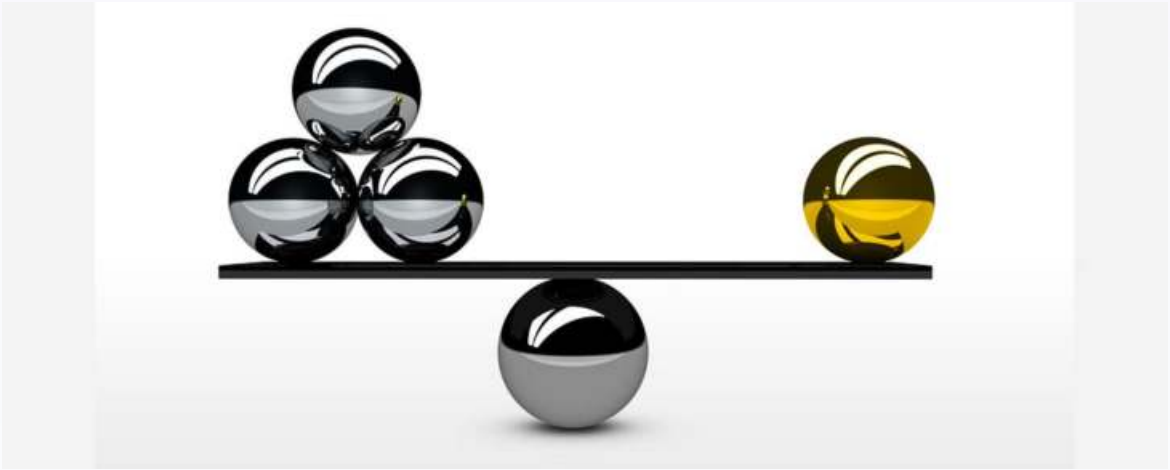
Safe Hoods have to manage the turbulence in and around them



Turbulence is the primary cause of loss of containment.

Safe hood = containment at safe levels



All hoods suffer loss of containment at some point

In determining risk we need to consider:

- How often does the hood fail to contain
- What is the magnitude of the leakage
- What are the fugitive chemical that are being used (how toxic are the chemicals?)
- How long does the user working at the hood

What comprises the laboratory ventilation system?

Common Misconception

Fume hoods are not stand alone devices.

Much like a fire sprinkler system, all you normally see is the sprinkler head in the ceiling of the lab, but it does nothing without all the pipes and pumps.









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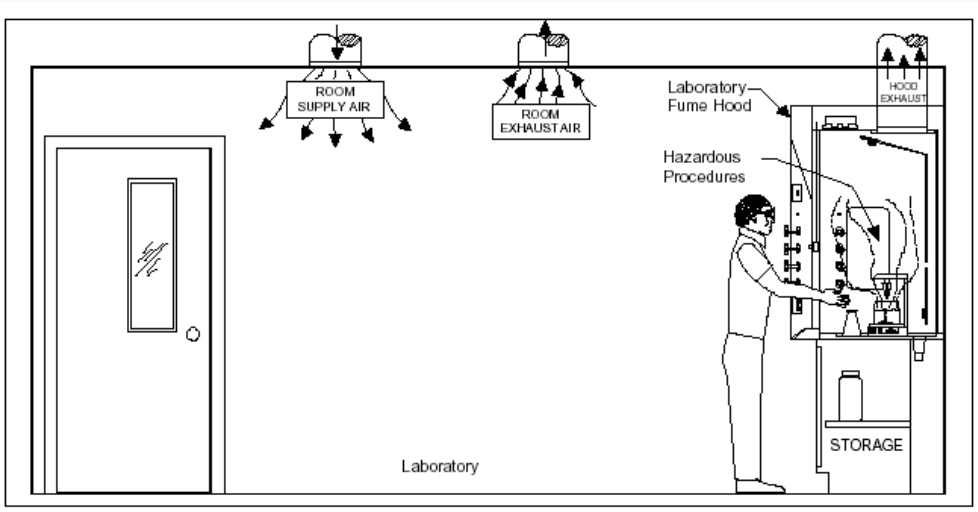
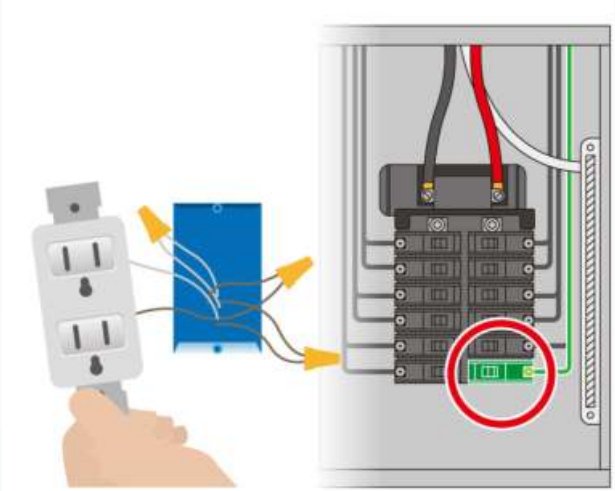
A Laboratory Ventilation system is very complex, similar to an electrical system.





The fume hood is the interface between the user and the laboratory ventilation system.

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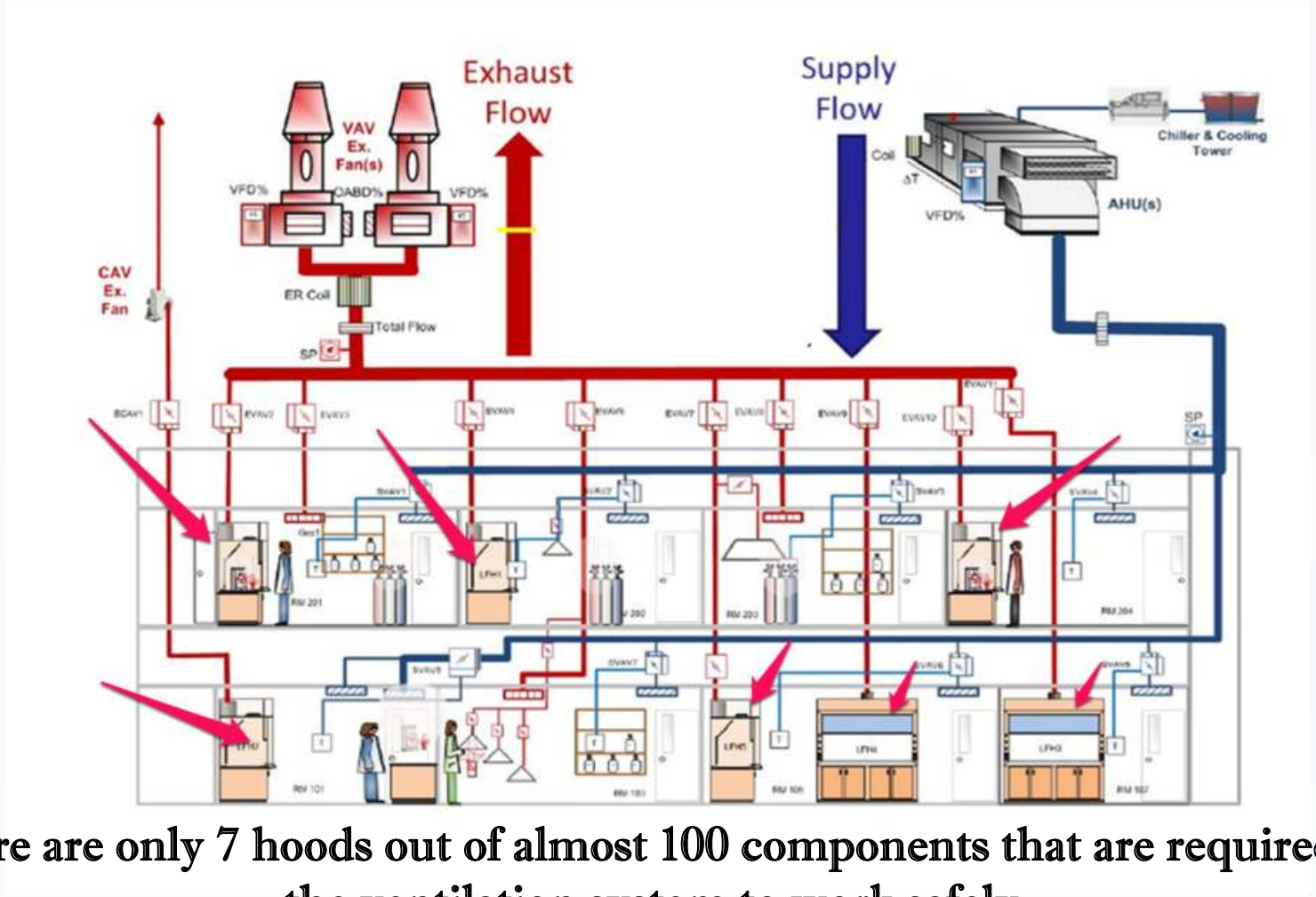
A fume hood is just a small part of the whole laboratory ventilation system.



There are only 7 hoods out of almost 100 components that are required for the ventilation system to work safely.

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Look at what it takes to make those fume hoods work:



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ANSI/AIHA® Z9.5–2012

5.4.6 Exhaust Stack Discharge

Minimum 10 feet above the roof.

Minimum 3000 fpm Discharge Velocity.





Without a properly designed exhaust there are more problems.

Z9.5 -2022 changes this. You will want to check it out.

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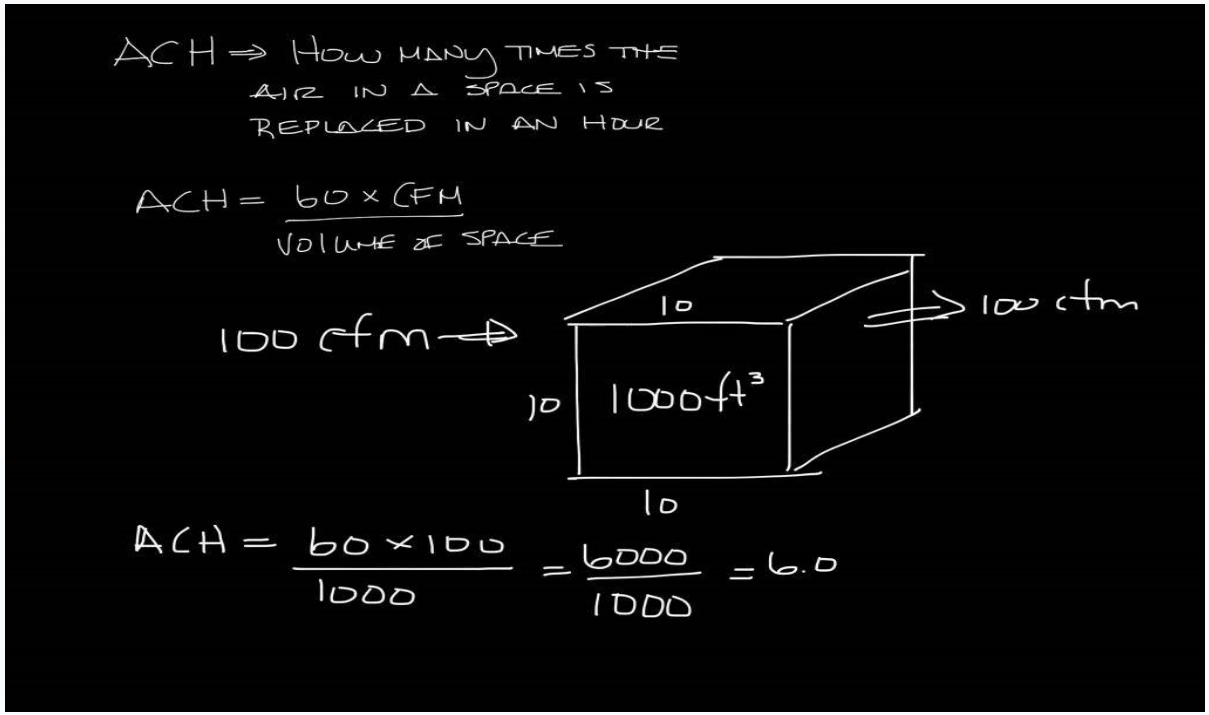
These are actually fume hood exhaust blowers, how well do you think they work?



When we slow down the face velocity and reduce room air changes per hour (ACH) and there is potential for other problems! The most significant is the impact on indoor air quality.

When there are not enough air changes per hour (ACH) the lab air becomes polluted.



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The fume hood is a primary containment device.



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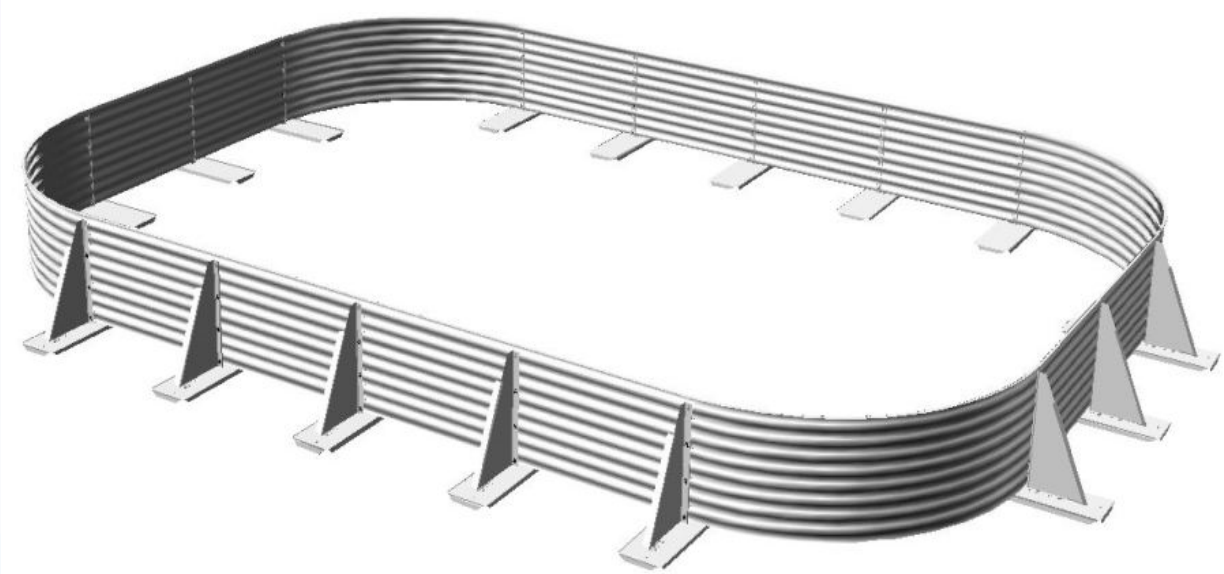
When fugitive chemicals escape as a result of loss of containment, they pollute the lab.



The room itself is a secondary containment device.



As the number of ACH is decreased, there may not be enough fresh air to dilute these fugitive chemical to a safe level.

Like a prison, labs should have multiple levels of security to manage fugitive chemicals.



A poor laboratory ventilation system is like a prison without a fence



Can you smell chemicals in the lab?

What you can't see or smell can hurt you.

Unlike biological exposure, chemical exposure can take years to present as a disease

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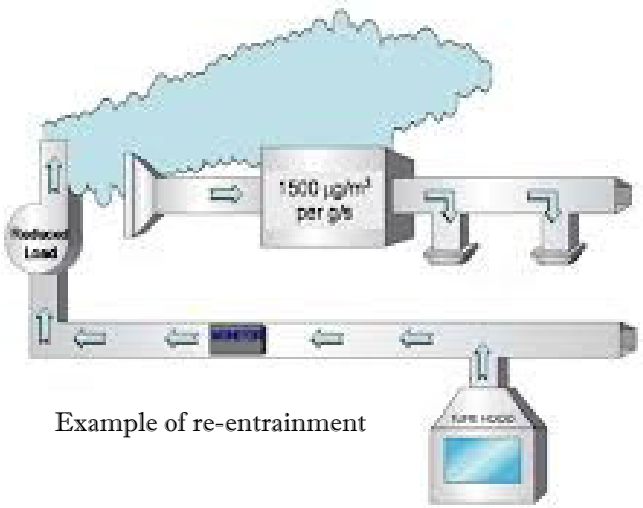
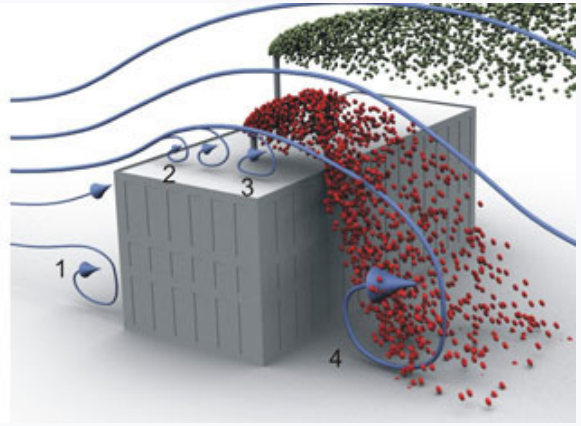
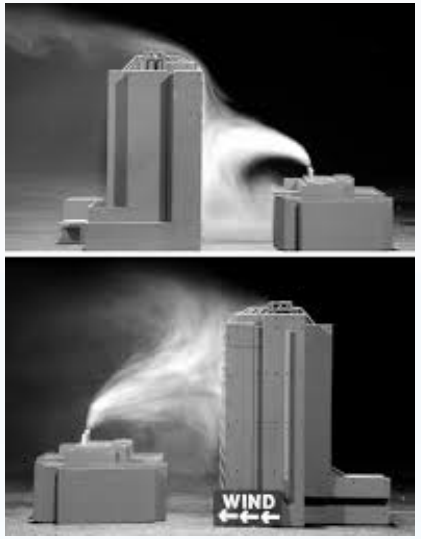
Are you poisoning the lab building occupants with chemical exhaust?



Example of re-entrainment





Re-entrainment does not just pollute the laboratory, but the whole building.

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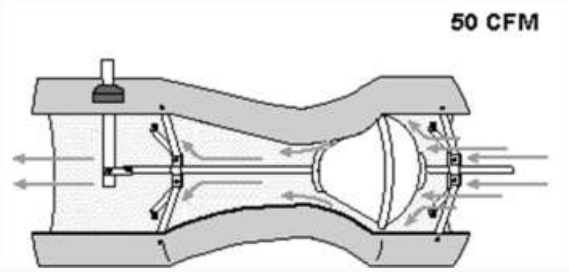
System Responsiveness

When room conditions are not constant and stable, the hood is at the greatest risk of loss of containment.

These periods of instability can be caused by:

- Lag Time in Hood VAV System
- Lag Time in Room VAV System
- Room and Hood DP in constant state of flux

VAV response time is a big factor in containment:



The response time or lag time in a VAV system adjusting can be a major cause in loss of containment

Slow System Response Time = Loss of Containment

ASHRAE 110 has a VAV Response Time Test

What Does a Fume Hood Need to Perform Well?

- Adequate Supply Air from Room to maintain stable Face Velocity
- Stable Differential Pressure Relation between the Hood chamber, the Room and the Corridor
- Smooth Air Flow In and Around the Fume Hood



This a real example of where system design and performance and user safety intersect.

Do you think this design is safe?

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User Safety

Training is Critical

- The best designed lab ventilation system can yield unsafe performance when users are performing activities outside the design envelope.
- Overloading the hood, blocking the baffles, and/or larger objects directly on the work surfaces cause turbulence and irregular airflow.
- How the user moves in and around the hood.
- The sash position determined by the user.

The user is part of the Laboratory Ventilation System,
Usually because of lack of training, Users cause 25% of the performance failures (loss of containment).



If we are not concerned about user safety; why even operate the hoods in the first place?

If we are truly concerned about user safety, how can you not test the hoods and train the users?

How do user actions influence containment?

- Rapid movements in and around the hood.
- Overloading the hood with obstructions that disrupt airflow.
- Pedestrian traffic around the hood.
- Using the hood for storage.
- Using heat sources that create temperature gradients and disrupt airflow.
- Working with the sash full open.
- Not properly managing violent reactions.

I have a fume hood, doesn't it protect me?



Having a fume hood and having one that is performing safely are two totally different things.

When user don't follow good work practices bad things can happen:











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- Users need to understand the risks and hazards and what they can do to minimize the likelihood of an incident.

- The best laboratory ventilation system in the world may perform at unsafe levels because of the users work practices.

- The tester is the one who should understand the performance of the system, and who often has direct contact with the users. This is why training is a critical role of the tester.

A different kind of containment

Fume hoods can also provide passive protection from physical threats.

The sash is a **"safety shield"** - a barrier between the user and the hazards

The sash protects users from hazards such as:

- Chemical splashes
- Sprays
- Runaway experiments
- Small fires
- Minor explosions

If you are hood user, the sash is your best friend!

Fires and Explosions

Lab incidents involving fires and explosions in fume hoods are all too common. This is where the fume hood becomes a PPE and the sash offers you the most protection.



Do you think this was the planned outcome when they prepared this demonstration?



Everything was ok until it wasn't

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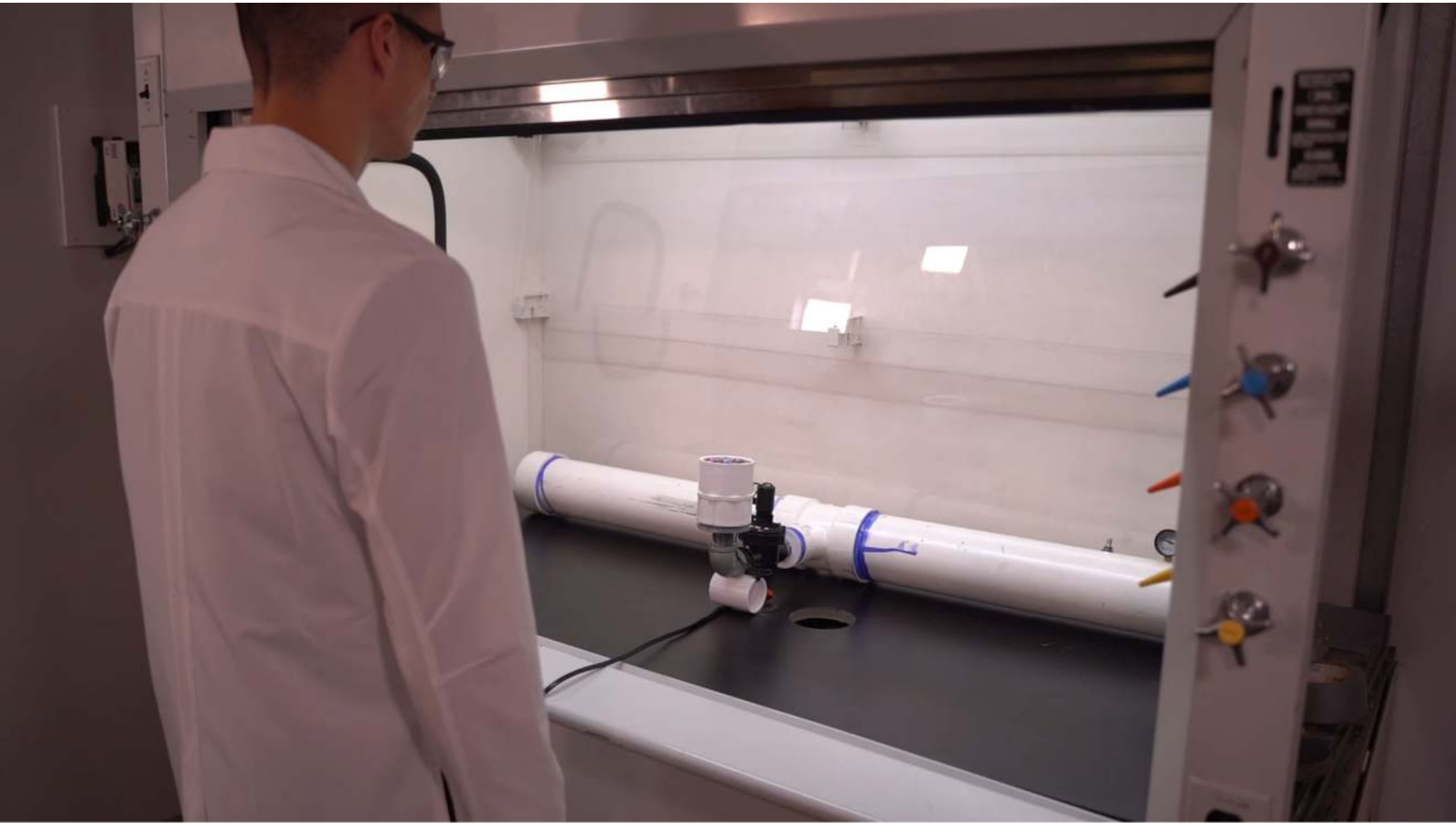
This is a concept called flame jetting. This is where you want the sash between you and the fire.



While this is not a typical loss of containment, it is an event that can seriously harm or kill the user. Part of fume hood testing is the training of the users in how their actions impact performance.





Watch how in 4 minutes this situation goes from routine to really bad (actual security camera footage).



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Not only can accidents hurt or kill people, they cause damage and disruption to the lab and the work being done.



If we could see air currents and the chemical contaminants, fume hood safety would be a matter of common sense.



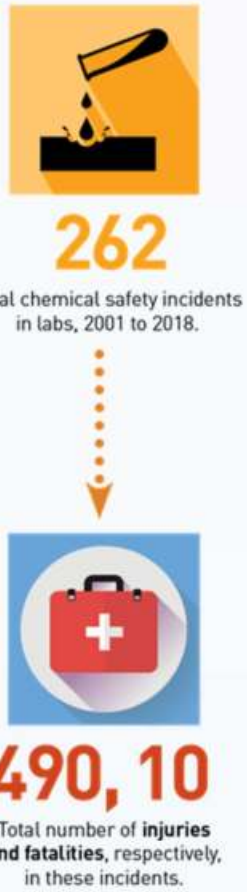


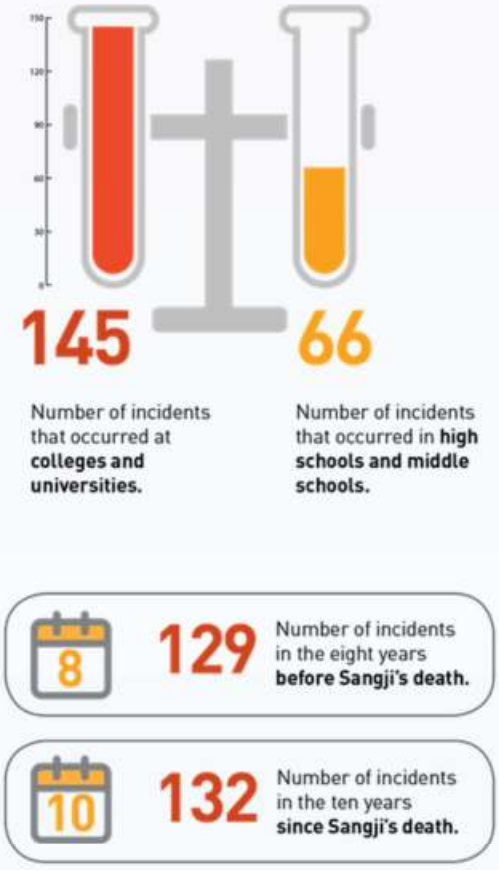
Even a small fire can cause hundreds of thousands of dollars in property damage and can cause the loss of years of research.

A link to anatomy of a fire at a lab at University of St. Andrews

https://news.st-andrews.ac.uk/archive/anatomy-of-a-fire/







How many is too many?

81% of the accidents were in an educational setting

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Laboratory Incidents January 2001–July 2018

U.S. Chemical Safety and Hazard Investigation Board

The U.S. Chemical Safety Board's (CSB) laboratory dataset includes chemical incidents that occurred in public and private laboratories from January 2001 through July 2018. The incidents occurred in a variety of organizations and settings, including private research laboratories, universities, high schools, middle schools, elementary schools, the National Laboratories, state-run laboratories and educational demonstrations. The CSB receives incident information from multiple sources, including the media and the U.S. Coast Guard's National Response Center. Not all incidents undergo secondary verification by the agency. Additional laboratory incidents may have occurred during this period but have not been identified by the CSB.

Date Prepared: August 16, 2018

Incident Date	Organization	City	State	Fatalities	Injuries
2001-07-23	University of California, Irvine	Irvine	California	0	3
2001-10-10	University of Utah	Salt Lake City	Utah	0	0
2001-10-12	Genoa-Kingston High School	Genoa	Illinois	0	7
2001-10-16	U.S. Army Research Laboratory	Adelphi	Maryland	0	1
2002-01-08	Los Alamos National Laboratory	Los Alamos	New Mexico	0	0
2002-03-11	New Berlin West High School	New Berlin	Wisconsin	0	1
2002-12-31	University of Washington Medical Center	Seattle	Washington	0	0
2004-01-30	Federal Way High School	Federal Way	Washington	0	2
2005-06-18	Huntington Beach High School	Huntington Beach	California	0	2
2006-01-23	Western Reserve High School	Hudson	Ohio	0	4
2006-01-24	Lansing Community College	Lansing	Michigan	0	0
2006-01-26	Middle Township High School	Cape May County	New Jersey	0	5
2006-01-31	Cornell University	Ithaca	New York	0	1
2006-02-20	West Chester University	West Chester	Pennsylvania	0	2
2006-02-24	University of Denver	Denver	Colorado	0	0
2006-03-02	University of Idaho	Moscow	Idaho	0	1
2006-03-07	Saratoga Springs High School	Saratoga Springs	New York	0	8
2006-03-12	Monahans High School	Monahans	Texas	0	3
2006-04-03	University of Maryland Biotechnology Institute	Baltimore	Maryland	0	1
2006-04-11	Southwest Minnesota State University	Marshall	Minnesota	0	1
2006-04-20	Scripps Research Institute	Jupiter	Florida	0	0
2006-04-21	Northwestern University	Evanston	Illinois	0	1
2006-05-05	Massachusetts Institute of Technology	Cambridge	Massachusetts	0	0
2006-05-09	Prosper High School	Dallas	Texas	0	1
2006-05-16	Georgia Institute of Technology (Georgia Tech)	Atlanta	Georgia	0	1
2006-06-08	Lafayette High School	James City	Virginia	0	1
2006-06-16	Binghamton University	Vestal	New York	0	0

Laboratory Incidents January 2001–July 2018

U.S. Chemical Safety and Hazard Investigation Board

Incident Date	Organization	City	State	Fatalities	Injuries
2006-06-28	Purdue University	West Lafayette	Indiana	0	0
2006-07-03	Cardiovascular Genetics	Salt Lake City	Utah	0	1
2006-07-09	Washington Middle School	Aurora	Illinois	0	0
2006-07-20	University of Colorado	Boulder	Colorado	0	3
2006-07-20	University of Minnesota, Twin Cities	St. Paul	Minnesota	0	0
2006-07-27	University of Colorado	Boulder	Colorado	0	1
2006-08-01	University of Washington	Seattle	Washington	0	1
2006-08-16	Virginia Tech	Blacksburg	Virginia	0	3
2006-08-24	Rice University	Houston	Texas	0	0
2006-08-27	Indiana University	Bloomington	Indiana	0	0
2006-09-06	Georgia State University	Atlanta	Georgia	0	6
2006-10-03	Hasbrouck Heights High School	Hasbrouck Heights	New Jersey	0	0
2006-10-10	Oakland High School	Oakland	Oregon	0	0
2006-10-11	Morrisville Pharmacy	Morrisville	Pennsylvania	0	1
2006-10-31	Louisiana State University	Baton Rouge	Louisiana	0	2
2006-11-01	Eastern Guilford High School	Greensboro	North Carolina	0	0
2006-11-03	University of Kentucky	Lexington	Kentucky	0	7
2006-11-12	Yale University	New Haven	Connecticut	0	1
2006-12-03	Clinical Pathology Labs	Springville	Utah	0	1
2006-12-19	Oak Ridge National Laboratory	Oak Ridge	Tennessee	0	0
2006-12-21	University of Arkansas	Fayetteville	Arkansas	0	0
2007-01-17	Pennsylvania State University	State College	Pennsylvania	0	0
2007-01-18	South Fremont High School	Saint Anthony	Idaho	0	0
2007-02-01	H.B. du Pont Middle School	Hockessin	Delaware	0	1
2007-02-07	Mead Middle School	Mead	Washington	0	2
2007-02-09	Dobyns-Bennett High School	Kingsport	Tennessee	0	0
2007-02-20	James Madison University	Harrisonburg	Virginia	0	0
2007-02-26	Duquesne University	Pittsburgh	Pennsylvania	0	0
2007-03-20	Boston College	Boston	Massachusetts	0	1
2007-03-27	North Carolina State University	Raleigh	North Carolina	0	1
2007-03-30	Frontier Scientific	Logan	Utah	0	1
2007-04-10	West Virginia University	Morgantown	West Virginia	0	3
2007-04-30	Volusia County Health Department	Daytona Beach	Florida	0	1
2007-05-01	University of Wisconsin, Milwaukee	Milwaukee	Wisconsin	0	0

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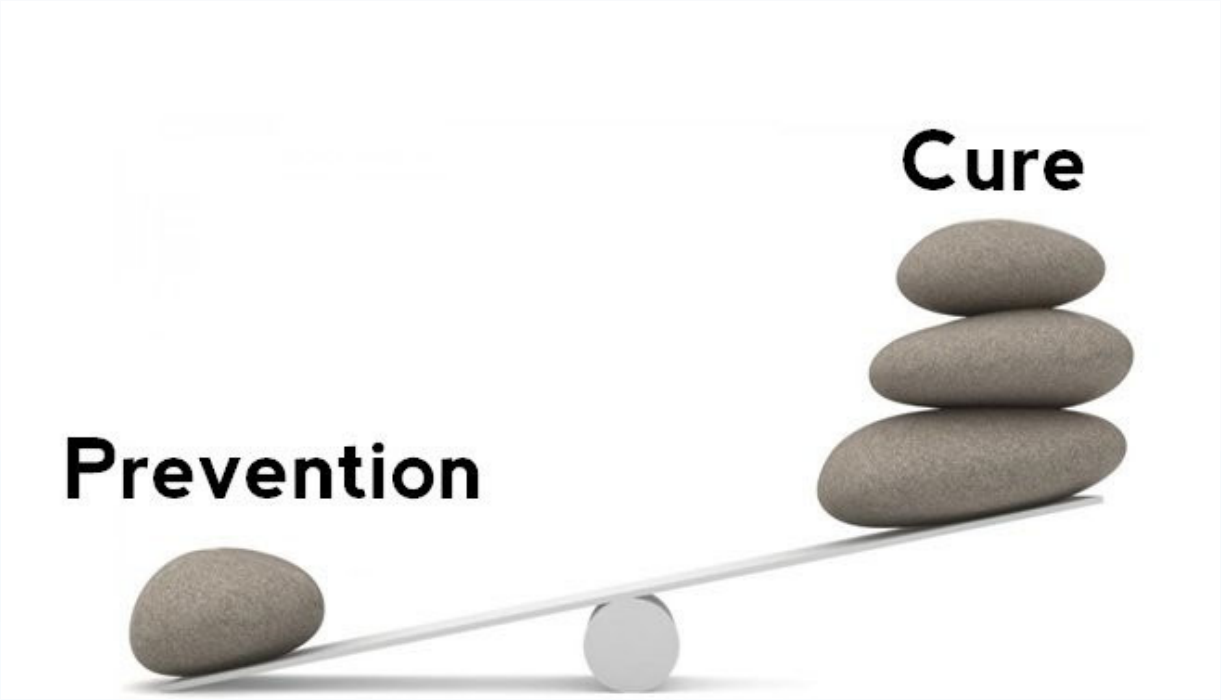
It's easier to stop something from happening in the first place than to repair the damage after it has happened.



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Why do we test?

If you can't see a problem, you can't fix it.



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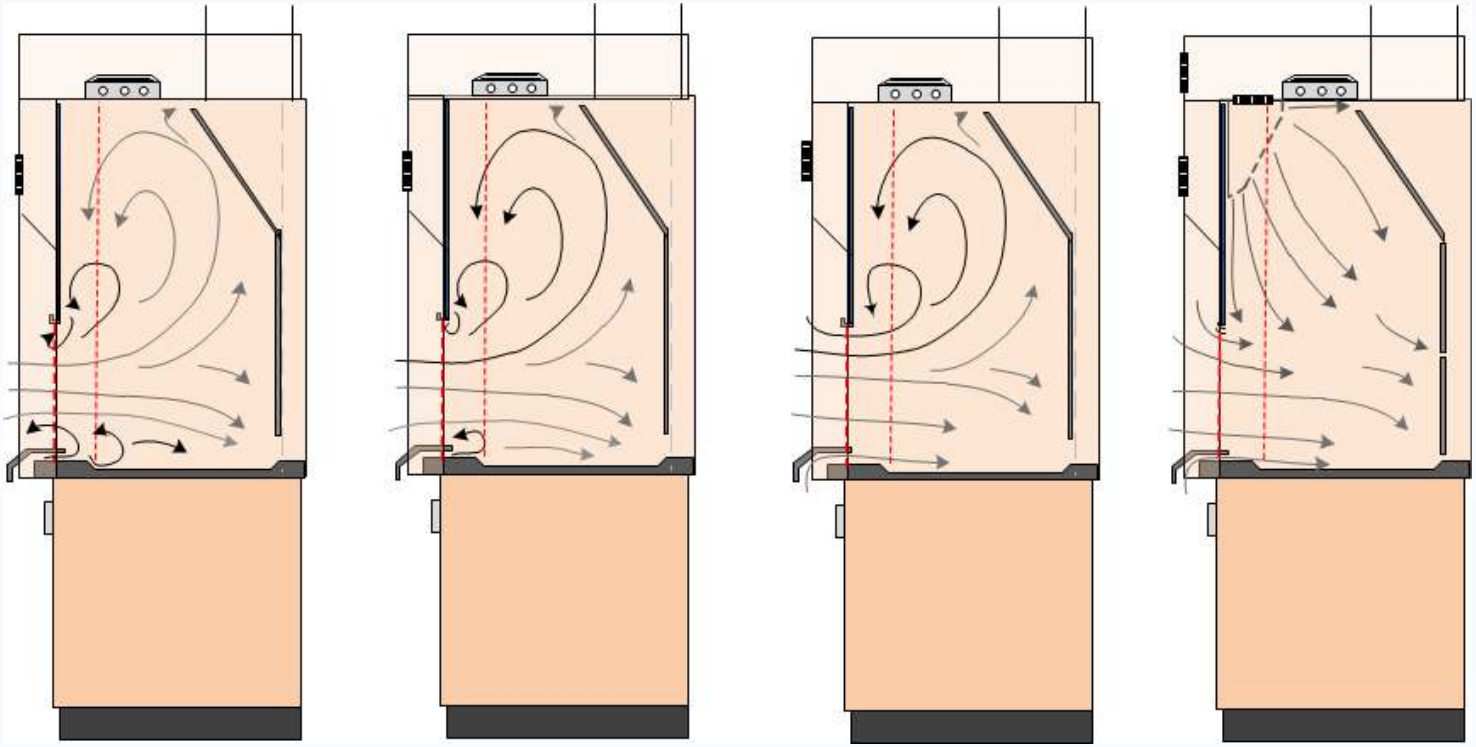
Airflow Visualization Ratings

Fail:
Visible Escape

Poor:
Reverse Flow at Sash Opening

Fair:
Reverse flow inside Hood within 6 inches.

Good:
No Reverse Flow



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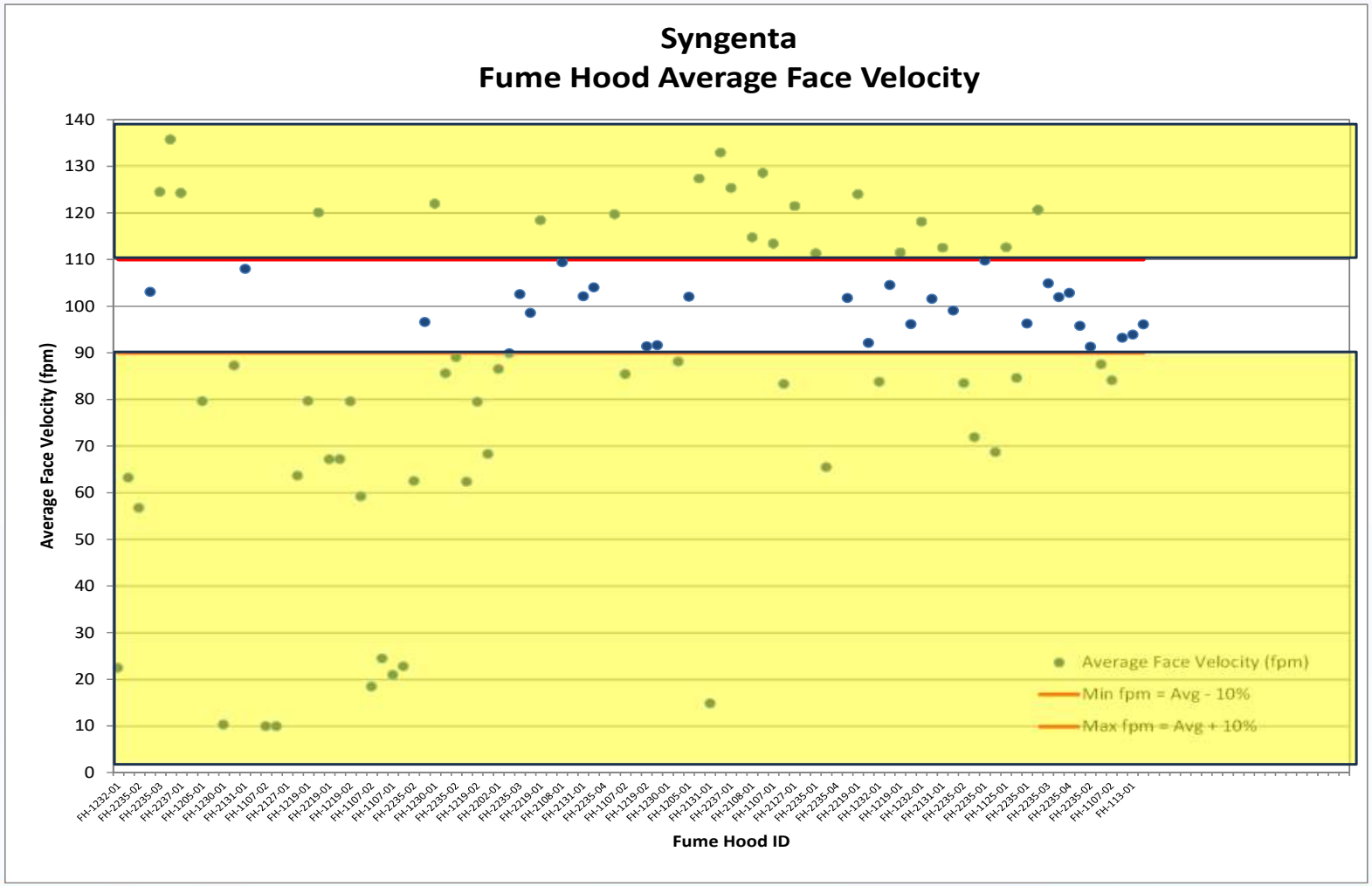
Fume Hood Face Velocity Tests



25 of the 46 hoods were outside the acceptable range

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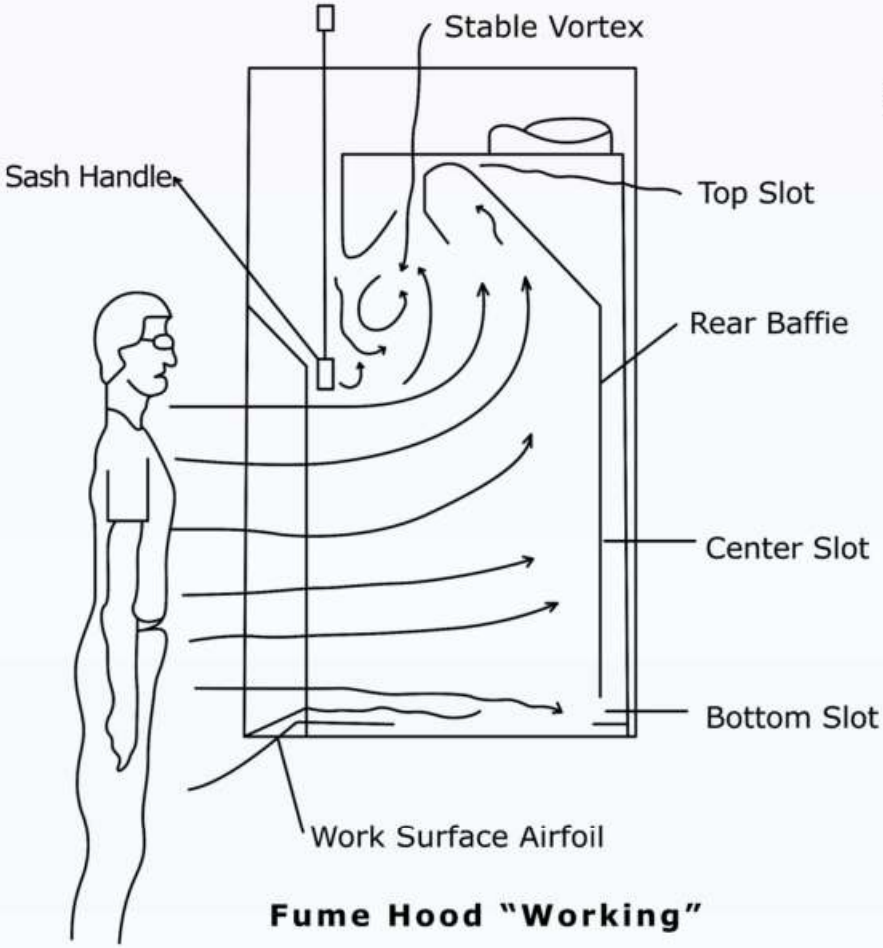
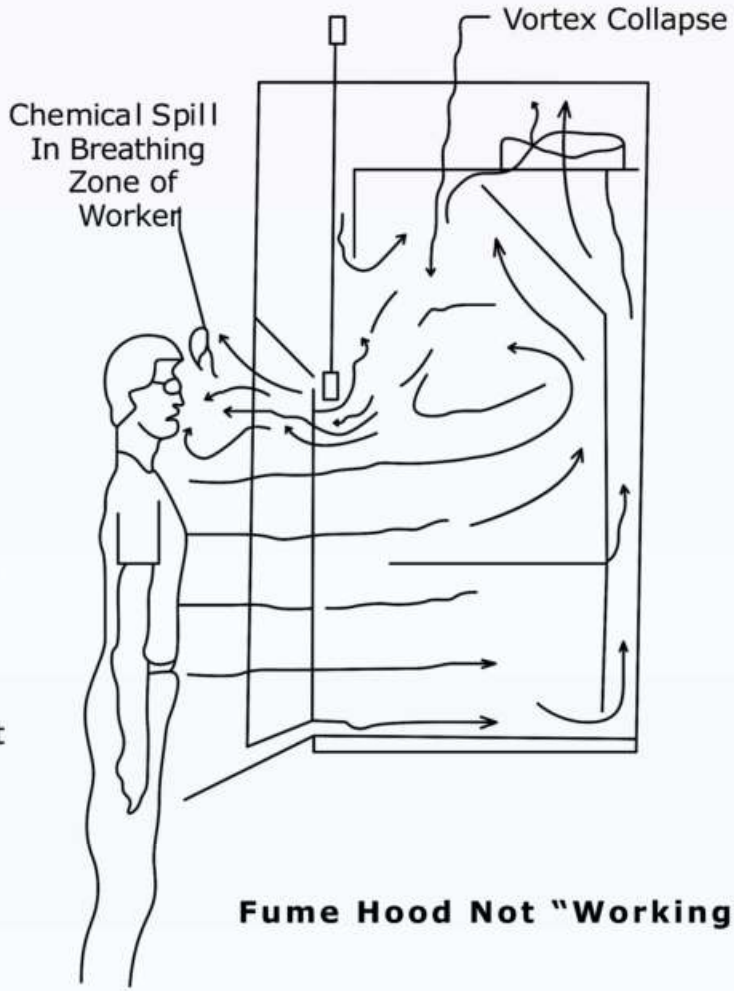


Fume Hood "Working"



Fume Hood Not "Working"

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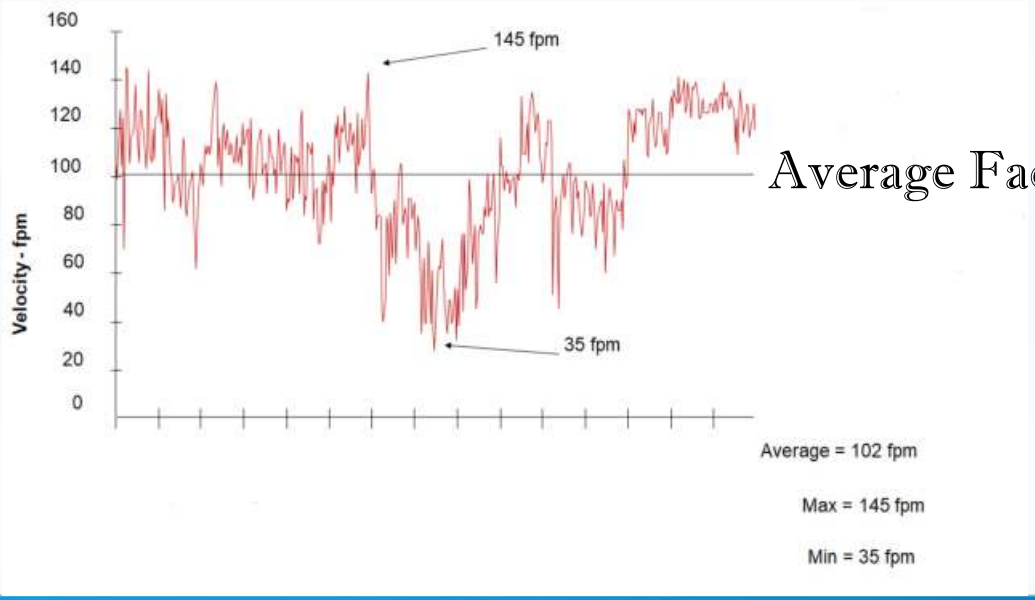
Why a hood with adequate average face velocity could still have unsafe loss of containment.

Safe Hood Performance isn't about face velocity.

There are many reasons that a hood could have an acceptable velocity but still not be performing safely

Look at how this hoods face velocity changes over time..



Average Face Velocity of 102fmp

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Fume Hoods are a safety device, but it is estimated that **as many as 70% do not contain properly**. Without containment testing there is no way to verify performance.



Fume Hoods are both an engineering control and a PPE. This hybrid situation make involving the user a critical step.

This operator is removing an object from the hood and is dragging the smoke out. If these were chemicals and not fog, those would be chemicals (loss of containment) coming out of the hood.



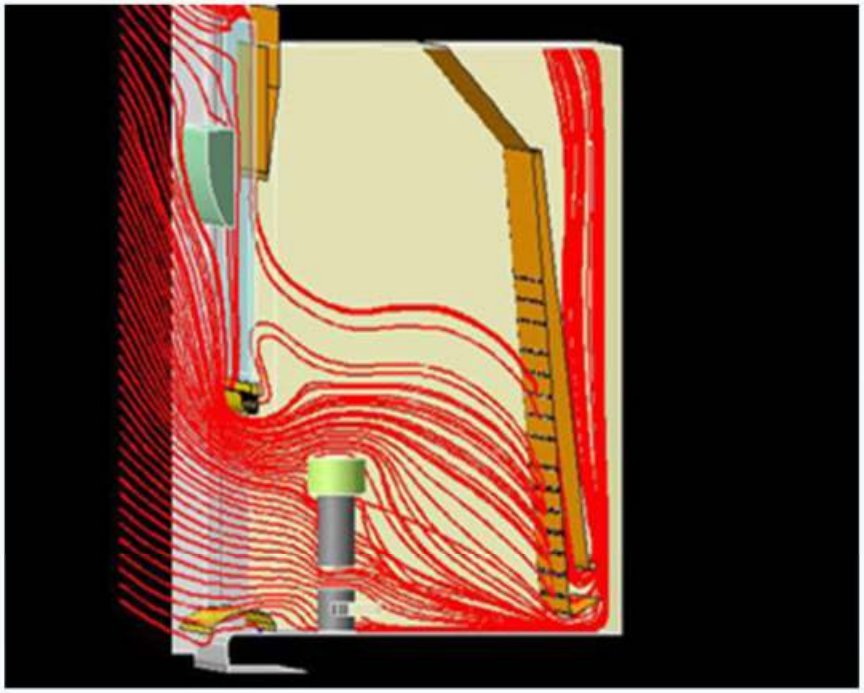
This is why Containment Testing is the only way to know if the hood is performing safely. And since ASHRAE 110 is mostly a static snapshot, you should consider dynamic containment like Tri-Color.

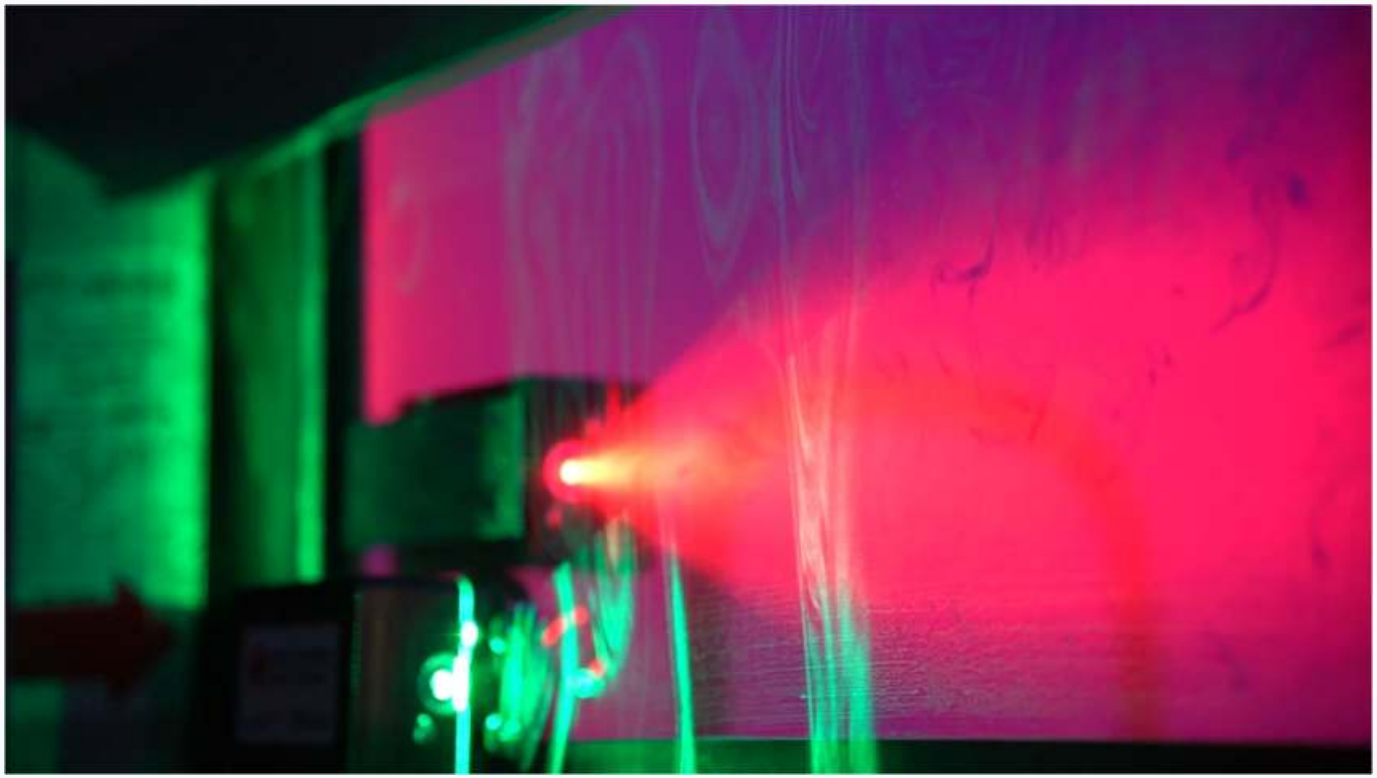
The role of the fume hood tester.

SF6 mostly challenges the lower portion of the hood because of weight of SF6 (6x of air).

Very little SF6 makes it into the vortex which is a primary source for loss of containment.

Hoods can also leak through the bypass and this is hard to detect with SF6



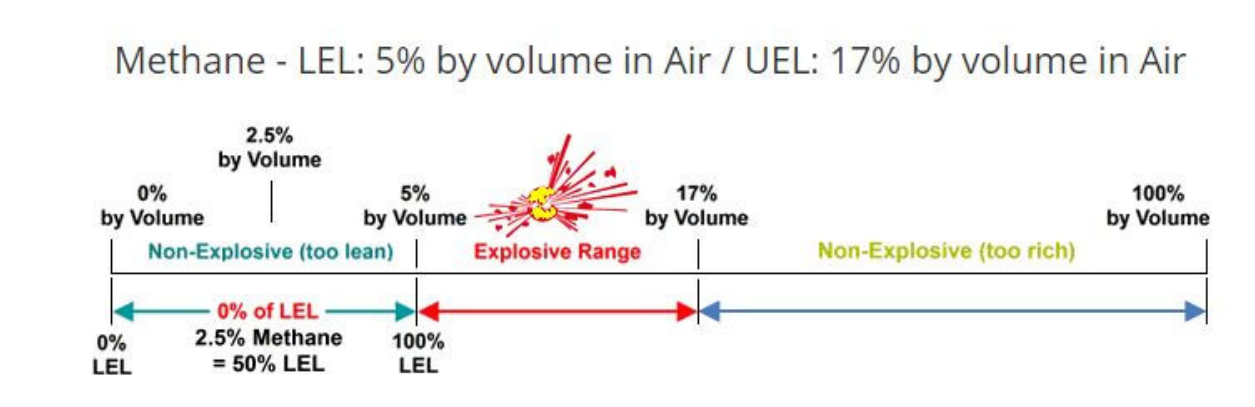


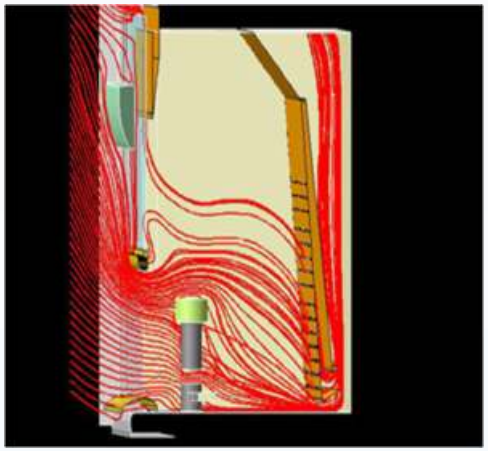
While Tri-Color clearly shows loss of containment in the top of the hood, the SF6 showed no leakage, even though the loss of containment is coming directly through the user's breathing zone.

Lower Explosion Limit

Small quantities of chemicals can pollute the air and create an explosive atmosphere.

Not all hoods do a good job at evacuating the vortex. As such, it is easy for the chemical concentration to build until it crosses the LEL.





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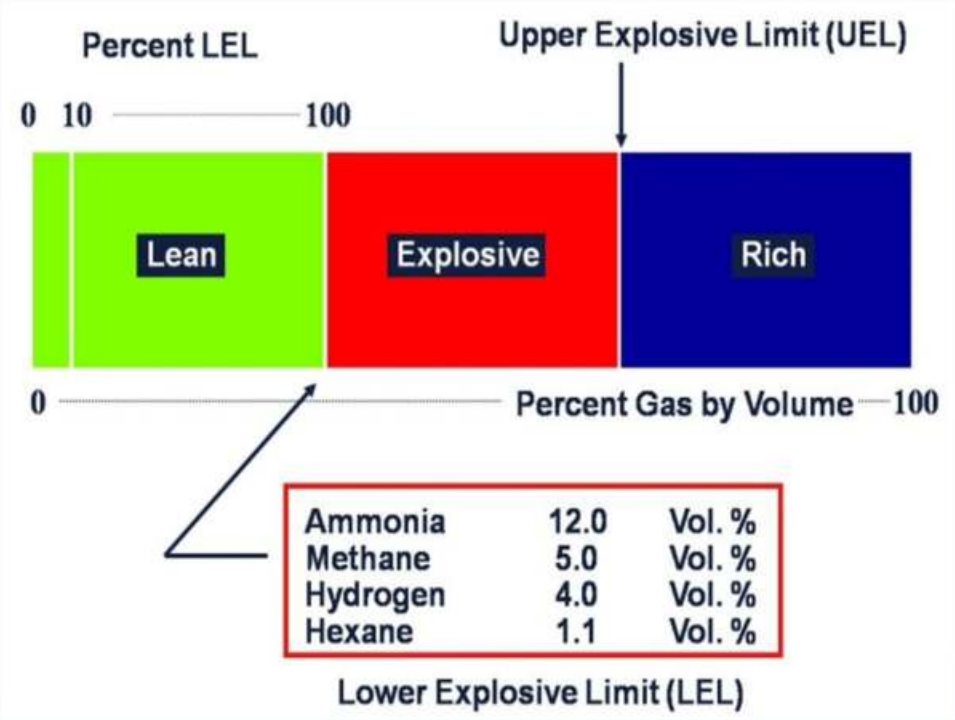



As you can see from the video, it doesn't take much of a chemical buildup to have a real problem.

ISOPROPYL ALCOHOL which is common in labs has a LEL 2.0% and a UEL 12.7%.

How many drops of IPA does it take for a poorly performing vortex to reach a 2% concentration?

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The role of a fume hood tester

- To test hoods to verify their safe performance.
- To train lab personnel about how hoods work and what they can do to maximize performance.
- To understand enough about lab ventilation to generally be able to answer these two questions:

    1) Why is my hood performing so poorly?
    2) What do we need to do to correct the performance problem?

The importance of each type of testing

AM-As Manufactured - This version of the ASHRAE 110 tests the hoods performance in a test lab with perfect room conditions, so you are really testing the hood only.

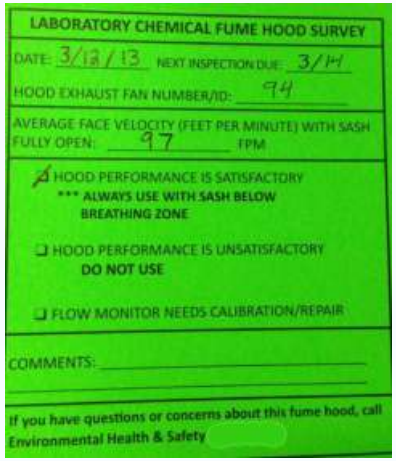
AI- As Installed - This version tests an empty hood before lab occupancy. With this version we are testing the interface of the fume hood to the lab ventilation system. When the test results differ greatly from the AM results, there is a problem with the room conditions.

AU-As Used - This version of the test is to see the impact of the User's work practices on performance. Much of this test is the basis for future training of the user.

Not all testing is the same

Testing primarily average face velocity *is next to worthless*. There is not direct correlation between face velocity and chemical containment.

While this testing may satisfy your compliance requirements, it does little to actually protect the users and reduce the risks of an incident. Plus it puts the tester at risk if there is an incident.


LABORATORY CHEMICAL FUME HOOD SURVEY

DATE: 3/13/13 NEXT INSPECTION DUE: 3/14

HOOD EXHAUST FAN NUMBER/ID: 94

AVERAGE FACE VELOCITY (FEET PER MINUTE) WITH SASH FULLY OPEN: 97 FPM

☑ HOOD PERFORMANCE IS SATISFACTORY
*** ALWAYS USE WITH SASH BELOW BREATHING ZONE

☐ HOOD PERFORMANCE IS UNSATISFACTORY
DO NOT USE

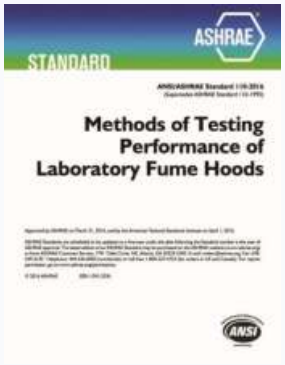
☐ FLOW MONITOR NEEDS CALIBRATION/REPAIR

COMMENTS:

If you have questions or concerns about this fume hood, call Environmental Health & Safety

How useful is this Safety Certification? If there were an incident, would this offer you much protection or proof that you did everything reasonable to ensure the hood was performing safely?

Fume Hood Testing



ASHRAE 110 -2016 is the most recognized testing method in North America.

ASHRAE 110 is often misunderstood. It is not a pass/fail standard, rather it is a method of testing.
You have to look elsewhere (Z9.5) for guidance to what is safe performance.

A large percentage of ASHRAE 110 tests are modified to fit the needs of the organization that is having its hoods tested

<u>NOT</u> A PASS/FAIL Standard

A Sad Story

I was troubleshooting for a large University in Florida. They had a hood that was performing very poorly.

I noticed that it had a safety certificate label from 2 months earlier.

I asked them to have the tester come back.

When he got there I was talking with him to try to learn what might have changed in those two months.

Finally after some conversation he said, “Well, nothing has really changed”.

I asked why he then labeled the hood as safe?

He said, “If I failed it, they would have asked what was wrong and what needed to be done to fix the problems. I have no clue, so I passed it.”

Could this be you?



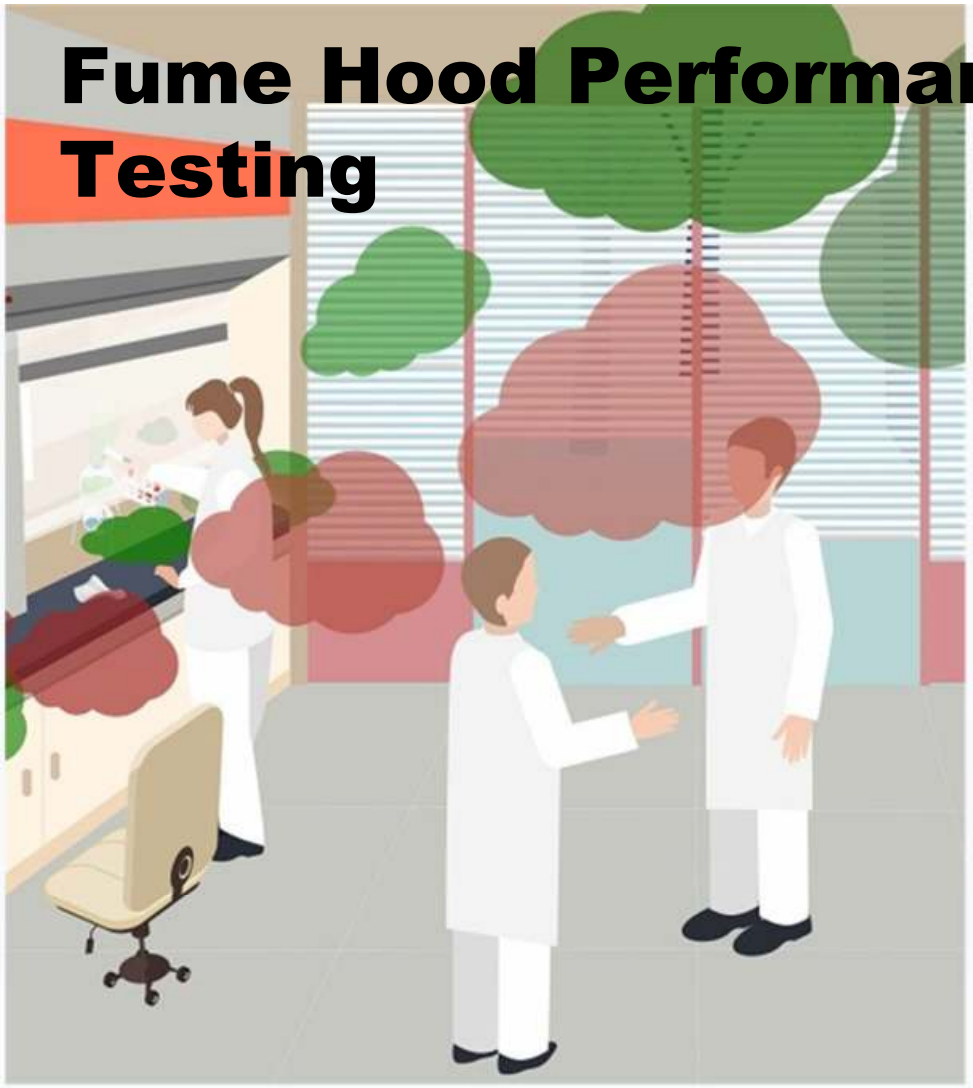
A major hospital had a complaint from an employee about smelling formaldehyde while working at a ventilated enclosure.

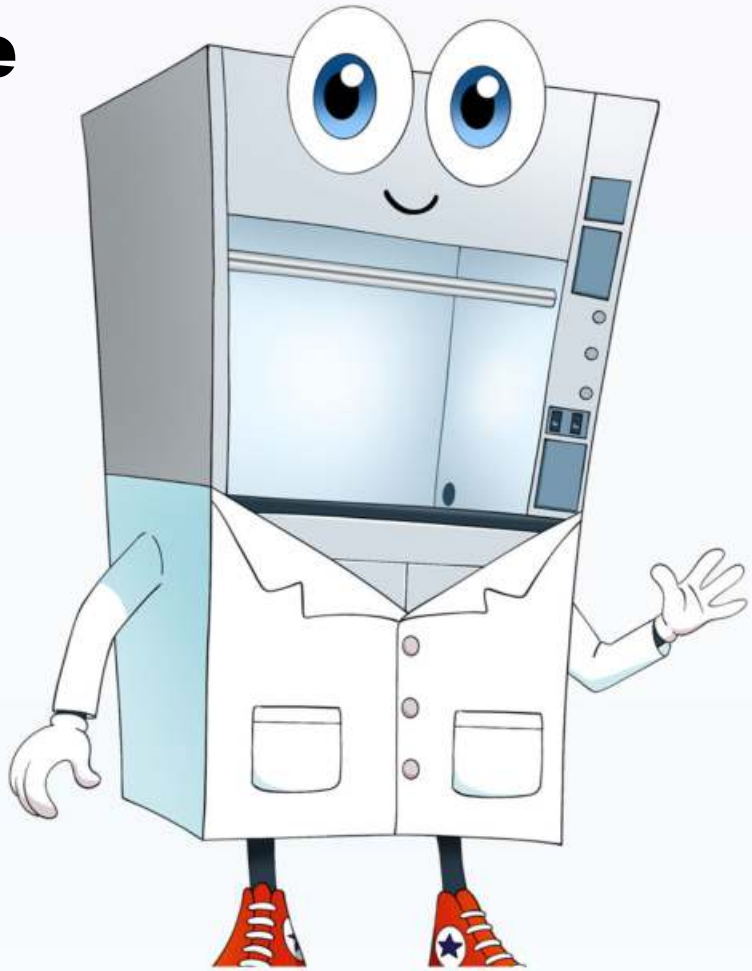
- After their internal people could not fix the problem, they brought in Tester A. This tester made some modifications and certified the enclosure safe.
- Employee continues to complain.
- Tester B was brought in and certified the unit safe.
- Now the employee, a young female, has gone on permanent disability and has sued the hospital and both testers.
- The user has a high probability of winning the suit. Given the hospital has excellent insurance, chances are they will settle and not let this go to court. The payout could easily be $10 million and maybe more.
- But because the hospital made good faith efforts to fix the problem, if their insurance settles, their insurance carrier will probably sue the two testers (likely to be considered defective work) to try to reclaim their payout.

As testers, you have a certain liability and need to make sure you have good insurance. You should look at not only your general liability, but at errors and omissions insurance

Good performance tracking software is also critical to prove what work you performed and what the test results were.

Fume Hood Performance Testing





Testing and Documenting Safe Performance

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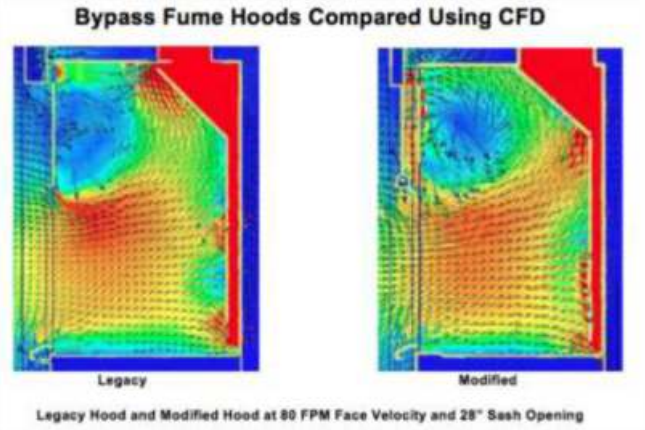
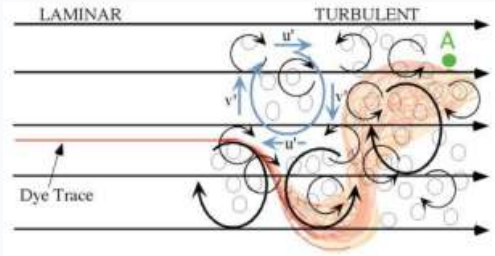
- Why hoods fail to perform safely.
- What does FAIL mean?
- It is a failure to contain at acceptable levels?

  - 25% fail because of a poorly designed fume hood or poor lab design (design issues)
  - 50% fail because of Laboratory Ventilations issues (Room Conditions)
  - 25% fail because of user work practices. (users)

Let's look at each one individually

Poor Hood Design and Lab Design Causes 25% of the hood failures (excessive loss of containment)





The smallest design details can make the difference between a hood that will fail and one with robust containment.

Not all hoods are equal.

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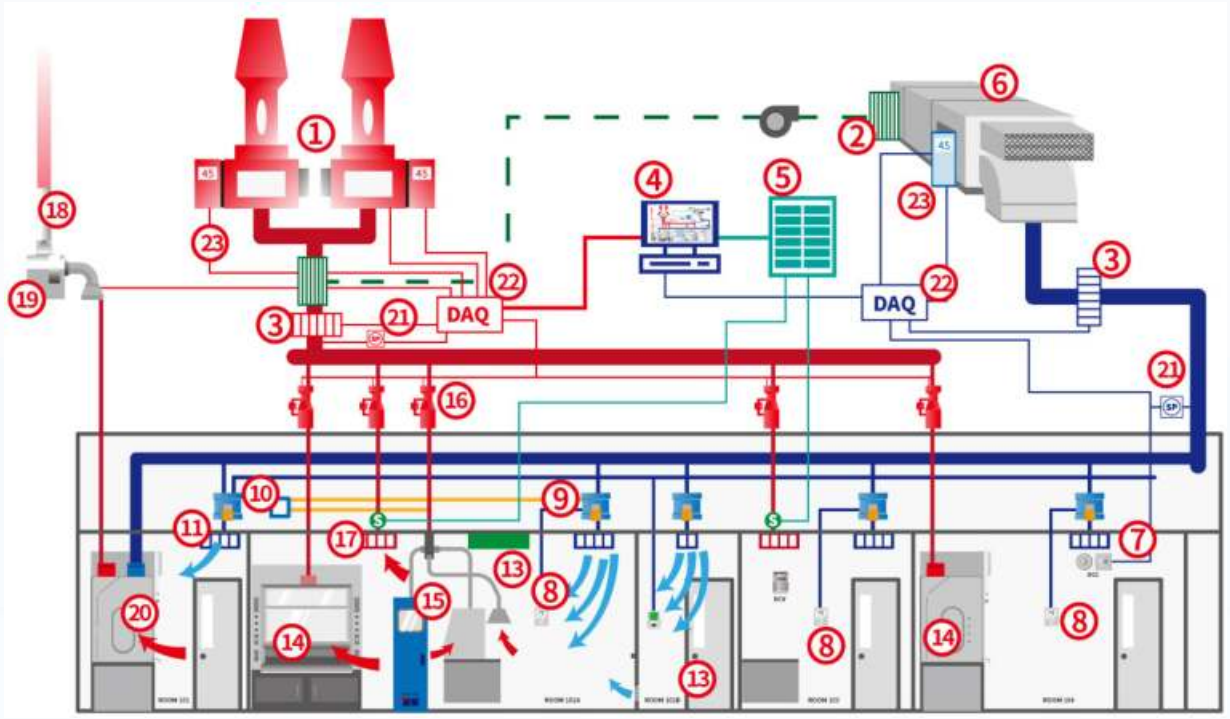
50% of hoods fail because of Laboratory Ventilations issues (Room Conditions).



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25% fail because of user work practices (users).



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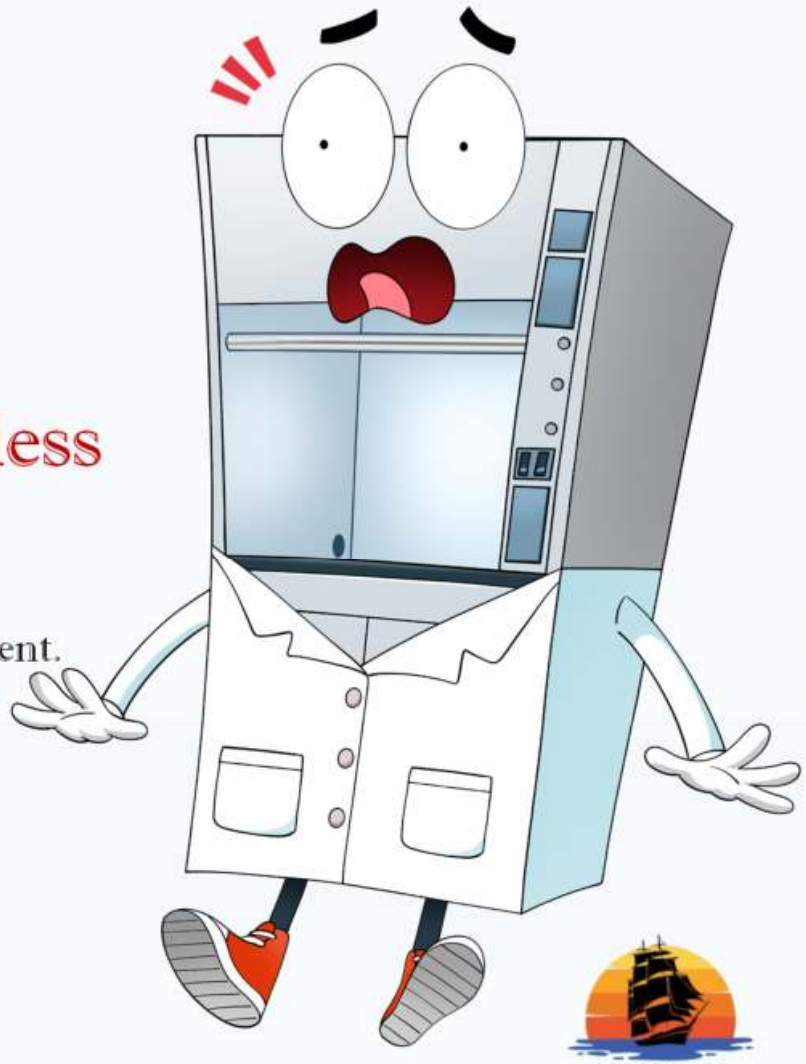
Health and Safety Risks

Laboratories by the nature of their work are hazardous places. The are many potential dangers, both to a occupants health (exposure) and safety (accidents).

Safety isn't expensive, it is priceless

The cost of compliance is nothing compared to the cost of an incident.



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What the ASHRAE 110 standard says this about the results from the testing:

This standard defines a reproducible method of testing laboratory hoods. ***It does not define safe procedures.*** *However, laboratory hoods are considered by many to be the primary safety devices in conducting laboratory operations. There are many important factors in the safe operation of laboratory hoods that are not described in this standard*

It is important to evaluate the performance of the laboratory hood under dynamic conditions. ***This performance test method may be modified to evaluate a dynamic challenge.*** *Specific operations, such as a pedestrian walking past the hood, laboratory doors opening, and specific actions at the hood, are only a few of the challenges that could be expected at the hood. This test method addresses only the dynamic challenge of sash movement.*

Dynamic Containment Testing

No one works at an empty hood, and room conditions have the most impact on fume hood performance. To truly understand how a fume hood is performing you need realistic challenges that mimic real world operating conditions.



What is Tri-Color all about?

- A disservice to fume hood community has occurred by allowing people to believe that there is a direct relationship between face velocity and containment.
- While face velocity is a component of containment, most hoods that fail containment testing have acceptable face velocity.
- **We need to change the conversation from face velocity to safe containment.**

TRI-COLOR
AIRFLOW VISUALIZER

Tri-Color is all about containment.
Dynamic Containment with real world challenges!

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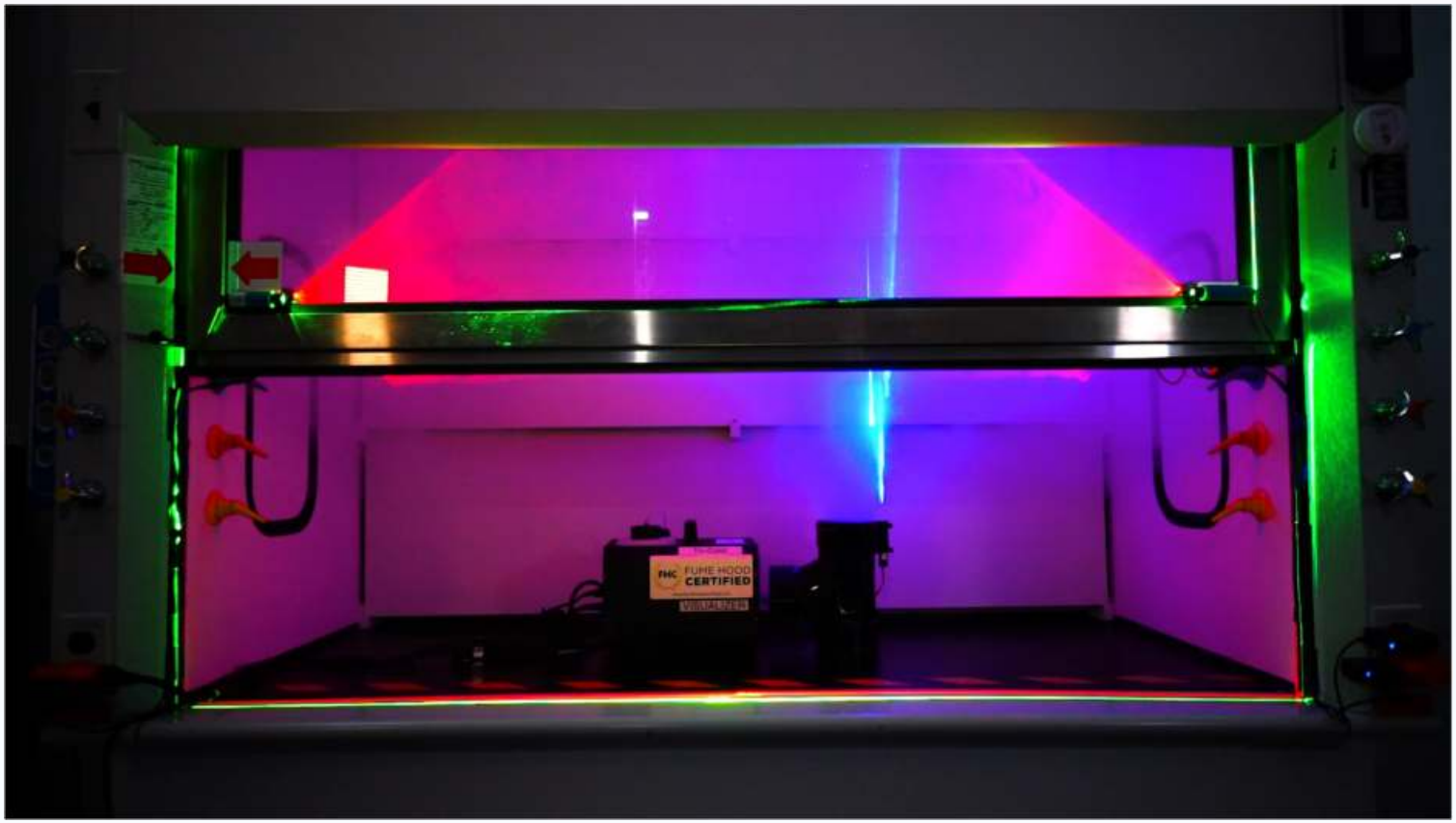
This is one way to visualize the impact of a walk by. While the loss of containment is apparent, it isn't very repeatable and it is not overly visual.



Tri-Color Challenge – Walk by



Can Tri-Color be used with BSC (Biological Safety Cabinets)



We are currently working on a Protocol for Biological Safety Cabinets (BSC). It will be an add-on to NSF49 not a replacement

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We do we use Red inside the hood and green outside?

Green has more contrast and can highlight smaller leaks

What is going to happen in the space between the bench hood and the floor mounted hood?



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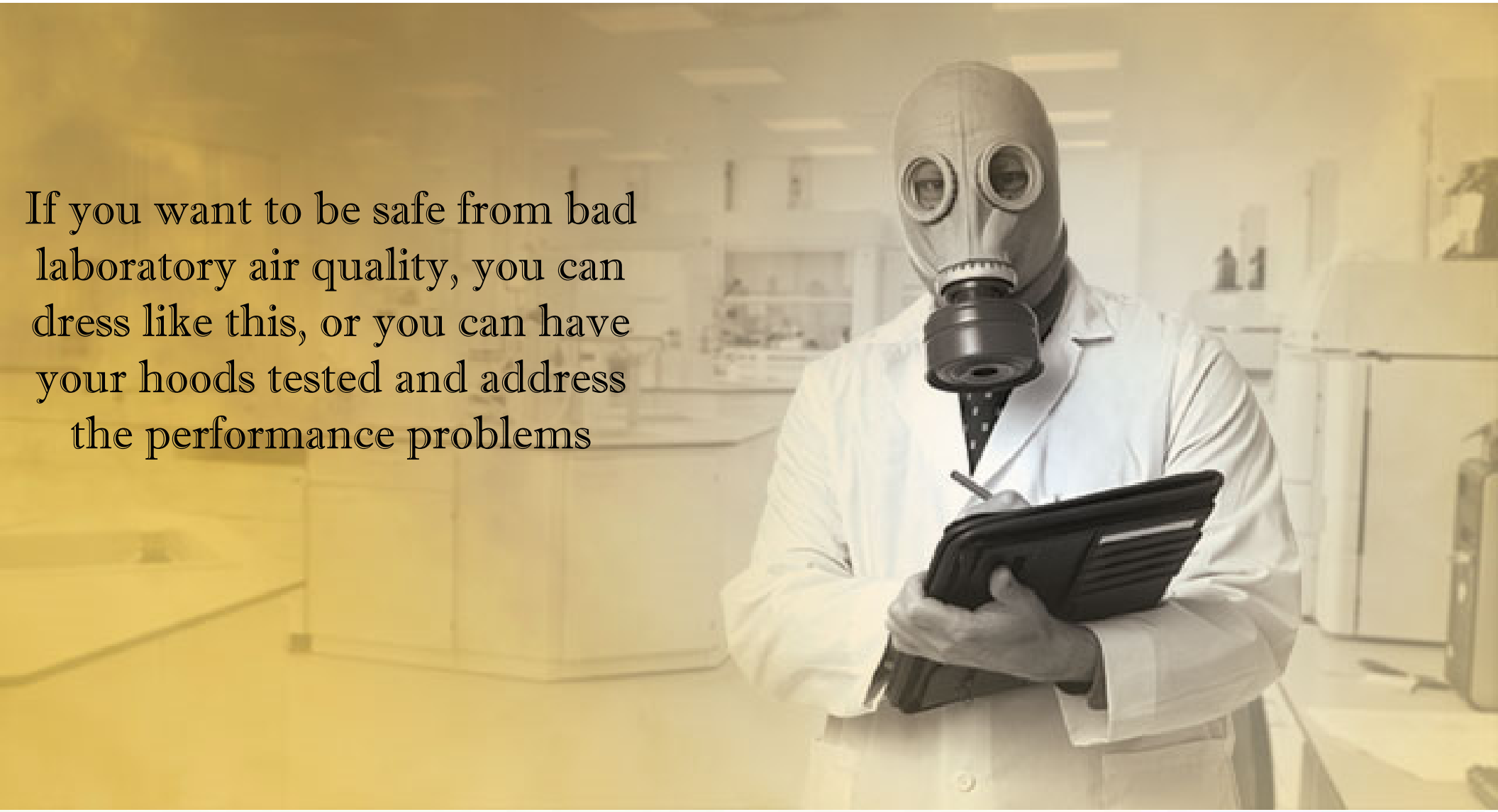
If you want to be safe from bad laboratory air quality, you can dress like this, or you can have your hoods tested and address the performance problems

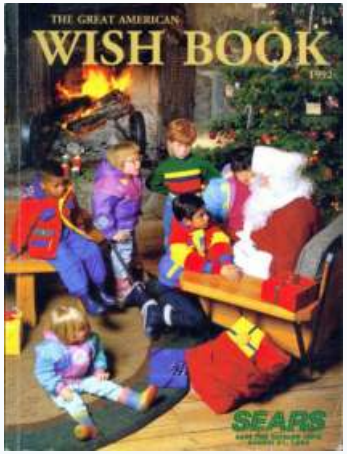


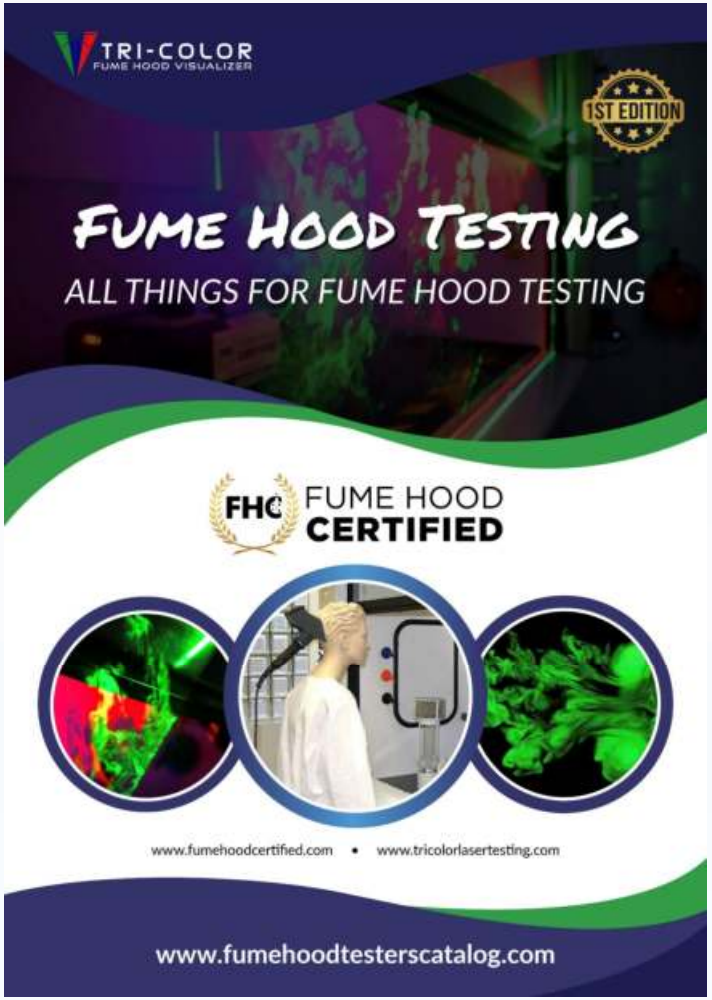
Why types of testing are an indications of containment?

- Traditional SF6 Testing
- Detailed Face Velocity Profile
- Tri-Color Dynamic Containment Testing



Remember the Sear's Christmas Wish Book? Well, we have created one for fume hood testers.





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The need for record keeping and the liabilities of testing.

Lab safety continues to be lacking in most labs.

Many experts agree the that an underlying problem is how we approach safety.

Many institutions and companies focus on regulatory compliance and the avoidance of liability

rather than on education, training, and creating a safety culture.





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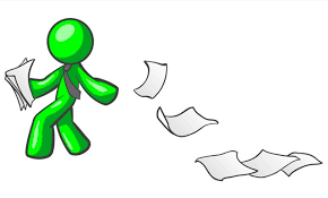
Testing helps to ensure compliance with regulations.



If there is an incident of someone being inquired or having health consequences, the outcome is very much related to who has the best paper trail.

Regular testing shows that an effort was made to comply with any regulations and to provide a safe workplace. Put is shows what the tester tested and what the results were.

Our Fume Hood Performance Tracker Software makes compliance simple.

Our software also minimizes your liability as a tester.

Digital Safety Certificate



FHC FUME HOOD CERTIFIED

Fume Hood HIN: 99-X99-T22
Hood Rating: Pass - Fair
Date: 05/09/2023

XYZ College (Demo)

Millis Hall

Floor 1 | Room G-28-1

Average Face Velocity

Full Open: 86 FPM

Half Open: 112 FPM

Tri-Color Visualization: Pass - Good

Exhaust Fan Number - Not Known

Tested By: Chip Albright (Creative Solutions (Demo))

Retest Due: 2024-05-09

View Full Report

CREATIVE SOLUTIONS

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https://fumehoodperformance.com/login

XYZ College (Demo) › Mills Hall › Floor 1 › Room G-28-1 › 99-X99-T22

Hood Info

HIN	99-X99-T22
FHC Subscription Tier	Basic
Alt ID	MIL-G28-1
Re-Test Frequency (Certificate Validity)	12 Months
Brand	Kewaunee
Exhaust Fan Number (n/a is acceptable)	Not Known
Hood Model	Supreme Air
Hood Width (required to create an ASHRAE report)	72
Hood Style (required to create an ASHRAE report)	Bench Top
Hood Type (required to create an ASHRAE report)	VAV - Variable Air Volume
Sash Type (required to create an ASHRAE report)	Vertical
Max Sash Opening-Width (required to create an ASHRAE report)	62
Max Sash Opening-Height (required to create an ASHRAE report)	28
Design Opening - Height in inches (required to create an ASHRAE report)	18
Design Velocity - FPM (required to create an ASHRAE report)	100
Alarm	Yes
Alarm Brand and Model	Phoenix Controls
Age of Hood	2015
CFM	1225
Static Pressure (inches of water gauge)	0.24

Hood Photo



HIN Label



Certificate Details

Certified: Yes

View Certificate

Performance Data

Add New Test

ID	Test Type	Result	Date	Data	Uploads	Actions
613994	Reference Materials	Not Graded	05/09/2023	View Results	No uploads Upload	
613993	Record Room Conditions	Not Graded	05/09/2023	View Results	No uploads Upload	
611718	Troubleshooting (Images & Videos)	Not Graded	09/18/2022	View Results	View Media	

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XYZ College (Demo) - Millis Hall - Floor 1 - Room G-28-1 - Hood 99-X99-T22

XYZ College (Demo) › Millis Hall › Floor 1 › Room G-28-1 › 99-X99-T22

Hood Info

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Alarm	Yes
Alarm Brand and Model	Phoenix Controls
Age of Hood	2015
CFM	1225
Static Pressure (Inches of water gauge)	0.24

Hood Photo



HIN Label

Hood Identification Number
22 A66 P49
SCAN ME
FHC FUME HOOD CERTIFIED

Certificate Details

Certified: YES

View Certificate

Sample data at www.TestMyHood.com

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Legal and Regulatory Requirements



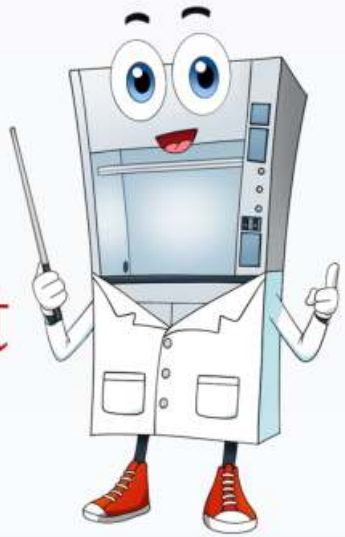
While there no national standards that directly require fume hood testing? There are requirements to keep the users safe, and there are substantial legal risks for failing to do so.

Failure to properly select, design, operate, use and maintain ECD systems may:

- Increase the potential for unacceptable impact to the health of people;
- Increase potential for harm to the environment;
- Increase potential for premature degradation of the ECDs;
- Increase potential for loss of productivity and operational efficiency;
- Increase unnecessary energy consumption and operating costs;
- Increase the risk of non-conformance with regulatory and industry standards; and
- Increase the risk of liability.

The consequences of non-compliance with regulations.

Safety is No Accident



Forget about the fines… The real cost is the potential lawsuits that often run in the millions of dollars. Along with damages to the lab.

An overview of standards that relate to fume hoods and testing.

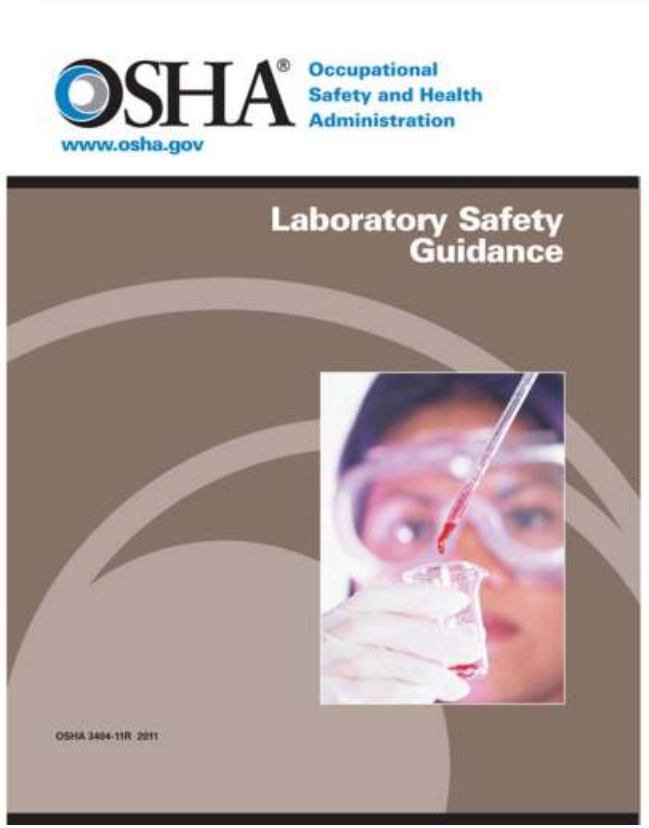


OSHA Oversight

- While OSHA doesn't have jurisdiction over all labs, it is generally considered to be the most comprehensive regulation when it comes to providing safe conditions in the lab.

29 CFR - 1910.1450 Occupational exposure to hazardous chemicals in laboratories

Many Lab Safety programs are more about compliance than improving safety



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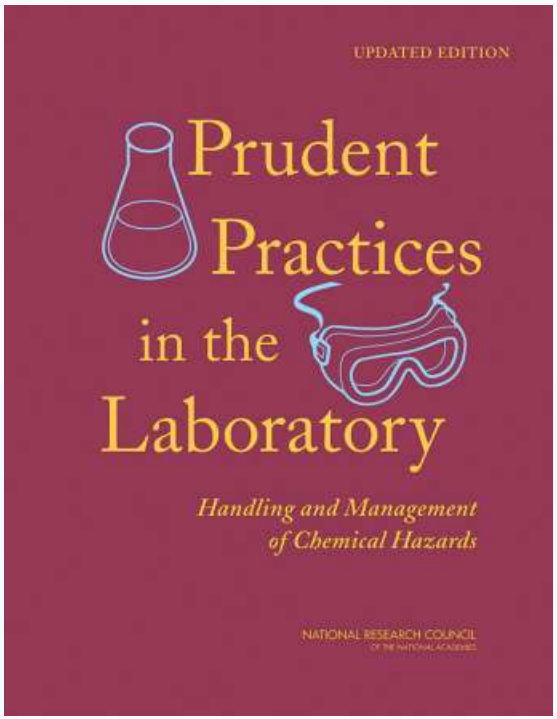
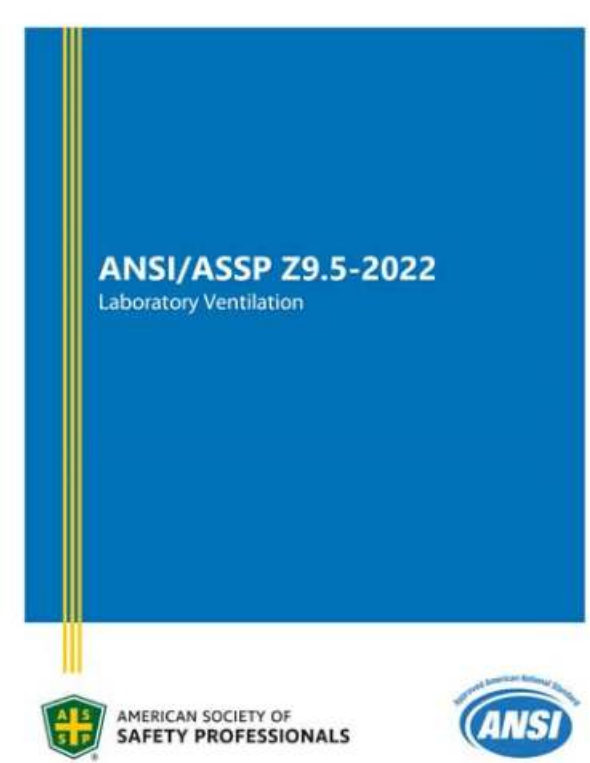
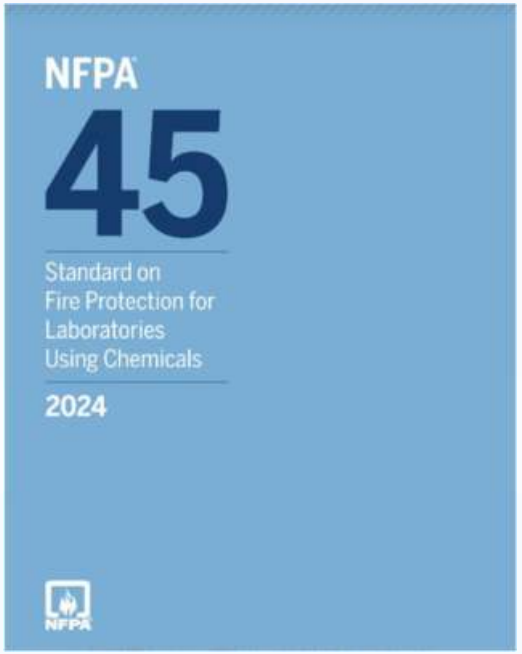
Prudent Practices in the Laboratory



Z9.5 is the most comprehensive standard related to Laboratory Ventilation. ASHRAE 110 references to this standard for acceptable limits for Loss of Containment using SF6.



NFPA 45, Standard On Fire Protection For Laboratories Using Chemicals 2024



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Classification of

Laboratory Ventilation Design Levels

January 13, 2018 ver.1

Developed by:

ASHRAE Technical Committee 9.10 - Laboratory Systems
Lab Classification Subcommittee

In partnership with:

American Chemical Society
Division of Chemical Health and Safety

and

American Industrial Hygiene Association
Laboratory Health and Safety Committee

Now Chemical Labs are classified the same way as BSL Biological Safety Labs based on risk. (BSL 1-2-3-4)

This ASHRAE Standard addresses fume hood performance based on risk

Risk based management can greatly reduce energy consumption based on supplying the right amount of performance based on the risk of exposure.



No more should we use a one size fits all strategy

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ASHRAE has a lab ventilation standard that is risk based.



ASHRAE

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Laboratory Ventilation Design Levels

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American Chemical Society
Division of Chemical Health and Safety

and

American Industrial Hygiene Association
Laboratory Health and Safety Committee

Chemical Safety Design Level

Example Types of Laboratories

CSDL-0

•Temperature controlled rooms (warm rooms and cold rooms)
•Demonstration rooms with single experiments of less than 5 grams or 100 ml
•Computer labs

CSDL-1

•Class laboratories with multiple concurrent experiments with small quantities (<100 ml) of non-volatile reagent chemicals
•Shop areas with consumer chemicals used and equipment emissions controlled by local exhaust
•Biological laboratories with no volatile chemical use beyond disinfectants

CSDL-2

•Laboratories with containers of more than 500 ml of volatile chemicals in storage or use
•Laboratories that contain a limited number of fume hoods (e.g., one fume hood per laboratory bay), and/or limited use of local exhaust

CSDL-3

•Laboratories requiring fume hoods or local exhaust associated with specific equipment

CSDL-4

•Laboratories requiring specific safety analysis and devices to support the work, such as nanomaterials laboratories, radioactive chemicals laboratories

Chemical Safety Design Level **Chemistry Expected to be Conducted in This Setting**

CSDL-0
Use of small containers of volatile reagent chemicals (500 ml or less), pre-packaged kits, or consumer chemicals as specified on the manufacturer's label.

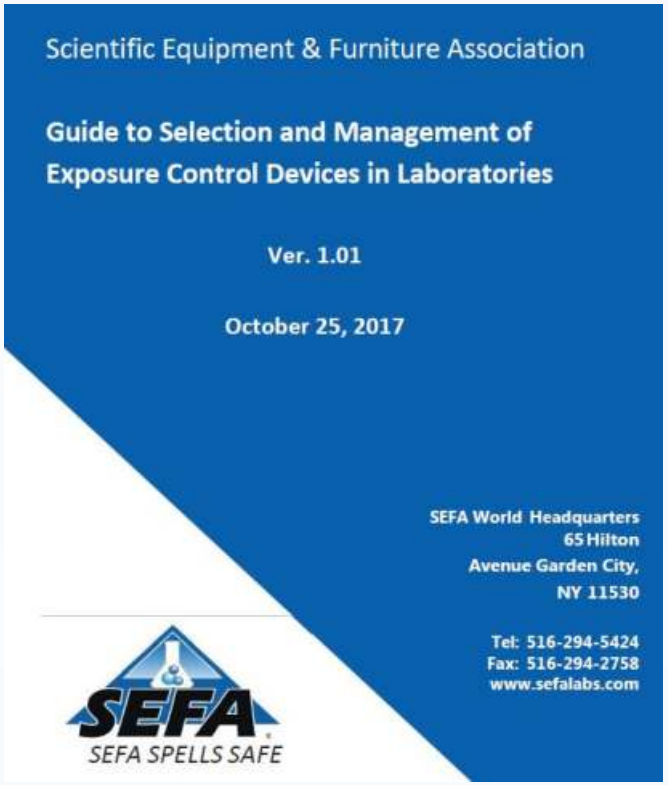
CSDL-1
Use of volatile chemicals for which dilution is an acceptable control strategy.

CSDL-2
Use of volatile chemicals where local exhaust or ventilated enclosures may be used for point sources. During use, overexposures due to inadequate air changes or inadequate mixing are not a concern. Some dilution and exchange of lab air by the general ventilation system is necessary to prevent flammable vapor buildup in the space. Therefore, general ventilation air exchange rates should be considered in terms of the potential for fugitive chemical emissions.

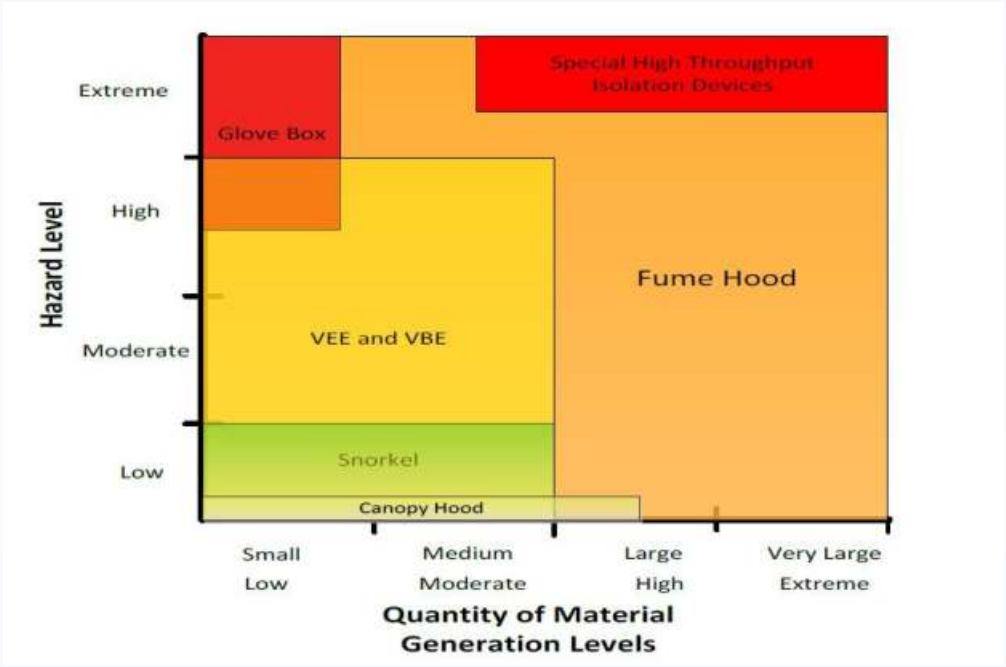
GHS Codes that might apply: H334 & H335, and H226 & H227 in small quantities, all restricted to local exhaust areas. No significant sources on the laboratory bench

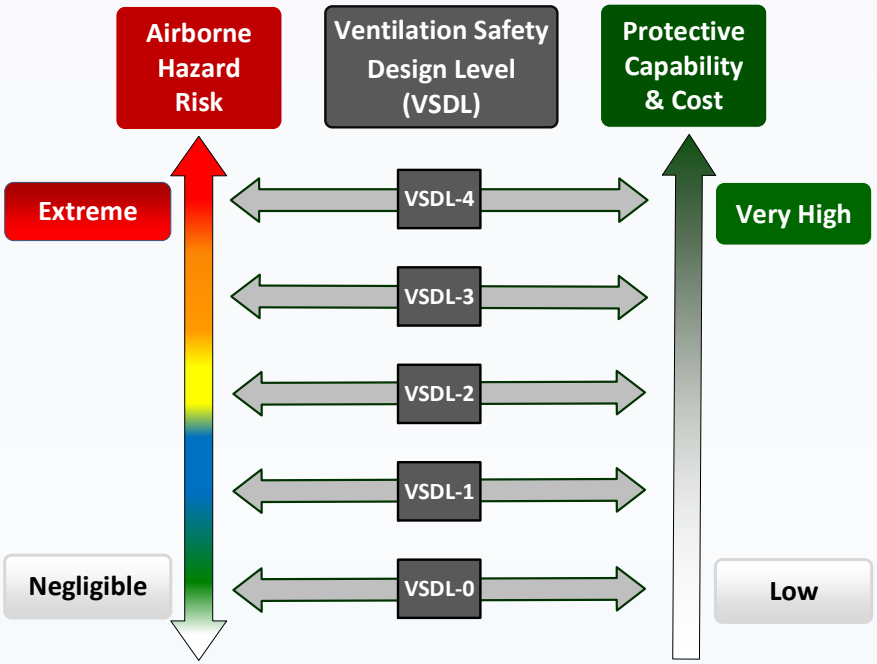
CSDL-3
Use of volatile chemicals which require use of local ventilation, such as fume hoods, to maintain safe and healthful working conditions. During use, operations without local exhaust ventilation may present a concern of overexposures due to inadequate air changes or inadequate mixing of the general ventilation system. GHS Codes that might apply: H224, H225, H226, H304, H331, & H332.

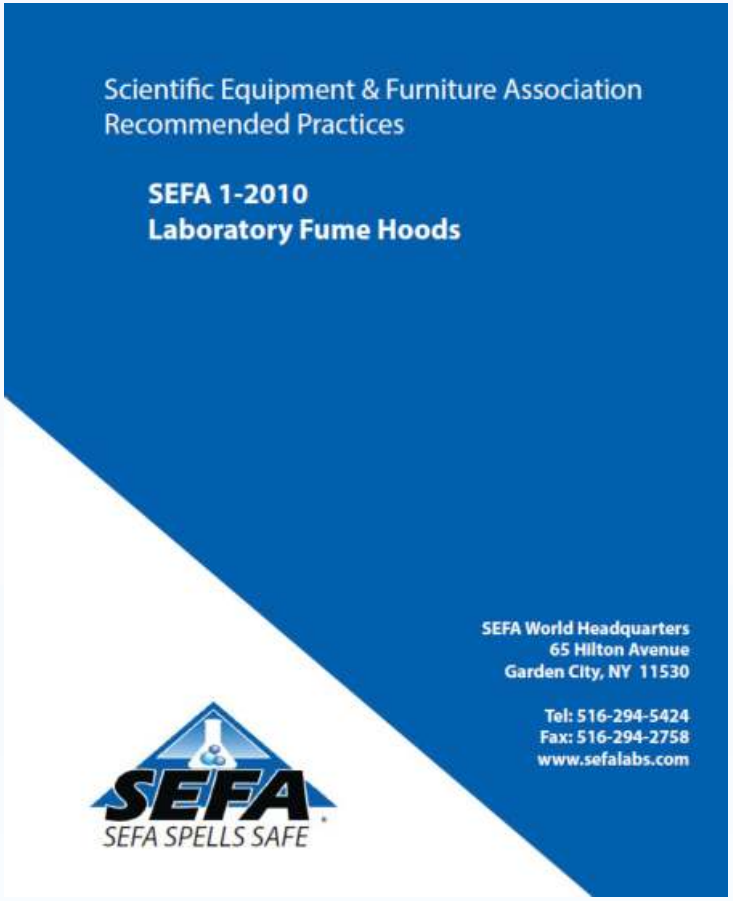
CSDL-4
Use of high hazard chemicals and/or volatile chemicals in volumes which require specific engineering designs. During use, overexposures due to inadequate air changes or inadequate mixing from the general ventilation system is a concern. Dilution and exchange of lab air is necessary to prevent flammable vapor or airborne toxic chemical buildup in space. GHS Codes that might apply: H331 & H332



SEFA published a standard on the selection of Exposure Control Devices which includes fume hoods.


Extreme
High
Moderate
Low
Hazard Level
Special High Throughput Isolation Devices
Glove Box
Fume Hood
VEE and VBE
Snorkel
Canopy Hood
Small
Low
Medium
Moderate
Large
High
Very Large
Extreme
Quantity of Material Generation Levels

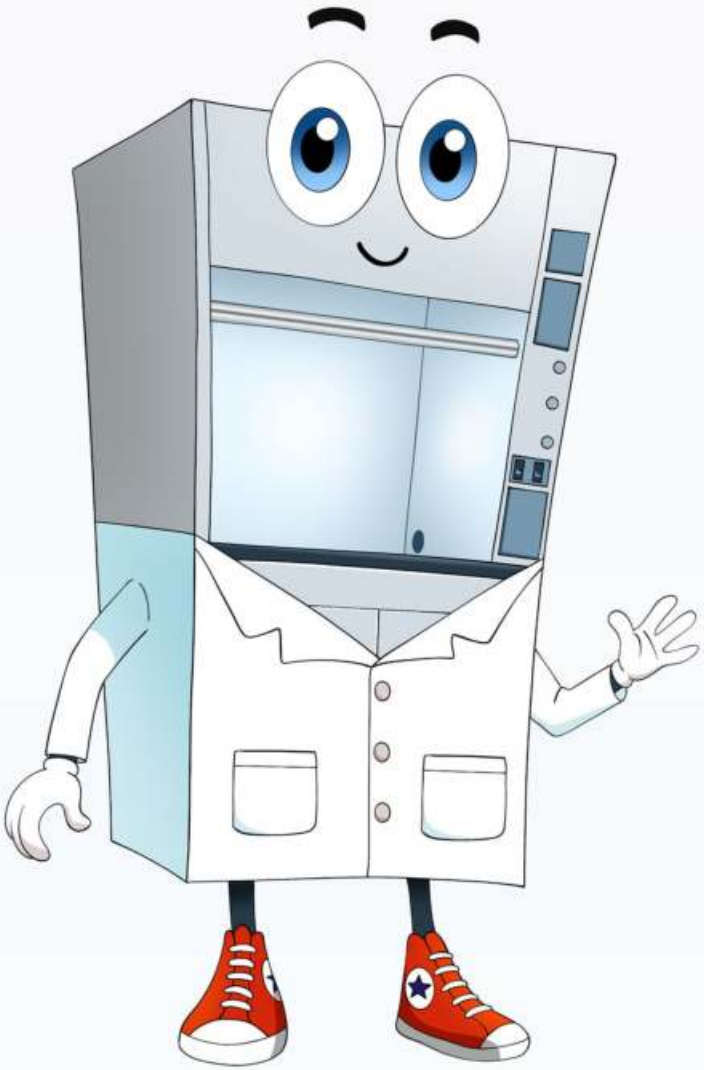

Airborne Hazard Risk
Ventilation Safety Design Level (VSDL)
Protective Capability & Cost
Extreme
Negligible
VSDL-4
VSDL-3
VSDL-2
VSDL-1
VSDL-0
Very High
Low



While somewhat outdated, this Standard still has lots of good information.

Currently SEFA is updating this document.

This is a comprehensive overview of laboratory fume hoods.



Thank you for your time and attention!

Any Questions?

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Making Labs Safer One Fume Hood at a Time

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Founder and President
Fume Hood Certified, LLC

chip@fumehoodcertified.com





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www.fumehoodperformance.com
www.testmyhood.com

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