Chemical
SAFETY AND SECURITY TRAINING

Chemical Safety and Security Officer Training

Bangkok, Thailand
June 2011

International Year of CHEMISTRY 2011

SAND No. 2009-8395P

Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company,
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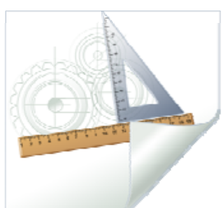
Sandia National Laboratories

Principles and Concepts of Laboratory Design

Purpose of Laboratory Design

Protect the Workers
Enable the Work
Secure the Facility
Protect the Environment
Comply with Regulations



Objectives of Laboratory Design

- Provide a safe/secure workplace
- Facilitate workplace activities
- Efficient
- Cost Effective

Barriers to Good Lab Design

- Cost
- Poor Communication
- Lack of Scientific Knowledge
- Complicated Project
- Trade-offs
- Personalities
- Maintenance

Good Laboratory Design

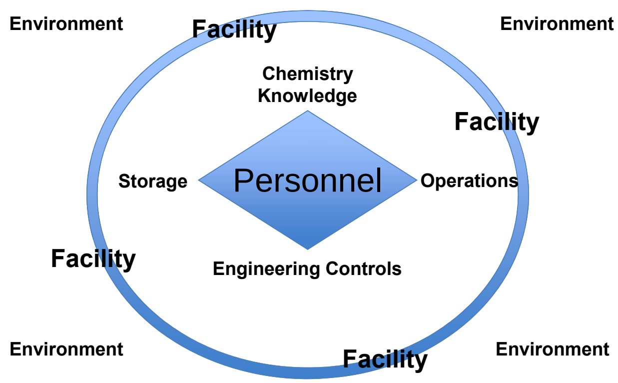
Based on:

Containment

Maximize Containment ⟷ Minimize Contamination

Redundancy is the Key

Chemical Containment Concept



Chemical Protection Depends on:

1
Chemistry Knowledge
Workers must have knowledge and understanding

2
Containment
Safe/Secure Storage
Proper Work Practices
Good Engineering Controls

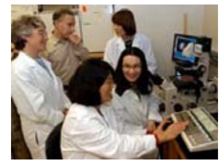
Chemical Protection Depends on, cont'd:

3

Construction

How well the facility is built

Key Stakeholders



- Architects
- Engineers
- Administrators
- Builders
- EHS Professionals
- *Laboratory Users*

Laboratory Design is an Iterative Process

Design Phases

Definition
(problems and needs)

↕ (iterative process)

Interpretation
(of requirements into design criteria)

↕ (iterative process)

Design
(translates specifications into pragmatic reality)

↕

Construction
(to accomplish goal)

Major US Standards & Guidelines

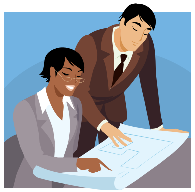
- ANSI Z9.5
  - American National Standards Institute, Z 9.5 Laboratory Ventilation Standard
- NFPA
  - National Fire Protection Association
- BOCA
  - Building Officials Code Association
- ASHRAE 110
  - American Society of Heating, Refrigeration and Air Conditioning Engineers, Standard 110 for Testing and Evaluating Laboratory Hoods
- Others
  - National Electrical Code
  - American Chemical Society, Green Chemistry Institute
    - www.acs.org/greenchemistry

Architectural Features Include:

- Layout of buildings and laboratories
- Space requirements
- Spatial arrangement of equipment and benches
- Emergency egress
- Storage requirements
- Waste requirements
- Access controls
- Security features

Lab Design Components

- Spatial
  - Floor plan
  - Location of rooms and equipment
  - Traffic flow of people and equipment
  - Access control
- Mechanical
  - Ventilation
  - Utilities
  - Effluent control
  - Control and monitoring
- Safety and Security



Factors in Laboratory Design

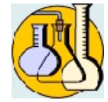
- Architectural
- HVAC*
- Safety and Security
  - Fire
  - Emergencies
  - Exposures
  - Access/exit control (facility, chemicals, equipment)

(* heating, ventilation, and air conditioning)

General Information Needed

- Number of occupants and their technical qualifications
- Space and storage requirements
- Utilities needed
- Equipment needs
- Time/duration of occupancy
- Anticipated changes in research/programs
- Sustainability (environmental, green initiatives)
- Security needs

Safety/Security Information Needed Before Design can Begin



Type of Work/Research

Type of Hazards

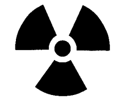
Type of Wastes

Chemical

Biological

Radiation

High Voltage



Safety/Security Information Needed for Lab Design, cont'd.

Types of Chemicals
(based on physical state and properties)

Flammable

Corrosive (acid or base)

Reactive

Acutely Toxic (poisons)

Regulated

Chronically Toxic (e.g.,carcinogens, repro-toxins)

Chemicals of security concern

Controlled Drugs

Wastes

Specific Chemical Laboratory Safety/Security Concerns

Include:

- Fire detection, alarms, and suppression systems
- Safety equipment (i.e. emergency showers, eyewash and contaminant control)
- Ventilation (i.e. laboratory hoods, glove boxes, ventilated enclosures)
- Management of chemicals and waste
- Access controls for facility and laboratories

Examples of Lab Design Considerations

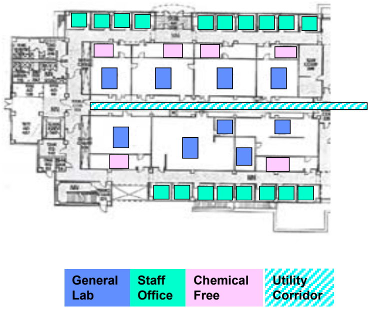
- Sample preparation and storage area
- Segregate sample digestion using acid-specialized laboratory hoods
- Segregate solvent extraction to reduce vapor contamination
- Proper eyewash placement
- Adequate egress
- Waste storage area
- Gas bottle storage

Building Layout: Divide into Zones

- Zones or control areas may have different:
  - Types and degree of hazards
  - Amounts of hazardous chemicals
- Allows better control over:
  - Personnel access
  - Hazards using
    - Equipment
    - PPE
    - Administrative procedures
- Examples: Fire safety zones, HVAC zones, Building floors

Building Layout: Corridors

- Best practice is to separate movement of:
  - General population
  - Laboratory personnel
  - Chemicals and laboratory materials.
- Internal "service corridors" between labs
  - Allow transport of chemicals away from public
  - Provide access to utilities and other support equipment
  - Provide additional lab exits with emergency doors to main corridors



Building Layout: Entrance/Exit Doors

- Good safety: two or more exits from each lab/room/building
- Good security: control who can enter a lab/room/building
- Emergency exit doors:
  - Lack handles or are locked on outside
  - Have "panic bar" on inside
  - May set off alarm when opened

Building Layout: Chemical Stockrooms

- Multiple, specialized stockrooms rather than one central storeroom
  - Chemicals dispensed across counter
  - Access restricted to stockroom personnel
  - Locked when unattended

- Teaching stockroom
  - High traffic
  - Only keep ~1 week supply of chemicals needed for student experiments
- Central Stockroom
  - Wide variety of chemicals and materials
  - Additional controls and containment for regulated, attractive, or dual-use chemicals
- Chemicals stored in compatible groups

Building Layout: Compressed Gases

- Install tanks outside building and pipe into lab
  - Long-term, frequent use of same gas
  - Highly hazardous gases
  - Restrict access
  - Out-building or outdoors, depending on conditions

Building Layout: Compressed Gases

- Tanks inside labs
  - Wide variety of gases
  - Low use rates
  - Strap to wall or bench
  - Transport safely

Building Layout: Chemical Waste

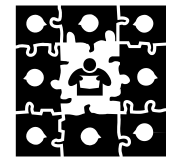
- Large volumes of chemical waste should be stored in areas with fewer people
  - Access restricted to responsible personnel
  - Locked when unattended
  - Divided into chemically compatible groups
  - Provide safety equipment and alarms

Building Layout: Chemical Waste

- Waste collection area in teaching/research labs:
  - Convenient student use
  - Emptied/moved frequently
  - Divided into chemically compatible groups
  - Provide safety equipment

Modular Laboratory Design

- Uses standard size and layout of benches, equipment and utility connections
- Customize layout for specific applications
- Allows for:
  - Cheaper lab design
  - Easier lab modifications
  - Easier lab renovations



Current Trends in Laboratory Design of Safety/Security Concern

- Open Laboratories
- Energy Conservation
- Ventilation Concerns
- Hood Designs
- Hood Manifold systems
- Effluent Modeling from Exhaust Stacks
- Lab Decommissioning

Open *vs.* Closed Laboratories

Open Laboratory

Closed Laboratory

Open *vs.* Closed Laboratories

Consider using both or having connected access:

Open laboratories

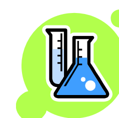
- Support team work
- Facilitates communication
- Shared:
  - Equipment
  - Bench space
  - Support staff
- Adaptable and flexible
- Easier to monitor
- Cheaper to design, build and operate
- The trend since mid 90's

Closed laboratories

- Specialized, dedicated work
- More expensive
- Less flexible
- Easier to control access
- Needed for specific work
  - NMR
  - Mass spec
  - High hazard materials
  - Dark rooms
  - Lasers

Energy Conservation, Sustainability and Green Chemistry Concerns

- Design leading to increased productivity
- Energy conservation and efficiency
- Centralized heat-generating equipment
- Manifolded hoods and ventilation
- Reduction/elimination of harmful substances and waste
- Efficient use of materials and resources
- Recycling and reuse

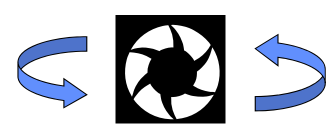


Energy Conservation Issues

- Vented Enclosures
- Ductless Hoods
- Diversity
- Manifolded Systems
- Recirculation of Room Exhaust Air
- Variable Air Volume Systems
- Automatic Sash Closers
- Air Change per Hour
- Low Flow Hoods

Ventilation Considerations Include

- Heating and cooling needs
- Maintaining directional airflow
- Type of hoods
- Single vs. manifolded hoods



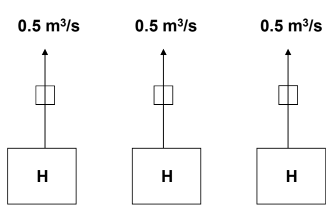
Laboratory hood design and ventilation are discussed in detail in later presentations.

General Laboratory Hood Considerations

- Determine minimum exhaust requirements.
- Communicate hood limitations to users.
- Label restrictions e.g., no perchloric acid.
- Alarm systems
- Consider future needs.

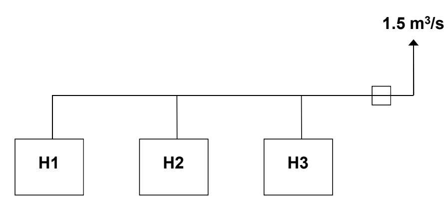
Hood Manifold Considerations

Single Hood - Single Fan



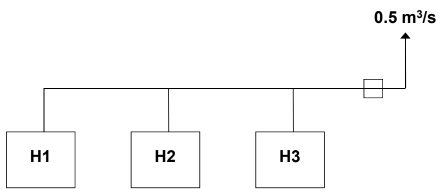
Hood Manifold Considerations

Manifold: 3 Hoods, 1 Fan



Hood Manifold Considerations

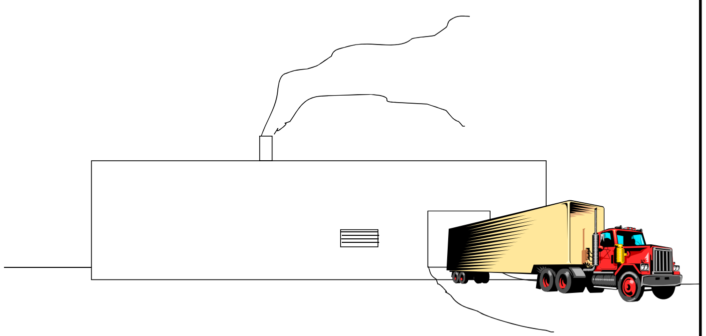
Hood Diversity = 33%



Avoid re-entrainment

Disperse emissions straight upward and downwind!

Ventilation Design: Avoid Exhaust Recirculation



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Lab Layout

- Try to locate hoods, utilities and safety equipment in the same relative position in all labs.
- Locate sinks centrally
- Space between benches should allow people to pass each other (≥1.5 m).
- Details on these topics given in later presentations:
  - Lab hoods
  - Safety showers / eyewashes
  - Chemical management

Teaching Lab Layout

- Higher occupancy than research labs
  - Need easy movement of people around lab
  - Two safe exits
  - Benches in "Islands"
  - 2m distance between benches so students can work "back-to-back"
  - Locate instruments, sinks, supply areas away from hoods to minimize traffic in front of them

- Floor space required per student
  - 3.0 m^2 absolute minimum
  - 6.5 m^2 allowing space for utilities, storage, cleanup, etc.

Lab Layout

- Construction materials should be appropriate for chemicals
  - Benchtops
  - Cabinets & shelving
  - Flooring
  - Avoid metal drainpipes
- Store chemicals and waste securely – not easily spilled or knocked over.
- Keep bulk chemicals in stockroom - not lab.
- Control access to labs, especially during off-hours

Laboratory Modifications or Decommissioning

- When a laboratory is modified or vacated, ensure that:
  - Chemicals have been safely moved to another lab, returned to the stockroom, or properly disposed of.
  - Any contamination has been removed from the:
    - Room (floor, ceiling, walls)
    - Furniture
    - Equipment and fixtures
    - Plumbing system
    - HVAC ductwork

Conclusion

Together we can design, build, and operate safe/secure laboratories!

References

- “Prudent Practices in the Laboratory: Handling and Disposal of Chemicals,” National Academy Press, 1995, ISBN 0-309-05229-7 also available online: http://www.nap.edu/catalog.php?record_id=4911
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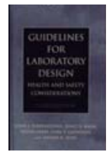
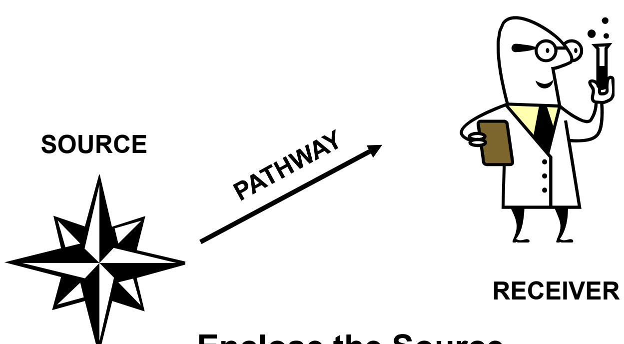
- “Handbook of Chemical Health and Safety”, Robert J. Alaimo, Ed., Oxford University Press, 2001, ISBN 0-8412-3670-4
- “Guidelines for Laboratory Design: Health and Safety Considerations, 3rd edition” Louis J. DiBerardinis, et al., Wiley, 2001, ISBN 0-471-25447-9



Principles and Concepts of Laboratory Ventilation

Hazardous Exposure



Enclose the Source

Hazardous Exposure

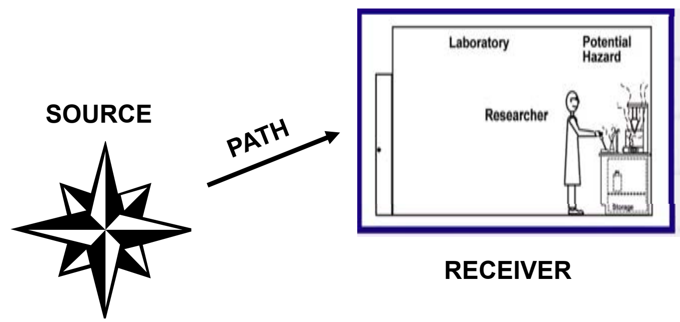
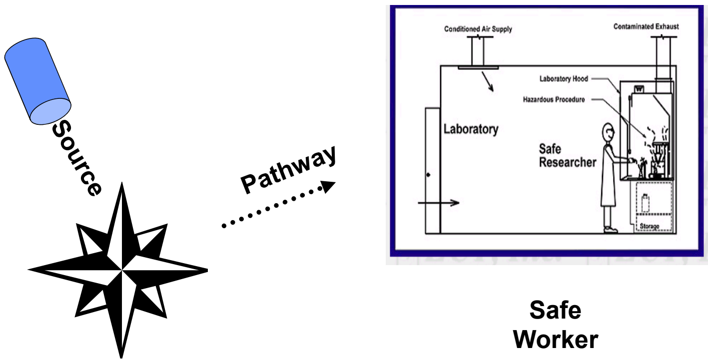


Illustration courtesy, Tom Smith, ECT Technologies, Cary NC USA

Ventilation



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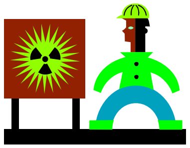
Reminder: Prioritization of Controls

- Engineering controls
- Administrative controls & Operational work practices
- Personal protective equipment

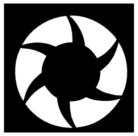
Engineering Controls

- **Change the process**
  - Eliminate the hazard
- **Substitution**
  - Non-hazardous substance for hazardous
    - **Trichloroethlyene for carbon tetrachloride**
    - **Toluene for benzene**
- **Isolate or enclose**
  - Process or worker
    - **Barrier**
- **Ventilation**
  - Dilution (general ventilation - not good)
  - Local Exhaust Ventilation (LEV)



Uses of Ventilation

- **Keep gas / vapor concentration below OEL**
- **Air movement to reduce heat stress**
- **Keep toxic contaminants below OEL**
- **Confined space entry**
- **Limit CO_2 buildup**
- **Control clean room or hospital environments**

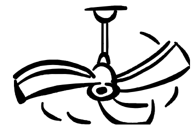


OEL = Occupational Exposure Limit

Limitations of Ventilation

- **May require large amounts of air (expensive)**
- **Outdoor air may create problems**
  - Need tempering
    - Heat, cool, dehumidify, humidify
  - May be "contaminated"
- **System design**
  - Remove contaminants from breathing zone
  - Insufficient air velocity or volume
- **Contaminant cleanup or discharge**
- **Users need training**

Engineering Ventilation Controls



General dilution ventilation

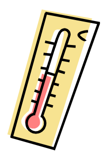
Not good

Local exhaust ventilation

Preferred

Use General Dilution Ventilation

- **For Control of:**
  - **Temperature**
  - **Harmless Substances**
  - **Nuisances**
  - **Odors**



Use Local Exhaust Ventilation (LEV)

- To enclose and contain
- When contaminant is toxic
- Employee works near the contamination
- When complete containment/enclosure is not feasible

Local Exhaust Ventilation

LEV Principles

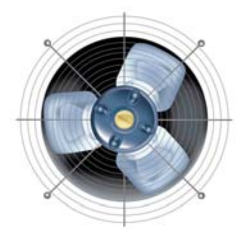
- Enclose source
- Capture contaminant near source
- Keep contaminant out of breathing zone
- Provide adequate make-up air
- Discharge away from air intake

Definitions

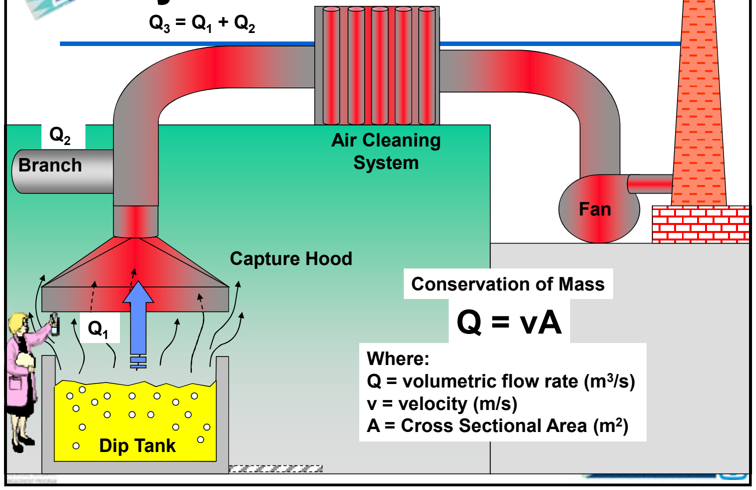
- **Hood** – includes any suction device, regardless of shape, that encloses, captures or removes contaminants.
- **Dilution Ventilation** – moves room air around by a fan that is sometimes exhausted to the outside.
- **Local Ventilation (LEV)** – ventilation system that captures and removes emitted contaminants.

System Components

- Hood
- Duct Work
- Optional Air Cleaning Devices
- Fan
- Discharge



System Characteristics



Q = vA

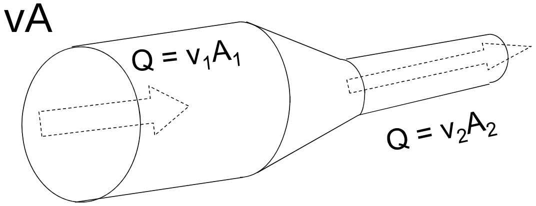
Q = volumetric flow rate of air (m^3/s)

v = velocity of air through an area (m/s)

A = cross sectional area air flows through (m^2)

Volumetric Flow Rate

Q = vA

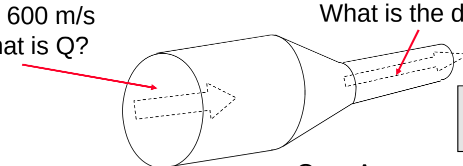


Q = Volumetric Flow Rate, m^3/s
v = Average Velocity, m/s
A = Cross-sectional Area, m^2

Flow Rate Example

Duct diameter = 1 m
v = 600 m/s
What is Q?

Duct diameter = 0.5 m
What is the duct velocity?



For circular ducts
$A = \pi d^2/4$

Q = vA

Q = (600 m/s)(π[1m]^2/4)

Q = **471 m^3/s**

Q = vA

471 m^3/s = v (π[0.5m]^2/4)

v = 2403 m/s

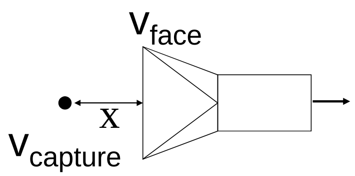
System Losses

- **Friction Loss**
  - Rougher surfaces lead to higher velocity
  - $FL \propto LV^2/d$
  - FL units of pipe length
- **Dynamic Loss**
  - Turbulence from elbows or cross-sectional area changes or transition
  - Turbulence at hood entry
    - Coefficient of Entry "C_e" measures efficiency of hood entry
  - DL increases with abruptness of elbow or transition
  - DL units of equivalent pipe length or fraction of VP
- **Pressure losses from system devices**
  - Fans, air cleaners, etc.

Press Room – Ventilation System

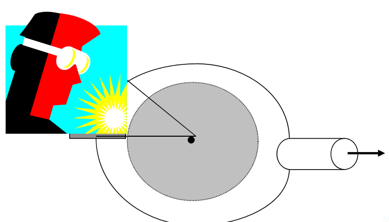
Local Exhaust Hoods

CAPTURE

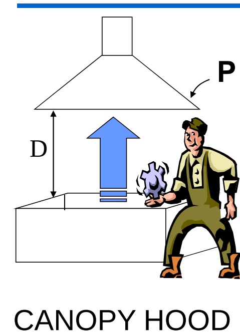


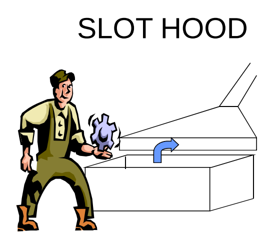
$$Q = vA$$

ENCLOSURE



Local Exhaust Hoods



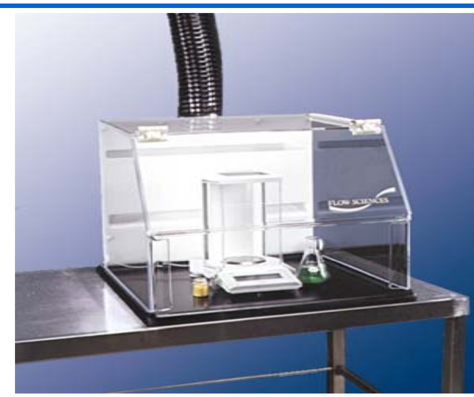


Canopy Hood – Machine Shop

Portable Welding Hood

Traditional Laboratory Chemical Hood

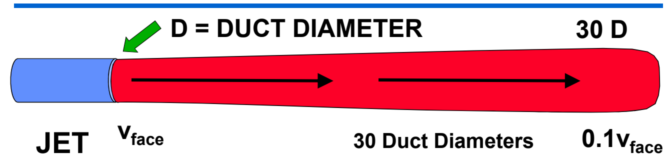
Special Purpose Hoods Vented to the Outside

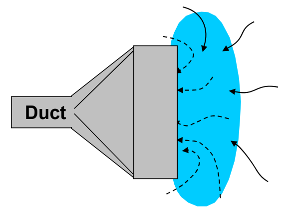


Design Goals for Balance Enclosures

- High level of containment
- Stable balance readings
- Ergonomic design, visibility, comfort
- Task specific flexibility
- Energy efficient
  - 2' (0.6 m) enclosure = 100 CFM (0.047 m^3/s) air
  - 6' (2 m) hood = 1200 CFM (0.566 m^3/s) air
  - 1200 CFM (0.566 m^3/s) = $5K/yr.

Flow at Exit and Entry



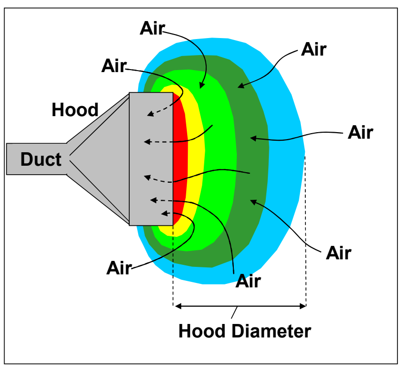


Capture of contaminant is only effective within one (1) duct diameter

Hood Capture Velocities

Equal Velocity Zones

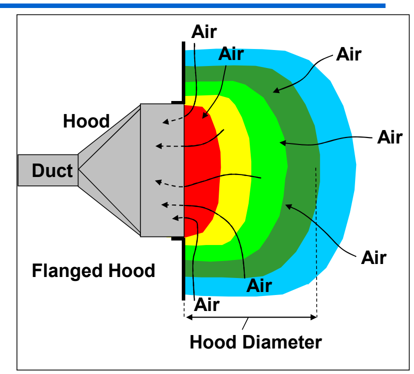
% Hood Capture Velocity	
	~100%
	~60%
	~30%
	~15%
	~7.5%



Hood Capture Velocities

Equal Velocity Zones

% Hood Capture Velocity	
	~100%
	~60%
	~30%
	~15%
	~7.5%

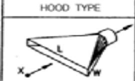
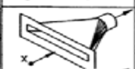
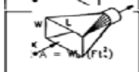
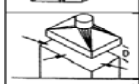
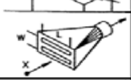
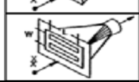


Recommended Capture Velocities

CONDITION	EXAMPLES	CAPTURE VELOCITY fpm (m/s)
No velocity, Quiet air	Evaporation from tanks, degreasers	50 – 100 (0.25 – 0.5)
Low velocity, moderately still air	Spray booths, container filling, welding, plating	100 – 200 (0.5 – 1.0)
Active generation into rapid air motion	Spray painting (shallow booths), crushers	200 – 500 (1.0 – 2.5)
High initial velocity into very rapid air motion	Grinding, abrasive blasting, tumbling	500 – 2000 (2.5 – 10.1)

Design Duct Velocities

CONTAMINANT	EXAMPLES	DESIGN VELOCITY (fpm, m/s)
Vapors, gases, smoke	Vapors, gases, smoke	1000 – 2000, 5.0 – 10.1
Fumes	Welding	2000 – 2500, 10.1 – 12.7
Very fine dust	Cotton lint	2500 - 3000, 12.7 – 15.2
Dry dusts & powders	Cotton dust	3000 - 4000, 15.2 – 20.3
Industrial dust	Grinding dust, limestone dust	3500 - 4000 , 17.8 – 20.3
Heavy dust	Sawdust, metal turnings	4000 - 4500, 20.3 – 22.9
Heavy/moist dusts	Lead dusts, cement dust	> 4500, > 22.9

HOOD TYPE	DESCRIPTION	ASPECT RATIO, W/L	AIR FLOW
	SLOT	0.2 OR LESS	Q = 3.7 LVX
	FLANGED SLOT	0.2 OR LESS	Q = 2.6 LVX
	PLAIN OPENING	0.2 OR GREATER AND ROUND	$Q = V(10X^2 + A)$
	FLANGED OPENING	0.2 OR GREATER AND ROUND	$Q = 0.75V(10X^2 + A)$
	BOOTH	TO SUIT WORK	Q = VA = VWH
	CANOPY	TO SUIT WORK	Q = 1.4 PVD SEE FIG. VS-99-03 P = PERIMETER D = HEIGHT ABOVE WORK
	PLAIN MULTIPLE SLOT OPENING 2 OR MORE SLOTS	0.2 OR GREATER	$Q = V(10X^2 + A)$
	FLANGED MULTIPLE SLOT OPENING 2 OR MORE SLOTS	0.2 OR GREATER	$Q = 0.75V(10X^2 + A)$

Capture Velocity

- Plain End Opening — $Q = v(10X^2 + A)$
- Flanged Opening — $Q = 0.75v(10X^2 + A)$
- Slot — Q = 3.7 LvX
- Flanged Slot — Q = 2.6 LvX
- Booth — Q = vWH
- Canopy — Q = 1.4 PvX

X = distance in front of opening
L = Length W = Width H = Height
v = velocity A = Area Q = Quantity of air

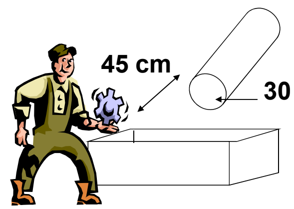
Hood Type Calculations

Plain Opening: $Q = v\,(10X^2 + A)$
Flanged Opening: $Q = 0.75\,v\,(10X^2 + A)$

Q = Quantity of air (m^3/s)
v = Velocity of air (m/s)
X = Distance from hood face to point of contaminant generation (m)
A = Area (m^2)

Hood Calculations: Example

Determine the air flow required to capture Trichloroethylene vapor from a degreaser using a 30 cm diameter plain end duct whose opening is 45 cm from the vapor source.



Assume a capture velocity = 0.5 m/s

$$A = \frac{\pi\,(30\ cm/100)^2}{4} = 0.071 m^2$$

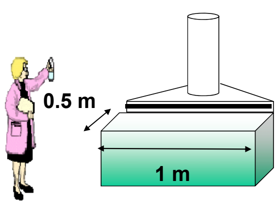
$$Q = v\,(10X^2 + A)$$

$$Q = 0.5\ m/s\ [(10 \times 0.45^2) + 0.071\ m^2]$$

$$Q = 0.5\ m/s\ (2.096\ m^2) = 1.048\ m^3/s$$

Hood Calculations: Example

Determine the air flow required to capture Trichloroethylene vapor from a degreaser using a flanged slotted hood with a 4 cm slot, 1 m long, located on the back side of the dip tank 0.5 m from the front edge.



Assume a capture velocity of 0.5 m/s

$$Q = 2.6LvX$$

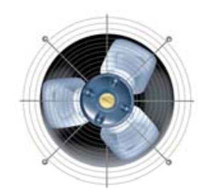
$$Q = 2.6(1\ m)(0.5\ m/s)(0.5\ m)$$

$$Q = 0.65\ m^3/s$$

The flanged slotted hood uses much less air and it is probably more effective overall.

Fan Speed and Air Flow

Fan rated to deliver 5.0 m^3/s of air running at 400 RPM. If fan speed increases by 25% to 500 RPM, what is the new air flow?



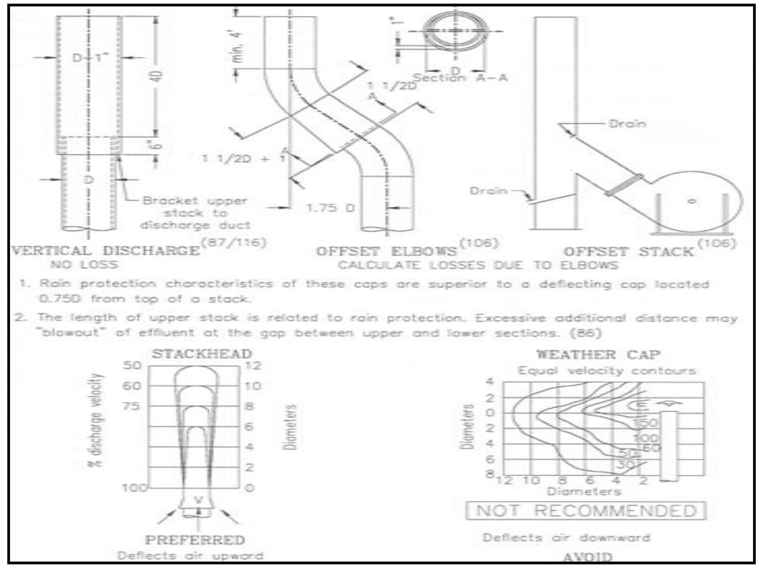
$$Q \propto RPM$$

$$Q_2 = Q_1\left(\frac{RPM_2}{RPM_1}\right)$$

$$Q_2 = 5\left(\frac{500}{400}\right) = 6.25\ m^3/s$$

Hood Exhaust

- Height
- Discharge velocity
- Configuration



Engineering Controls: Avoid Exhaust Recirculation

Hood Exhaust

Air Intake

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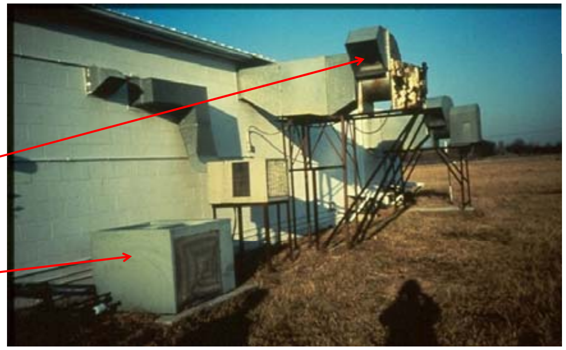
Engineering Controls: Avoid Exhaust Recirculation

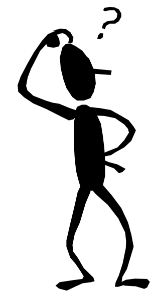


High Hazard Hood Exhaust

Air Intake

Potential Issues

- Insufficient air volume
- Too much air flow
- Wrong location
- Wrong configuration
- Bad hood design
- Duct velocity too low
- Insufficient make up air
- Clogged system
- Noise



Acknowledgements

- Tom Smith, Exposure Control Technologies, Cary NC USA http://www.labhoodpro.com/
- Nelson Couch, PhD, CIH, CSP, Triangle Health & Safety Inc., Durham, NC USA ncouch@earthlink.net
- Ray Ryan, Flow Sciences International, Leland NC, USA http://www.flowsciences.com

Any Questions?

BREAK

Laboratory Chemical Hoods:

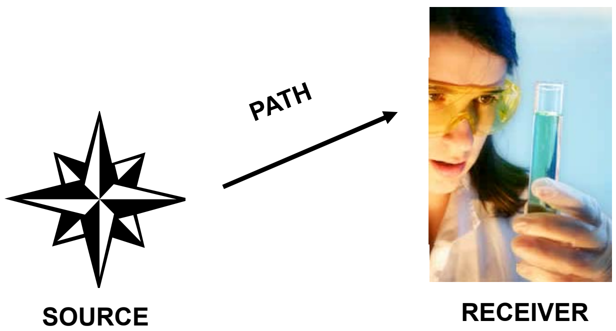
How they work & when they don't.

Improper Hood Use

Laboratory Chemical Hood

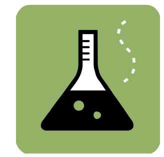
- Also called a fume hood or fume cupboard
- Designed to limit exposure to hazardous or unpleasant aerosols
- First used by alchemists 500 years ago

Control Concept



LEV Objectives

- **Maximize Containment**
- **Minimize Contamination**
- **Redundancy is the Key**

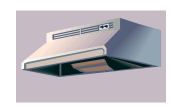


LEV Implementation

- Identify/Characterize Contaminant
- Characterize Air Movement
- Identify Alternative Controls
- Choose Most Effective Control
- Implement Control
- Evaluate Control
- Maintain Control

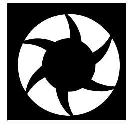
LEV Capture Ability

- Hood configuration (type of hood)
- Extent of enclosure
  (e.g., glove boxes completely enclose)
- Air movement in hood
  (smooth, laminar, non-turbulent)



Duct Design

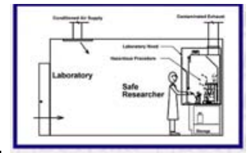
- Provide adequate capture velocity
  - Usually 80-120 fpm (0.4 - 0.6 m/s)



- Maintain duct transport velocity
  - For chemical laboratories ~ 2500 cfm ($1.2\ m^3/s$)

Duct Design, cont'd.

- Keep system balanced,
  - i.e., equalize supply and return air
  - match airflows among manifolded hoods



- Minimize power consumption
  - i.e., conserve energy
  - save money

http://www.clf.rl.ac.uk/facilities/AstraWeb/images/Photo7/Air_duct_TA3.JPG

LEV Hood Design Requirements

- Capture emissions close to source.
- Move contamination away from breathing zone.
- Consider existing air movement when locating hood.
- Minimize air movement in source area.
- Should not interfere with work.

Laboratory Hoods

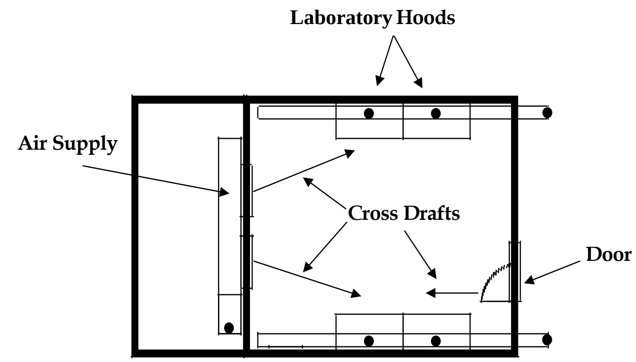
Laboratory hoods and ventilation are the basis of engineering controls.

But they must be properly: *selected*, *located*, *used*, and *maintained*.

Hood Location Requirements

- As near to contamination source as possible
- So contamination moves away from operator
- Minimize cross-drafts
- Don't place near windows and doors
- Don't place near air conditioning/heater diffuser
- Doesn't interfere with other workers
- Locate out of traffic flow
- Place near rear of laboratory

Problem Cross-drafts



A person walking at 2-3 mph (0.9-1.3 m/s) generates cross drafts of 250 fpm (1.3 m/s) that can interfere with hood capture

Principles of Hood Design and Operation

- Enclose as much of the operation as possible
- Place utility controls (gas, electric) outside or as near hood front as possible
- Hood lights should be vapor tight
- Mount hood motor *outside building* and *away from* building *air intakes*
- Don't use hoods for uses not intended (e.g., perchloric acid digestion, radioisotopes)
- Ensure duct material compatible with exhausts
- Don't use without indication it is working properly

Hood Design & Operation, cont'd.

- Don't put your head in the hood.
- Use proper PPE (gloves, eyewear, etc)
- Place large equipment above surface on 5 cm blocks to allow uniform air flow
- Lower sash height to 30 - 50 cm during operation
- Keep sash fully closed when not in use
- Use liner or tray inside hood to contain spills

http://www.news.harvard.edu/gazette/daily/0403/photos/03-meltonstem_1.jpg

Hood Design & Operation, cont'd.

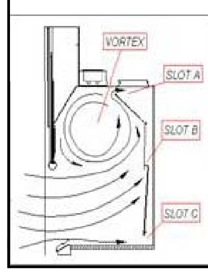
- Work in the center of hood and 15 cm in from hood sash.
- Don't store chemicals or equipment in hood.
- Don't block baffles (slots).
- Maintain hood regularly (check fan belt, lubricate motor).
- Regularly evaluate hood (flow rate, mark operating sash height).
- Reports problems, concerns, malfunctions immediately.

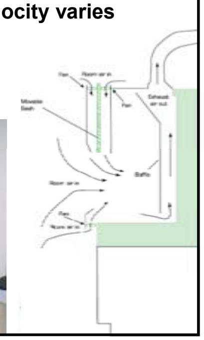
Laboratory Hood Types

- Constant Air Volume (CAV)
  - Traditional/Standard/Conventional
  - Bypass
  - HOPEC (horizontal/vertical sash)
  - Auxiliary Air (not recommended for Lab operations)
- Variable Air Volume (VAV)

Traditional Constant Volume Hood

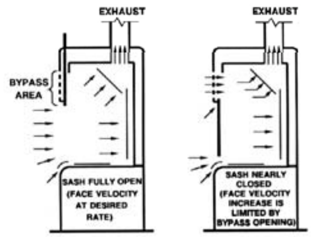
- All make up air enters through hood face.
- Air exhausted is constant regardless of size of face opening or sash height.
- Volume of air movement is constant but velocity varies with sash height.





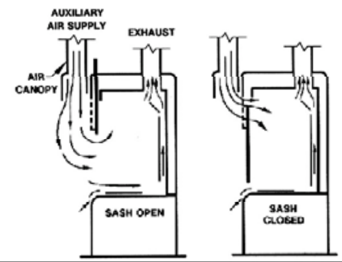
Constant Volume Bypass Hood

- Make up air enters through face and through a bypass.
- Bypass opening varies in size as sash is opened or closed.
- As sash moves, an almost equivalent area is uncovered to maintain a constant open area, hence, a constant volume of air movement through the face is achieved.



Auxiliary Air Hood
(not recommended for Lab operations*)

- Designed to reduce energy consumption.
- Discharges unconditioned make-up/auxiliary air from outside directly above and over user in front of hood.
- Uncomfortable to use and can produce turbulence at hood face.



* According to ANSI Z9.5

HOPEC Hood
(Hand Operated Positive Energy Control)

Combination Horizontal/vertical sash limits sash opening to no more that 50%.

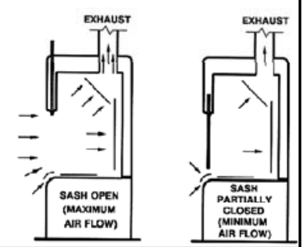
Maintains constant air volume and limits energy consumption.

Variable Air Volume (VAV) Hood

Uses mechanical and electronic controls to maintain constant air velocity.

Interfaces with room supply air to conserve energy by maintaining constant face velocity.

Uses complicated electronic components that require special training to maintain.



Specialized Hoods

- Perchloric acid (with water wash down)
- Radiological (with special filters)
- Floor level (improperly called walk-in)
- Distillation/California hoods (~1.5 ft or 0.5m above floor)
- Canopy hoods (not suitable for most lab operations)
- Slot hoods
- Ductless fume hoods
- Vented enclosures or special purpose hoods
- Glove Boxes (complete enclosure)
- Biological Safety Cabinets (BSC)

Specialized Hoods

ADA Hood

Glove Box

Canopy Hood

Floor Hood

Example: Typical Walk-In Fume Hood

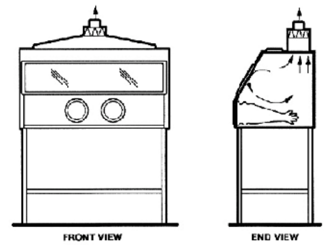
EXAMPLE: "Snorkel" Fume Extractor

Extracting Lead Solder Fumes

Example: Canopy Hood

Glove Boxes

- Glove boxes are used when the toxicity, radioactivity level, or oxygen reactivity of the substances under study pose too great a hazard for use within a fume hood.
- The major advantage is protection for the worker and the product.

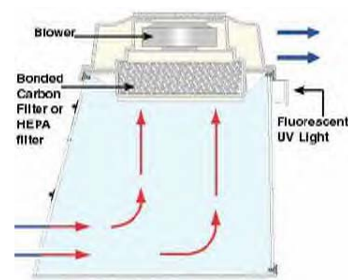


Special purpose vented hood

Chemical weighing station

Bulk powder transfer station

Ductless Hoods



Ductless Hoods

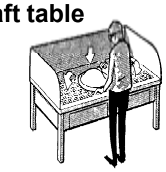
Should only be used in laboratories with:

- Small quantities of known non-volatile substances.
- Only with HEPA filters
- Never with volatile substances
- Unless breakthrough time for the specific chemical being used is known, carbon filters are unreliable.

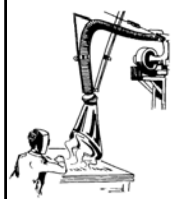
Specialized Hoods

Dust hood, Animal feed

Downdraft table



Snorkel hood



Slot Hood

Biological Safety Cabinets (BSC)

Several types/classes and configurations.

Designed to protect the sample, and sometimes the worker, from biological contamination.

Most types not suitable for hazardous, volatile chemicals.

Often not vented to the outside.

Reference: http://www.cdc.gov/od/ohs/biosfty/bsc/bsc.htm

Hood Problems and Pitfalls

- **Face velocity**
  - **Recommended 80 - 100 fpm (0.4 - 0.5 m/s)**
- **Air changes/hour**
  - **Recommended 6 – 10 / hour**

Neither of these measurements can guarantee hood capture or containment.

Hood Evaluation

- Face Velocity, a necessary but not sufficient condition.
- Smoke Tubes
- Smoke Candles
- Incense
- ASHRAE 110-1995 Test (SF_6)
- Protection Factors (300-10,000):

PF = <u>Contaminant Concentration in Exhaust Air</u>
Contaminant Concentration in Breathing Zone

Ventilation System Evaluation

- Smoke sources
  - Visualize air movement
  - Assess capture effectiveness
- Smoke tubes
- Smoke candles
- Theatrical smoke generators
- Incense sticks

Ventilation System Evaluation

- Velocity measurements
  - Anemometer/velometer
    - fpm or m/s
    - Directional
  - Hot-wire anemometer
    - fpm or m/s
    - Non-directional

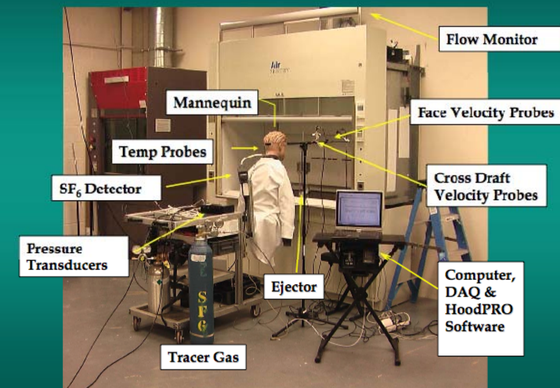
Hood Smoke Evaluation Face velocity *vs.* Containment

- **Lab hood performance testing evaluates containment of contamination. How do we determine containment?**
- **Is face velocity the right measurement?**
- **Studies show that 59% of the hoods passed face velocity criteria, but only 13% of these hoods met ASHRAE 110 tracer-gas standards.**
- **30% - 50% of hoods leaking excessive levels of contaminants pass face velocity tests.**
- **Lab hoods with face velocities as low as 50 fpm (0.25 m/s) can provide protection factors 2,200 times greater than hoods with face velocities of 150 fpm (0.76 m/s).**

ASHRAE 110 Containment Test

- Measures containment using SF_6 as a tracer gas
- SF_6 is generated inside the hood at 4L/min.
- A mannequin with a detector in the breathing zone (mouth) is placed outside the hood
- The detector is connected to a recorder
- The hood is also tested with smoke
- The hood is subjected to a walk-by test
- Effect of opening & closing sash is determined

Fume Hood Test Apparatus

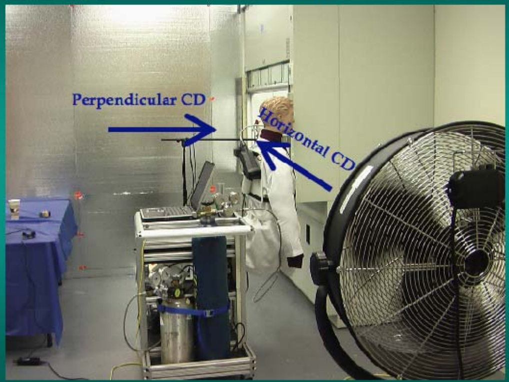


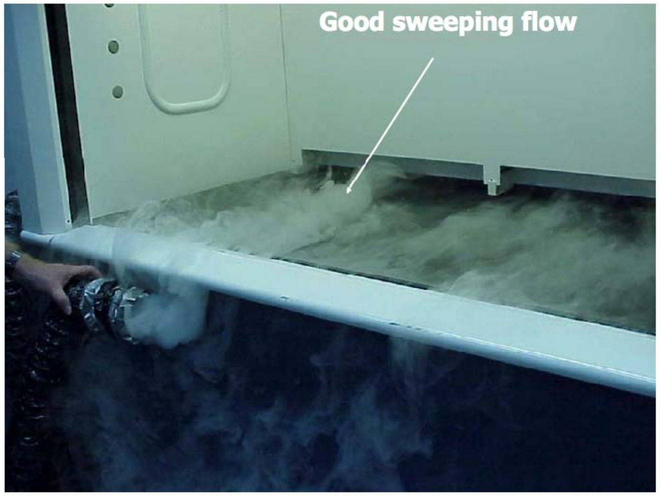
Gas Cylinder Inside Hood

Hood Loading Challenge Test

Walk-By Challenge Test

Cross Draft Challenge Tests





Summary of Results

- Improved Aerodynamics and Airflow Patterns
- Equivalent Performance (Containment) as Typical Fume Hoods
  - < 0.05 ppm As Manufactured
  - < 0.1 ppm As Installed and As Used
  - Better Containment With Sashes Full Open
  - Less Dependence on Mannequin Height
- Minimum Face Velocity at Least 60 fpm
- Still Affected by External Factors
  - Cross Drafts greater than 50 fpm
  - Perpendicular Cross Drafts are worse than Horizontal Drafts
  - Hood Loading and Thermal Challenges Can Influence Containment
  - Traffic Past Hood Can Influence Containment
- Not All HP Hoods Perform The Same
- Fume Hood Monitors Need Better Accuracy and Precision at Low Velocities

Conclusions

- Ensuring laboratory hood safety depends on many factors including:
  - Hood design
  - Hood use
  - Lab design
  - System operation

Acknowledgements

- Tom Smith ECT, Inc., Cary NC USA
- University of North Carolina, Chapel Hill NC USA
- Texas A & M University
- Flow Sciences Inc, Leland NC USA
- Knutson Ventilation, Edina MN USA
- AirClean Inc, Raleigh NC USA

Any Questions?

Chemical Management

Best Practices

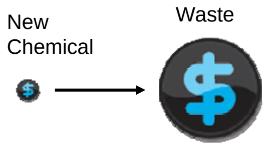
Cradle - to - grave care of chemicals

Receipt → Storage →

Use → Disposal

Chemical Management is a Best Practice for Safety *and* Security

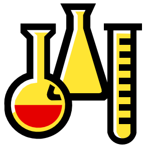
- Reduces hazardous waste
- Reduces cost
  - New purchases
  - Waste disposal
  - More efficient
- Improves security
  - Insider threat
  - Outsider threat
- Facilitates environmental compliance
- Improves quality of research
- Improves quality of lab instruction



Proper chemical management program has several essential elements

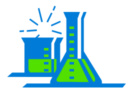
Chemical Management Elements

- Source reduction
- Procedure for chemical ordering and disposal
- Inventory and tracking
- Storage in stockrooms
- Access control
- Recycling of chemicals, containers and packages



Plan experiments in advance!

What chemicals are needed?



How much is needed?

How will the chemicals be handled?

What are the reaction products?

How will the chemical be stored?

How will disposal take place?

Inventory management

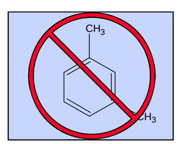
Less is Better !

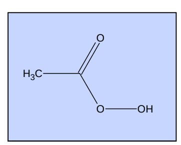
- Order only what you need
- Reduce size of experiment
  - It cost less to store
  - It cost less to dispose

"Less is Better: Guide to minimizing waste in laboratories", Task Force on Laboratory Environment, Health and Safety, American Chemical Society, 2002. http://portal.acs.org/portal/acs/corg/content?_nfpb=true&_pageLabel=PP_SUPERARTICLE&node_id=2230&use_sec=false&sec_url_var=region1&__uuid=ef91c89e-8b83-43e6-bcd0-ff5b9ca0ca33

Substitute reagents to reduce waste

- Citrus based solvents for xylene in histology lab
- Peracetic acid for formaldehyde for cleaning kidney dialysis machines
- Non mercury thermometers
- Enzyme and peroxide based cleaners for chromerge (NoChromix)
- When purchasing automated equipment think of chemical waste





Best practice - ordering and stocking chemicals

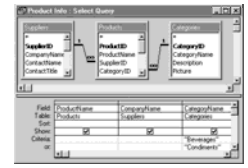
- See if your institution already has it (surplus)
- Order minimum needed (large quantities are not a bargain)
- Check on special storage (refrigeration, dry box…)
- Mark the receipt /open date (unstable chemical)
- Can it eventually be disposed of (rad waste, mixed waste)

Ordering chemicals- chemical inventory

- Database or Spreadsheets are tools to track the chemical inventory
  - Barcoding can be used
  - Chemicals can be found easily
  - Chemical ages can be tracked
  - Chemical standards maintain traceability
  - Disposal can be documented
- Physical reconciliation
  - Assures accuracy of database
  - Provides visual inspection of chemical condition

Inventory and tracking

Database or spreadsheet designs



Home made – Access or Excel programs

Freeware – Based on Access or Excel

Commercial – Chemicals and MSDS included

Database helps safely track and report chemical storage and use

Searches and Reports:
Find an (M)SDS
Chemical Inventory Search Menu
Chemical Regulatory Reports Search Menu
Find Chemical Storage Locations

Transfers, Removal, Verification and Inventory Entry:
Transfer or Remove a Bar-coded Chemical from the Inventory
Verify Chemical Inventory Menu
Add Chemical Inventory
Chemical Exchange Menu

Procedures, Forms and Links:
See Inventory procedures, forms and other documents
See Other Chemical Related Links

Inventory queries

Chemical or tradename search
CAS number search
Ingredient search
Location/organization search
Location owner search
Requester search
Barcode search

Query result for toluene – barcode, location, department, quantity and order date

BARCODE	LOCATION	DEPT	QUANTITY	UNIT	Purchase Date
AQ00600682	NM/518/1111	1725	1	L	10/24/2006
AQ00602185	NM/518/1123	1111	100	mL	11/20/2006
AQ00582298	NM/518/1302	1131	1	L	8/8/2006
AQ00602186	NM/518/1302	1131	100	mL	11/20/2006
AQ00602187	NM/518/1302	1131	100	mL	11/20/2006
AQ00582307	NM/518/1302	1131	4	L	8/8/2006

(M)SDS and Certificates of Analysis may also be included

Chemicals likely to be useful in other labs

ACIDS
Acetic acid (glacial)
Hydrochloric acid
Sulfuric acid

SOLVENTS
Dichloromethane (methylene chloride), Acetone Chloroform, Ethyl acetate, Glycerol, Hexanes Isopropyl alcohol, Methanol, Petroleum ether Toluene, Xylenes

OXIDIZERS
Bromine, Potassium chlorate, Potassium dichromate, Silver nitrate

POISONS
Indicators, Iodine (solid or solution) Metals (powders, dust, shot)
Sodium, calcium, silver, and potassium salts

Excess chemicals are made available to others and can be searched

CHEMICAL NAME	MSDS	QTY	STATE	PURCHASE DATE	OPEN?
DEVCON 5 MINUTE EPOXY KIT	NL203800	2.5 OZ	Liquid	07/25/2001	Not Open
5 MINUTE EPOXY KIT	NL203800	2.5 OZ	Liquid	08/06/2003	Not Open
TOLUENE	OHS23590	500.0 ML	Liquid	03/25/1999	Not Open
TOLUENE	OHS23590	500.0 ML	Liquid	03/25/1999	Not Open

Inventory management

Less is Better !
It's Safer!

It may be cheaper to order diethyl ether in large containers

But, if it's opened for a long time—peroxides can form!

Inventory management – chemical aging

- How old are your chemicals?
- Some chemicals degrade over time
  - rotate stock
  - label & date
- Chemical assays have expiration dates

Explosives and Reactives

Examples:
- Peroxide-forming - ethers
- Perchlorate-forming – perchloric acid
- Water/moisture sensitive – Na, K, Li, LAlH, flammable metals

Control measures:
- Inventory control
- SOPs, inspections

Inventory management

-R-O-O-R-

Peroxide Forming Chemicals

Even with inhibitors they can become dangerous over time

- discard or test if unsure
- label & date when received, when opened, and provide expiration date

Peroxide test kits and strips should be available

Peroxide forming chemicals

- Peroxide formation is caused by an autoxidation reaction.
- The reaction is initiated by light, heat, introduction of a contaminant or the loss of an inhibitor (BHT).
- Inhibitors slow, but do not stop peroxide formation.
- Most organic peroxide crystals are sensitive to heat, shock, or friction.
- It is important not to let peroxide forming chemicals evaporate to dryness or accumulate under screw caps.

-R-O-O-R-

Peroxide forming chemicals

Peroxides can explode when exposed to thermal or mechanical shock

Examples: ethers, dioxane, tetrahydrofuran

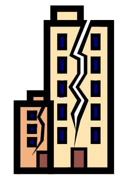
References:

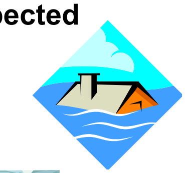
There are excellent websites on peroxide forming chemicals and their hazards, use, storage, and disposal. For example, see:

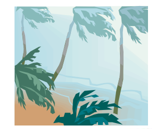
http://www.med.cornell.edu/ehs/updates/peroxide_formers.htm

Chemical storage

- Protect chemicals during normal operations
- Protect chemicals during unexpected events
  - Floods
  - Tidal waves
  - Earthquakes
  - Typhoons
  - Hurricanes







Chemical storage: Basic concepts

- Separate incompatible chemicals
- Separate flammables/explosives from ignition sources
- Use flammable storage cabinets for large quantities of flammable solvents
- Separate alkali metals from water
- Separate acids and bases

Use flammables storage cabinets

Chemical storage: Basic concepts

- Store nitric acid separately
- Store large containers on bottom shelves
- Lock up drugs, chemical warfare agents, highly toxic chemicals
- Do not store food in refrigerators with chemicals

Compressed Gas Cylinders

- Uses
- Types
- Hazards
- Control Measures
  - Inventory control
  - Procurement authorization
  - Training
  - Inspection

Chemical storage: Gas cylinders

- Secure (chain/clamp) and separate gas cylinders
- Screw down cylinder caps
- Store in well-ventilated area
- Separate & label empty cylinders
- Store empty cylinders separately
- Separate flammable from reactive/oxidizing gases

Improper gas cylinder storage

Damage from Gas-cylinder fire

An Accident Waiting to Happen

CSB video: Compressed gas fire

Chemical storage: Good practices

- Limit access
  - Label “Authorized Personnel Only”
  - Lock area/room/cabinets when not in use
- Be sure area is cool and well ventilated
- Secure storage shelves to wall or floor
- Shelves should have a ¾” front lip
  - In earthquake territory, have a rod several inches above shelf

Chemical storage: Bad practices

- Do Not Store Chemicals
  - on top of cabinets
  - on floor
  - in hoods
  - with food or drinks
  - in refrigerators used for food
  - where there are wide variations in temperature, humidity or sunlight

Chemical storage: Containers

- Don’t use chemical containers for food
- Don’t use food containers for chemicals
- Be sure all containers are properly closed
- Wipe-off outside of container before returning to storage area
- Transport/carry all containers safely
  - Preferably use outer protective container

Improper chemical storage

Never use hallways for storage

Safety Hazard!!

Blocks exit path in emergencies!!!

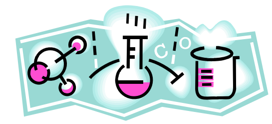
Chemical storage: Good practices

- Separate incompatible chemicals
  - Organize chemicals by compatible groups
  - Alphabetize chemicals only within compatible groups

Suggested shelf storage groups: Organics

- Acids, anhydrides
- Alcohols, amides, amines
- Aldehydes, esters, hydrocarbons
- Ethers, ketones, halogenated hydrocarbons
- Epoxies, isocyanates
- Azides, peroxides
- Nitriles, sulfides, sulfoxides
- Cresols, phenols

From: "School Chemistry Laboratory Safety Guide," US NIOSH Publication 2007-107



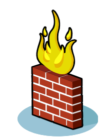
Suggested shelf storage groups: Inorganics

- Metals, hydrides
- Halides, halogens, phosphates, sulfates, sulfides
- Amides, azides, nitrates, nitrites
- Carbonates, hydroxides, oxides, silicates
- Chlorates, chlorites, perchlorates, peroxides
- Arsenates, cyanides, cyanates
- Borates, chromates, manganates
- Acids
- Arsenics, phosphorus, sulfur

From: "School Chemistry Laboratory Safety Guide," US NIOSH Publication 2007-107

Best practice: access control

- Proper training of chemical handling personnel
- Only trained and approved personnel
  - have access to stock room and keys
  - administrative privileges to inventory and database
- Locked doors and cabinets for controlled substances
  - Radioactive materials
  - Drugs and consumable alcohol
  - Explosives (special handling facility)
  - Dual use chemicals
  - Hazardous waste - high toxicity chemicals



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"Less is Better," American Chemical Society, Washington DC, 2003, available online:
http://portal.acs.org/portal/acs/corg/content?_nfpb=true&_pageLabel=PP_SUPERARTICLE&node_id=2230&use_sec=false&sec_url_var=region1&__uuid=ef91c89e-8b83-43e6-bcd0-ff5b9ca0ca33

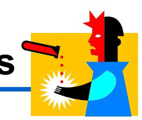
"School Chemistry Laboratory Safety Guide," US NIOSH Publication 2007-107, Cincinnati, OH, 2006, available on-line:
http://www.cpsc.gov/CPSCPUB/PUBS/NIOSH2007107.pdf

"Prudent Practices in the Laboratory: Handling and Disposal of Chemicals," National Academy Press, 1995, available online:
http://www.nap.edu/catalog.php?record_id=4911

LUNCH

Accident and Incident Investigation

Reporting Chemical Incidents and Accidents



- All accidents, incidents, or suspicious occurrences should be reported to the supervisor, regardless of the perceived seriousness of the incident.
- Reporting helps indicate potential problem areas.
- Reports serve as a basis for corrective measures to prevent accidents/incidents from re-occurring with a more serious outcome.

Serious Chemical Accidents and Incidents

- Should be reported in detail and should include:

  - Cause of accident/incident
  - Place, time, personnel involved
  - Diagram if necessary
  - Type of contamination or hazard
  - List of personnel possibly exposed
  - Decontamination procedures
  - Corrective actions taken
  - Medical attention taken (if appropriate)

Investigation and Prevention of Chemical Laboratory Accidents

- Emergency notification and response
- Written report of accident/incident
- Accident/Incident investigation response
- Review/investigation of accident/incident
- Determination of Cause
- Report and Implementation of Corrective Measures
- *Follow-up*

Accident/Incident Investigation Personnel

- Laboratory staff exposed or involved in accident/incident
- Laboratory Supervisor
- Safety/Security staff
- Medical personnel
- Administrative personnel
- Safety/Security Committee
- External experts, if needed

Written Accident/Incident Report

- A well written A/I Report provides quality information and data for investigation and remediation.

- Complete and accurate A/I information is critical to investigate the circumstances and to help prevent against future A/I occurrences.

Accident/Incidence Investigation Response

- Have a written procedure to submit A/I reports
- Include:
  - Procedure to form an *ad hoc* A/I Safety/Security Investigation Team for each A/I with designation of special A/I investigation team members if necessary (e.g., biological, radiation).
  - Specify an odd number of Investigation team members.
  - Specify that CSSO or organization SO is secretary but *ex-offico* (non-voting) member of Investigation Team.
  - Designate time required for A/I Investigation Team members to review and respond (by e-mail, if possible) on A/I Report.
  - Time required for Safety/Security Committee to determine if an A/I Investigation is necessary, when it is to be conducted, and who should be on Team.
  - Time required for Investigation Team and Safety/Security Committee to issue written investigation report, who the report goes to and that it contain corrective recommendations to help assure A/I will not reoccur, if appropriate.

Review/Investigation of Accident/Incident

- Site investigations and interviews can be the center of an A/I investigation program
- An A/I analysis and corrective actions can be determined from the data and information provided during this phase
- The data quality is important and a uniform approach to conducting the investigation is essential
- It is important in this step to obtaining and verify relevant personal and facility information
- The data may include testing, evaluation or verification of records for safety procedures, training, reporting, regulations, documentation and equipment
- The use of interviews of injured persons and witnesses can be very important to obtain all the facts

Determination of Cause

- An analysis of the A/I is performed using the information collected during the site investigation and interviews
- The analysis determines the cause of an A/I and tracks it back to the cause
- The object is to reveal the causes of the A/I and to understand what happened, how, when and why it occurred

Report and Implementation of Corrective Measures

- After the investigation and interviews, Team members meet to draft an Investigative report .
- An objective written report is issued that summarizes the feeling of the Team members that includes effective corrective measures to be implemented to prevent or minimize similar future accidents/incidents.
- The Team's recommended corrective actions should include:
  - The extent of the measures (i.e., specific to a laboratory or wider).
  - Resources needed for implementation.
  - Expected outcome.
- The Team's Report should be sent to all individuals involved in the A/I as well as the Laboratory Supervisor, Administration, and Institute Higher Management, External Government Agencies, if appropriate.

Accident/Incident Follow-up

- The corrective measures recommended by the Investigation team should be monitored to insure they implemented properly and have the desired effect
- Recommended actions should include a timeframe for completion

Accident/Incident Follow-up Timeline

- Length of timeline depends on nature and severity of incident.
- Starts at time/date of accident or incident.
- Incident should be reported immediately to:
  - CSSO, PI, Security Office, and/or Medical Office
  - Management or administration. Depends on incident severity, but usually with 2 days.
- Investigation usually starts within 24 hours.
- Written report is issued within a week.
- Report should include time for recommended follow-up actions, usually days to months.

CSB Video –Incident Investigation Example

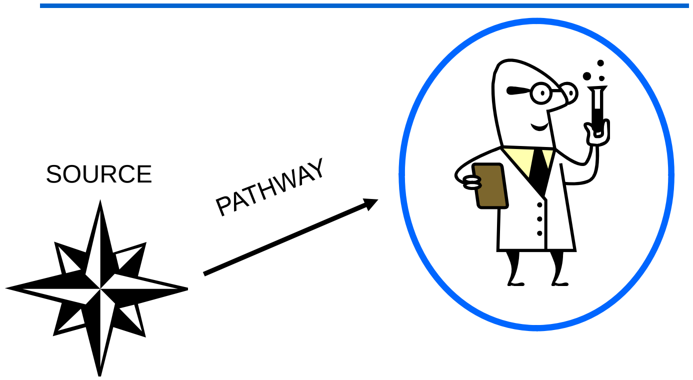
Small Group Discussions

Engineering Controls and PPE Used/Needed

BREAK

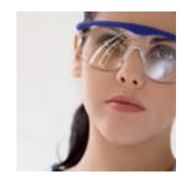
Personal Protective Equipment (PPE) and Safety Equipment Performance Specifications

Worker Protection



Personal Protective Equipment (PPE)

- **Should be a last resort, but may be necessary if:**
  - engineering controls inadequate or being installed
  - administrative controls don't do the job
  - emergency response or spill cleanup
  - supplement other control techniques if can't achieve required level
- **Depends upon human behavior**
  - proper selection, fit and comfort issues
- **Hazard is still present with PPE …**



US/OSHA PPE Regulations

- Eye and face protection
  - 29 CFR 1910.133
- Respiratory protection
  - 29 CFR 1910.134
- Head protection
  - 29 CFR 1910.135
- Foot protection
  - 29 CFR 1910.136
- Hand protection
  - 29 CFR 1910.138
- Hearing Protection
  - 29 CFR 1910.95

www.cdc.gov/nasd/menu/topic/ppe.html
www.osha.gov/SLTC/personalprotectiveequipment/index.html
www.osha.gov/Publications/osha3151.pdf

Training and Qualification

Employees should be trained to know:

- When PPE is necessary?
- What PPE is necessary?
- How to properly don, doff, adjust and wear PPE.
- Limitations of PPE.
- Proper care, storage, maintenance, useful life, and disposal of PPE.

www.free-training.com/osha/ppe/ppemenu.htm

Training and Qualification

Retraining is necessary when there is:

- Change in the process.
- Change in type of PPE used.
- Inadequate employee knowledge or use of PPE.
  - retrain to reinforce understanding or skill

Personal Protective Clothing (PPE)

- Evaluate task, select appropriate type and train to use it properly
  - lab coats, gowns, aprons
  - safety glasses (with side shields), goggles, face shields
  - gloves
- Remove PPE before leaving the lab

Protective Equipment Works

"It's a hot day, why wear a lab coat?"

An experiment reacted unexpectedly and a flammable solvent from a hood splashed out and landed on the bottom of the lab coat

Eye and Face Protection

- **Thousands are blinded each year from work-related eye injuries.**
- **Nearly *three out of five* workers are injured while failing to wear eye and face protection.**

Eye & Face Protection

- **Safety glasses**
- **Goggles**
- **Face shield**

Eye and Face Protection

Eye protection shields eyes by:

- **Primary protection:**
  - **Safety glasses with side shields protect from flying objects.**
  - **Goggles prevent objects from entering under or around the eyewear.**
- **Secondary protection:**
  - **Face shields**
    - **Combine with safety glasses or goggles**
    - **Do not protect from impact hazards**

Hazard Assessment

Hazard Type	Hazard Type	Common related tasks
Impact	Flying objects such as large chips, fragments, particles, sand, and dirt	Chipping, grinding, machining, masonry work, wood working, sawing, drilling, riveting, sanding,…
Heat	Anything emitting extreme heat	Furnace operations, pouring, casting, hot dipping, welding, …
Chemicals	Splash, fumes, vapors, and irritating mists	Acid and chemical handling, degreasing, plating, and working with blood or OPIMs
Dust	Harmful dust	Woodworking, buffing, and general dusty conditions
Optical Radiation	Radiant energy, glare, and intense light	Welding, torch-cutting, brazing, soldering, and laser work

Biohazards

Use caution anytime you are working with blood or other bodily fluids.

Contaminated blood or bodily fluids may result in transmission through the eyes.

Eye and Face Protection

Optical Hazards

- Welding helmets are secondary protection to shield from UV, heat, and impact.
- Exposure to laser beams requires suitable laser safety goggles with protection for the specific wavelength.

Eye and Face Protection Requirements

- Eye and face protection should comply with the American National Standards Institute:
  - ANSI Z87.1-1989
- Ensure employees who wear prescription lenses or contact lenses:
  - Use safety eyewear that incorporates the prescription
  - Use eye protection that can be worn over prescription lenses

Additional Considerations

- Provide adequate protection against the specific hazards.
- Safe design and construction for the work to be performed.
- Comfortable.
- Don't interfere with the wearer's movements.
- Durable!
- Capable of being disinfected.
- Easily cleaned.
- Distinctly marked to indicate they are approved eye protection.
- Worker satisfaction.
  - – Include workers in the selection process.

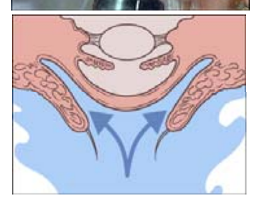
Eyewash and Showers

- US regulations
  - 29 CFR 1910.151(c)
  - ANSI Z358.1-2004
- Types
  - eyewash
  - shower
  - drench hose
- Concerns
  - drainage
  - freezing
  - contaminated water

Eyewash and Showers

- Know their locations
- Maintenance and testing program
- Concerns:
  - drainage
  - freezing
  - contaminated water

Eyewash Standards

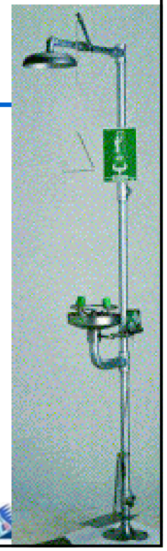


ANSI Z358.1
NC DOL Guide:
www.nclabor.com/osha/etta/indguide/ig28.pdf

- Eye wash stations
  - Minimum 0.4 to 3.5 gal/min (1.4 – 13.2 l/min.)
  - Flush for 15 minutes
- Provide flow for both eyes
  - Hold eyes open
  - Tepid, pH match eye (preferred)
- Easily accessible locations
  - 33 to 45 in. (84-114 cm) from floor
  - 6 in. (15cm) from wall
- Test weekly
  - Portable: clean/refill (6 mo – 2 yrs)
- Various types

Safety Shower Standards

- Within 55 ft. (17 m) or 10 seconds
  - Normal walking = 3.8 mph (6.1 km/hr)
- Test monthly
- Pull within reach (highly visible)
  - 82 to 96 in. high (208 – 244 cm)
  - Deliver 20 in (51 cm) column
  - Height: 60” (152 cm) above floor
- 20–30 gal/min (76-114 L/min)
- Tepid: 60 to 100 °F (16 – 38°C)



Safety Shower Standards cont.

Consider:

- Drains
- Blankets/modesty curtains

Avoid or protect electrical outlets

- ANSI Z358.1-2004

Blocked Eyewash & Safety Shower

Dirty Eyewash Station

Blocked Eye Wash Station

Hand Protection

- Glove considerations
  - Type glove
    - Dexterity required
    - Chemical & physical
      - material
      - strength
    - Exposure time
      - breakthrough time
    - Size, comfort, reusable/disposable
  - Manufacturer selection charts

Glove Selection

- Considerations:
  - Chemicals (splashes vs immersion)
  - Thermal (extreme heat/cold)
  - Abrasion; cuts; snags; splinters; punctures
  - Grip: oily, wet, dry
  - Comfort, fit, size
  - Ergonomics

Chemical Protective Gloves/ Clothing

- Permeation (“silent killer”)
  - Substances pass through intact material on a molecular level.
- Penetration
  - Substances pass through seams, zippers, stitches, pinholes, or damaged material.
- Degradation
  - Substance damages material making it less resist or resulting in physical breakdown.
- Contamination
  - Substances transferred inside material (improper doffing or decontamination).

Permeation Rate (PR)	Permeation Breakthrough (PB)	Permeation Degradation rate (DR)
E- Excellent; permeation rate of less than 0.9 mg/cm²/min	>Greater than (time - minutes)	E - Excellent; fluid has very little degrading effect.
VG - Very Good; permeation rate of less than 9 mg/cm²/min	< Less than (time - minutes)	G - Good; fluid has minor degrading effect.
G - Good; permeation rate of less than 90 mg/cm²/min		F - Fair; fluid has moderate degrading effect.
F - Fair; permeation rate of less than 900 mg/cm²/min		P - Poor; fluid has pronounced degrading effect.
P - Poor; permeation rate of less than 9000 mg/cm²/min		NR - Fluid is not recommended with this material.
NR - Not recommended; permeation rate greater than 9000 mg/cm²/min		† Not tested, but breakthrough time > 480 min DR expected to be Good to Excellent
		†† Not tested, but expected to be Good to Excellent based on similar tested materials

Gloves

- It's important to have the right glove for the job and know how long it will last.
- Glove Chart Examples:
  - Consider several glove manufactures data before final selection.
  - www.bestglove.com/site/chemrest/

The first square in each column for each glove type is color coded. This is an easy-to-read indication of how we rate this type of glove in relation to its applicability for each chemical listed. The color represents an overall rating for both degradation and permeation. The letter in each square is for Degradation alone....

GREEN: The glove is very well suited for application with that chemical.

YELLOW: The glove is suitable for that application under careful control of its use.

RED: Avoid use of the glove with this chemical.

CHEMICAL	LAMINATE FILM BARRIER			NITRILE SOL-VEX			UNSUPPORTED NEOPRENE 29-865			SUPPORTED POLYVINYL ALCOHOL PVA			POLYVINYL CHLORIDE (Vinyl) SNORKEL			NATURAL RUBBER CANNERS AND HANDLERS*			NEOPRENE/ NATURAL RUBBER BLEND CHEMI-PRO*		
	Degradation Rating	Permeation: Breakthrough	Permeation: Rate	Degradation Rating	Permeation: Breakthrough	Permeation: Rate	Degradation Rating	Permeation: Breakthrough	Permeation: Rate	Degradation Rating	Permeation: Breakthrough	Permeation: Rate	Degradation Rating	Permeation: Breakthrough	Permeation: Rate	Degradation Rating	Permeation: Breakthrough	Permeation: Rate	Degradation Rating	Permeation: Breakthrough	Permeation: Rate
1. Acetaldehyde	■	380	E	P	—	—	E	10	F	NR	—	—	NR	—	—	E	7	F	E	10	F
2. Acetic Acid	■	150	—	G	270	—	E	60	—	NR	—	—	F	180	—	E	110	—	E	260	—
3. Acetone	▲	>480	E	NR	—	—	E	10	F	P	—	—	NR	—	—	E	10	F	G	10	G
4. Acetonitrile	▲	>480	E	F	30	F	E	20	G	■	150	G	NR	—	—	E	4	VG	E	10	VG
5. Acrylic Acid	—	—	—	G	120	—	E	390	—	NR	—	—	NR	—	—	E	80	—	E	65	—
6. Acrylonitrile	E	>480	E	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
7. Allyl Alcohol	▲	>480	E	F	140	F	E	140	VG	P	—	—	P	60	G	E	>10	VG	E	20	VG
8. Ammonia Gas	■	19	E	▲	>480	—	▲	>480	—	—	—	—	■	6	VG	—	—	—	■	27	VG
9. Ammonium Fluoride, 40%	—	—	—	E	>360	—	E	>480	—	NR	—	—	E	>360	—	E	>360	—	E	>360	—
10. Ammonium Hydroxide	E	30	—	E	>360	—	E	250	—	NR	—	—	E	240	—	E	90	—	E	240	—
11. Amyl Acetate	▲	>480	E	E	60	G	NR	—	—	G	>360	E	P	—	—	NR	—	—	P	—	—
12. Amyl Alcohol	—	—	—	E	30	E	E	290	VG	G	180	G	G	12	E	E	25	VG	E	45	VG
13. Aniline	▲	>480	E	NR	—	—	E	100	P	F	>360	E	F	180	VG	E	25	VG	E	50	G
14. Aqua Regia	—	—	—	F	>360	—	G	>480	—	NR	—	—	G	120	—	NR	—	—	G	180	—
15. Benzaldehyde	▲	>480	E	NR	—	—	NR	—	—	G	>360	E	NR	—	—	G	10	VG	G	25	F
16. Benzene, Benzol	▲	>480	E	P	—	—	NR	—	—	E	>360	E	NR	—	—	NR	—	—	NR	—	—
17. Benzotrichloride	—	—	—	E	>480	E	NR	—	—	—	—	—	—	—	—	NR	—	—	NR	—	—
18. Benzotrifluoride	—	—	—	E	170	G	F	—	—	E	—	—	G	<10	F	P	50	G	—	—	—
19. Bromine Water	—	—	—	E	>480	E	E	>480	E	—	—	—	—	—	—	—	—	—	—	—	—
20. 1-Bromopropane	▲	>480	E	■	23	F	■	<10	P	▲	>480	E	■	<10	F	■	<10	P	■	<10	P

Types of Gloves

Polyethylene/Ethylene-vinyl Alcohol {"Silver Shield®"}

- Resists permeation and breakthrough with chemicals.
- Uses: aromatics, esters, ketones, and chlorines.

Butyl

- Highest permeation resistance to gas or water vapors.
- Uses: ketones (MEK, acetone) and esters (amyl acetate, ethyl acetate).

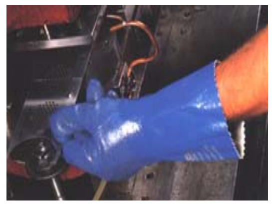
Types of Gloves

Viton®

- Highly resistant to permeation by chlorinated and aromatic solvents
- Can be used with water/water based solvents

Nitrile (acrylonitrile-butadiene rubber)

- Good replacement for latex
- Protects against acids, bases, oils, aliphatic hydrocarbon solvents and esters, grease, fats
- Resists cuts, snags, punctures and abrasions



Types of Gloves

Neoprene

- Protects against acids, caustics, DMSO.
- Resists amines, alcohols, glycols.
- Limited use for aldehydes and ketones.

Poly vinyl chloride (PVC)

- Protects against acids, caustics.
- Resists alcohols, glycols.
- Not useful for aromatics, aldehydes and ketones.

What is latex allergy?

- **Natural rubber latex is from the rubber tree *Hevea brasiliensis.***
- **The major route of occupational exposure is absorption of latex protein through the skin.**
- **Allergens in or on gloves can be transferred to the person's tissue.**

Latex Allergies

- **Symptoms may occur within minutes of exposure or may take several hours depending on the individual.**
  - **Skin Redness**
  - **Hives**
  - **Itching**
  - **Respiratory Symptoms**
    - **Runny Nose**
    - **Itchy Eyes**
    - **Scratchy Throat**
    - **Asthma**

Latex Allergy

Latex Allergies

- To prevent latex allergies consider:
  - Using non-latex gloves.
  - If you choose latex gloves, use the powder-free version.
  - When using gloves, do not use oil-based hand cream or lotions (these cause glove deterioration).
  - Recognize the symptoms of latex allergy.
  - Always wash hands after removing gloves.

http://www.cdc.gov/niosh/topics/latex/

http://www.nursingworld.org/osh/latex.htm

Proper Steps for Removing Gloves

1

2

3

4

5

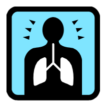
6

Respiratory Protection Program

- Written program
- Administered by Safety Office
- Medical clearance
  - Respiratory Protection Questionnaire
  - No beards
- Fit testing
- Respirator selection
  - Air monitoring
- Training (annual refresher)

Respiratory Protection Standards

- 29 CFR 1910.134
  - OSHA Respiratory Protection Standard
  - New OSHA Assigned Protection Factors
- ANSI Z88.2–1992
  - ANSI Voluntary Consensus Standard



Conduct an Exposure Assessment:
www.osha.gov/SLTC/etools/respiratory/haz_expose/haz_expose.html

Types of Respirators

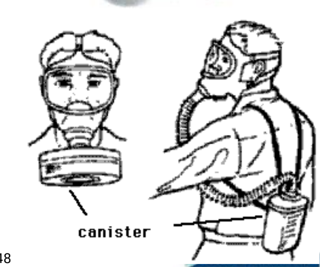
- Air purifying (APR)
  - Half Face
  - Full Face
  - PAPR
- Air supply
  - Air line
  - SCBA

Air Purifying Respirators

- *Must have at least 19.5% oxygen.*
  - <u>Never</u> use in O_2 deficient atmospheres
- *Only filters the air.*
  - Particulate filters
    - Removes aerosols
  - Chemical cartridges or canisters
    - Remove gases and vapors
- *Concentrations must not exceed limitations of filter/cartridge.*
- PAPR (Powered Air Purifying Respirator)
  - Uses a blower to force air through an air purifying element

APR Chemical Cartridge Selection

- Specific gases or vapors
- NIOSH or MSHA approval
- Adequate warning properties
- End of service life
- Mechanisms
  - adsorption
  - absorption
  - chemical reaction
- Breakthrough times
- *Proper maintenance and storage*



Cartridge Selection

Cartridge	Description
	Organic Vapor
	Organic Vapor and acid gases
	Ammonia, methylamine and P100 any particulates filter 99.97% minimum filter efficiency

End of Service Life Indicators (ESLI)

There are very few NIOSH-approved ESLI's:

- ammonia
- carbon monoxide
- ethylene oxide
- hydrogen chloride
- hydrogen fluoride
- hydrogen sulfide
- mercury
- sulfur dioxide
- toluene-2,4-diisocyanate
- vinyl chloride

Assigned Protection Factors (APF)

- Level of workplace respiratory protection that a respirator or class of respirators is expected to provide.
- Each specific *type* of respirator has an Assigned Protection Factor (APF).
- Select respirator based on the exposure limit of a contaminant and the level in the workplace.

Maximum Use Concentration (MUC)

= APF x Occupational Exposure Limit (e.g.OEL, TLV)

Assigned Protection Factors

Type of Respirator	Half Face Mask	Full Facepiece	Helmet/ Hood	Loose-Fitting Facepiece
Air-Purifying	10	50	-	-
PAPR	50	1,000	25/1,000	25
Supplied-Air or Airline				
– Demand	10	50	-	-
– Continuous flow	50	1,000	25/1000	25
– Pressure demand	50	1,000	-	-
SCBA				
– Demand	10	50	50	-
– Pressure Demand	-	10,000	10,000	-

Assigned Protection Factors

Workplace air sampling indicates the exposure to benzene is 30 ppm. OEL is 1 ppm. What respirator should you choose?

Maximum Use Concentration (MUC) = OEL x APF
Half Face Mask: MUC = 1 ppm x 10 = 10 ppm
PAPR (LFF): MUC = 1 ppm x 25 = 25 ppm
Full Face Respirator: MUC = 1 ppm x 50 = 50 ppm

Dust Masks *vs.* Hospital Masks




High Efficiency Particulate Air Filter (HEPA) Respirator



Fit Testing

- **Qualitative**
  - **Irritant smoke (stannic chloride)**
  - **Isoamyl acetate (banana oil)**
  - **Saccharin**
  - **Bitrex (bitter taste)**
  - *Employees should perform a user seal check each time they put on a tight-fitting respirator*
- **Quantitative**
  - **Portacount**

Qualitative Fit Test

Pass/Fail Fit Test

- Assess the adequacy of respirator fit
- Relies on the individual's response to a test agent

Qualitative Fit Test

Positive / Negative pressure fit test

Supplied Air

- Supplies breathing air to employee
- Examples:
  - SCBA
  - Airline
- Grade D Air
- Limitations

Breathing Air Quality and Use

- Compressed breathing air must be at least Type 1 - Grade D [ANSI/CGA G-7.1-1989]:
  - Oxygen content = 19.5 - 23.5%
  - Hydrocarbon (condensed) = 5 mg/m^3 or less
  - CO $\leq$ 10 ppm or less
  - CO_2 of 1,000 ppm or less
  - Lack of noticeable odor
- Compressors equipped with in-line air-purifying sorbent beds and filters.

Breathing Air Quality and Use

- Non-oil lubricated compressors
  - CO levels in the breathing air ≤ 10 ppm
- Oil-lubricated compressors
  - High-temperature or CO alarm, or both
  - If only high-temperature alarm, the air supply must be monitored to prevent CO levels from exceeding 10 ppm

Maintenance and Storage Procedures

- Disposable filtering face-piece:
  - Dispose after use
- Half-mask:
  - Write expiration date (current date +estimate) making sure to keep entire label legible
  - Discard cartridges based on expiration date, end-of-service life indicator or calculated service life
  - Clean
  - Dry
  - Place in sealable bag (write your name on bag)
  - Contact Safety Office for repairs

Maintenance and Storage Procedures

- Exclusive use of an employee:
  - Clean and disinfect as often as necessary to be maintained in a sanitary condition.
  - Discard cartridges based on expiration date, end-of-service life indicator or calculated service life.
- Respirators issued to more than one employee or maintained for emergency use:
  - Clean and disinfect before worn by different individuals or after each use.
- Respirators used in fit testing and training:
  - Clean and disinfect after each use
- All respirators *must* be stored in clean, dry bags

Hazards Requiring Body Protection

- *Hazardous chemicals.*
- Potentially infectious materials.
- Intense heat.
- Splashes of hot metals and hot liquids.

Body Protection for Emergency Response

Full suits:
- Class A
- Class B
- Class C
- Class D

Level A Protective Suits

Potential exposure to unknown:
- Greatest level of skin, respiratory, and eye protection.
- Positive-pressure, full face-piece Self Contained Breathing Apparatus (SCBA) or positive pressure supplied air respirator with escape SCBA.
- Totally encapsulated (air-tight) chemical and vapor protective suit.
- Inner and outer chemical-resistant gloves, and boots.

Level B Protective Suits

- **Atmospheric vapors or gas levels not sufficient to warrant level A protection.**
- **Highest level of respiratory protection, with lesser level of skin protection.**
  - Positive-pressure, full face-piece self contained breathing apparatus (SCBA) or positive pressure supplied air respirator with escape SCBA
  - Hooded chemical resistant clothing or coveralls (non-totally-encapsulating suit), inner and outer chemical-resistant gloves, and boots

Level C Protective Suits

- **Concentration or contaminant known**
- **Full-face air purifying respirator permitted with** a lesser skin protection
- **Inner and outer chemical-resistant gloves, hard hat, escape mask, disposable chemical-resistant outer boots**
  - ***Difference in Level C and level B is respiratory protection***

Level D Protective Suits

- **Minimum protection.**
- *No* respiratory or skin protection.
- Used only if no known or suspected airborne contaminants present.
- **May include gloves, coveralls, safety glasses, face shield, and chemical-resistant, steel-toe boots or shoes.**

Foot Protection

Should meet or exceed ANSI Standard.

Types:

- **Impact, penetration, compression, steel toe, etc.**
- **Non-skid, with slip resistant soles.**
- **Chemical resistant** (rubber, vinyl, plastic, with synthetic stitching to resist chemical penetration).
- **Anti-static**
- **Temperature resistant (high or low extremes).**
- **Electrical protection (non-conducting).**
- **Water resistant**
- **Combination shoes**

Personal Protective Equipment Foot Protection

Steel toe-safety shoes are not necessary for laboratory work *unless* there is a serious risk from transporting or handling heavy objects.

However,

open toe shoes

should NOT be worn in labs.

Head Protection

Should meet or exceed Z89.1-2003

Types:

- **Bump caps - don't meet ANSI standard, provide minor protection**
- **Electrical protection 2200-22,000 v, depends on class)**
- **Mining protection**
- **Classic-- high impact general purpose protection.**
- **Impact 850-1000 pounds (386 - 454Kg)**
- **Penetration 3/8" (~1cm)**

Any Questions?

Questions?
Open Discussion