Chemical

SAFETY AND SECURITY TRAINING

Chemical Safety and Security Officer Training

Irbid, Jordan

February 2010

SAND No. 2009-8395P

Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company,
for the United States Department of Energy's National Nuclear Security Administration

Principles and Concepts of

Laboratory Design

Purpose of Laboratory Design

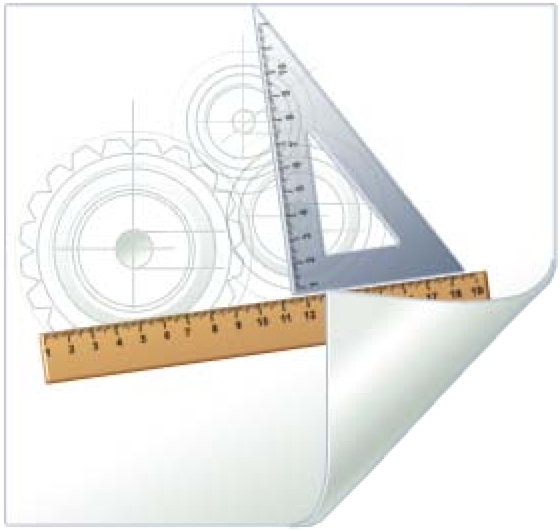
Protect the Workers

Enable the Work

Secure the Facility

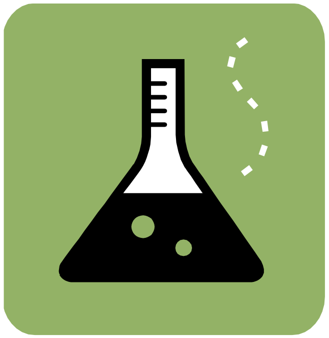
Protect the Environment

Comply with Regulations



Objectives of Laboratory Design

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



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Barriers to Good Lab Design

Cost

Poor Communication

Lack of Scientific Knowledge

Complicated Project

Trade-offs

Personalities

Maintenance

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Good Laboratory Design

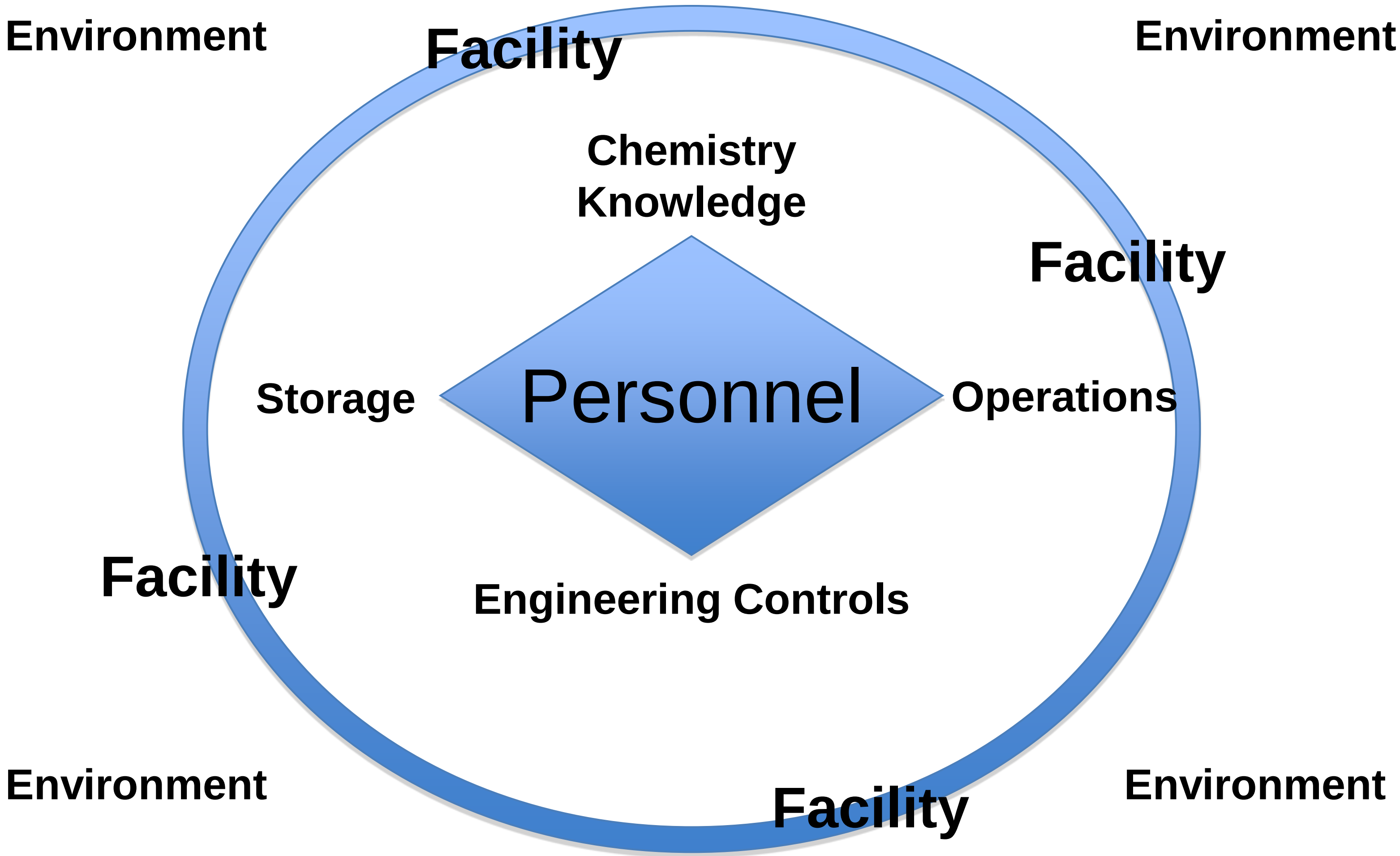
Based on:

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

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Safety/Security Information Needed Before Design can Begin

Type of Work/Research

Type of Hazards

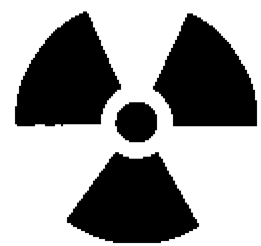
Type of Wastes

Chemical

Biological

Radiation

High Voltage



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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:

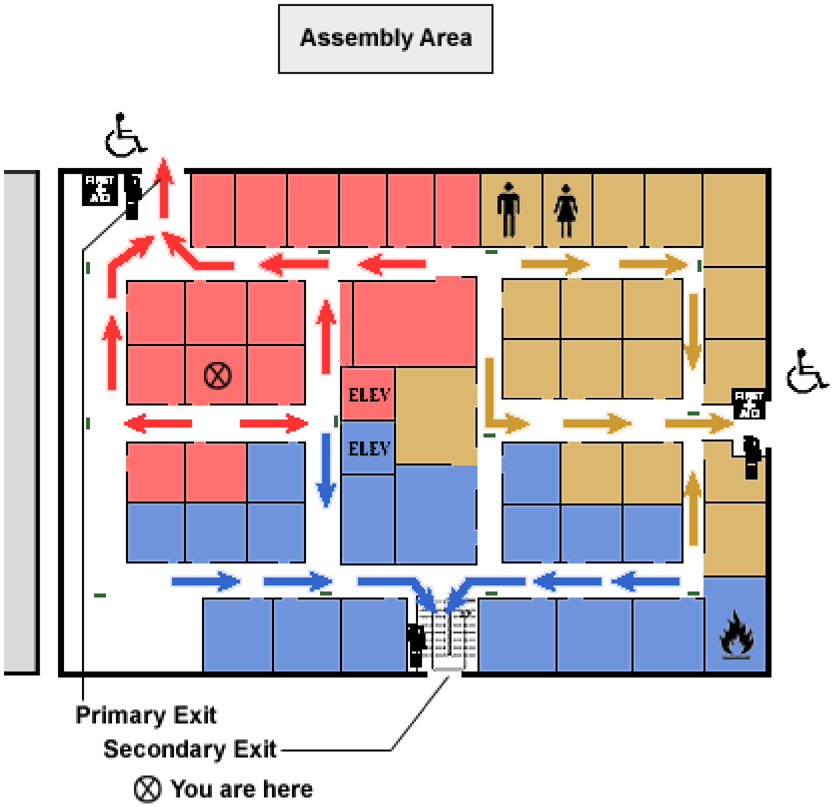
- Fire detection, alarms, and suppression systems
- Safety equipment (i.e. emergency showers, eyewash and contaminant control)
- Ventilation (i.e. laboratory hoods, glove boxes, ventilated enclosures)
- Management of chemicals and waste
- Access controls for facility and laboratories

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

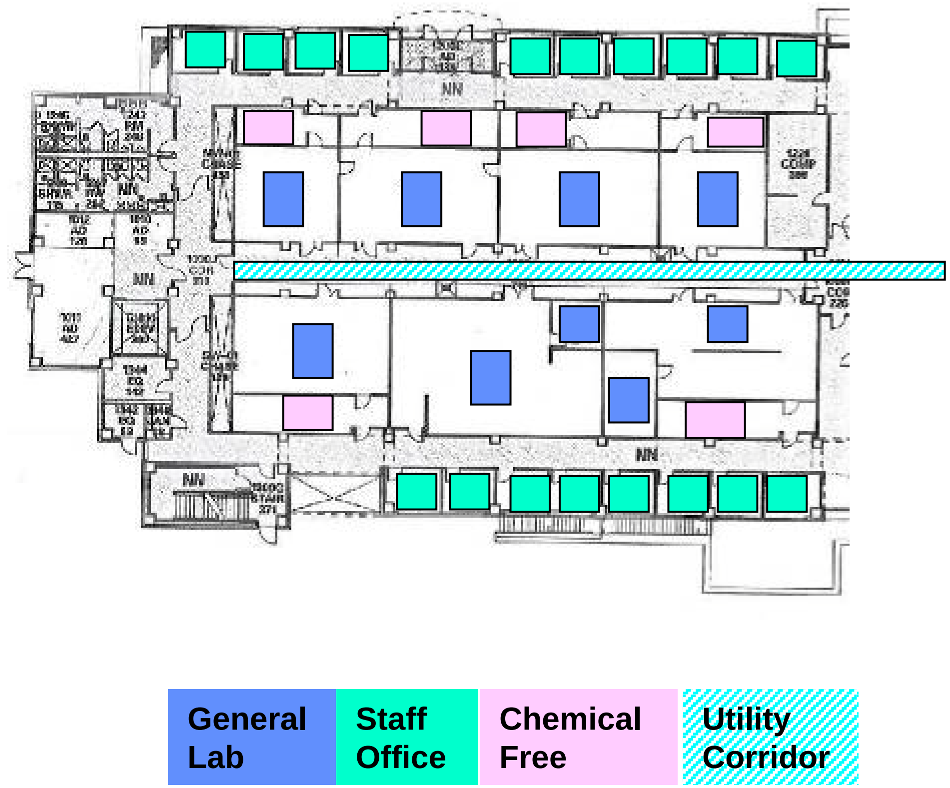
Building Layout: Divide into Zones

- 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

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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

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Building Layout: Chemical Waste

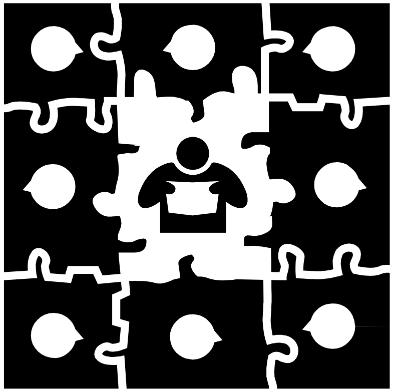
- Large volumes of chemical waste should be stored in areas with fewer people
  - Access restricted to responsible personnel
  - Locked when unattended
  - Divided into chemically compatible groups
  - Provide safety equipment and alarms

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

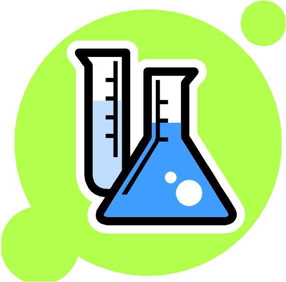
- Support team work
- Facilitates communication
- Shared:
  - Equipment
  - Bench space
  - Support staff
- Adaptable and flexible
- Easier to monitor
- Cheaper to design, build and operate
- The trend since mid 90's

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

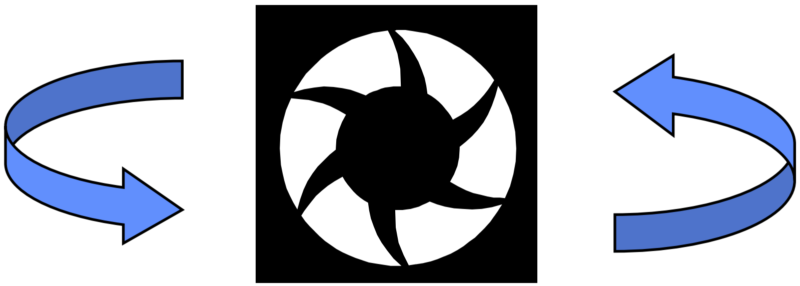


Energy Conservation Issues

- 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



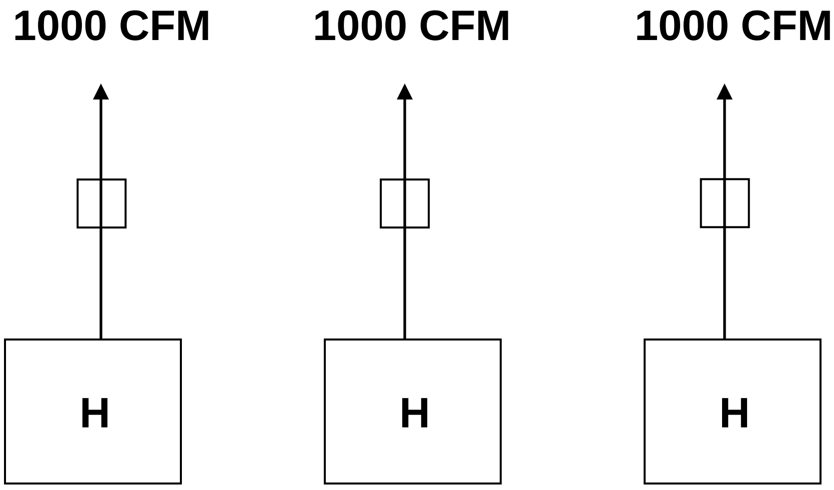
Laboratory hood design and ventilation are discussed in detail in later presentations.

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.

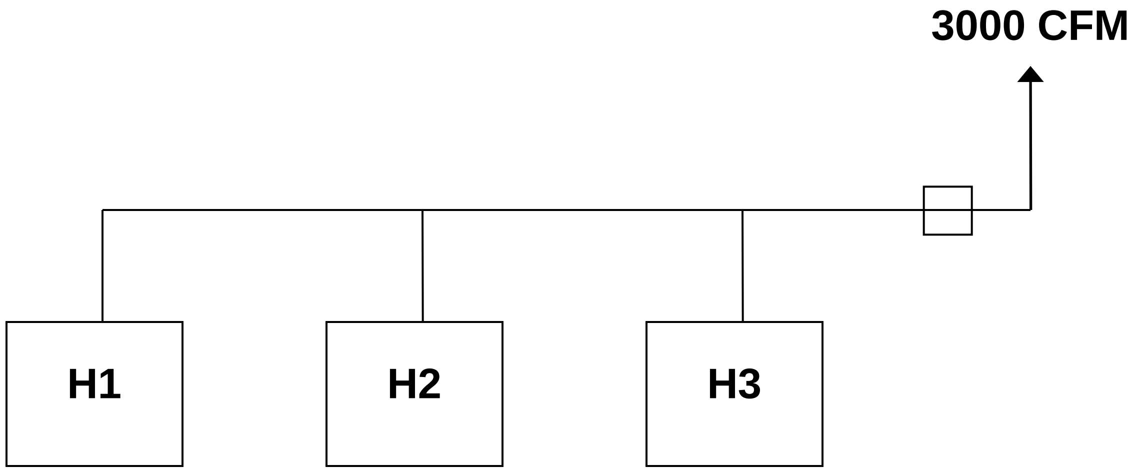
Hood Manifold Considerations

Single Hood - Single Fan



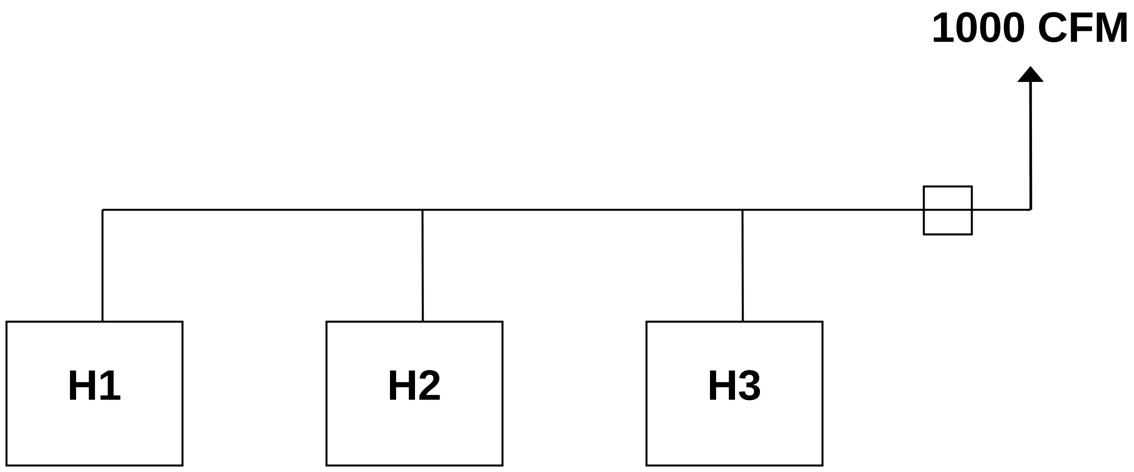
Hood Manifold Considerations

Manifold: 3 Hoods, 1 Fan

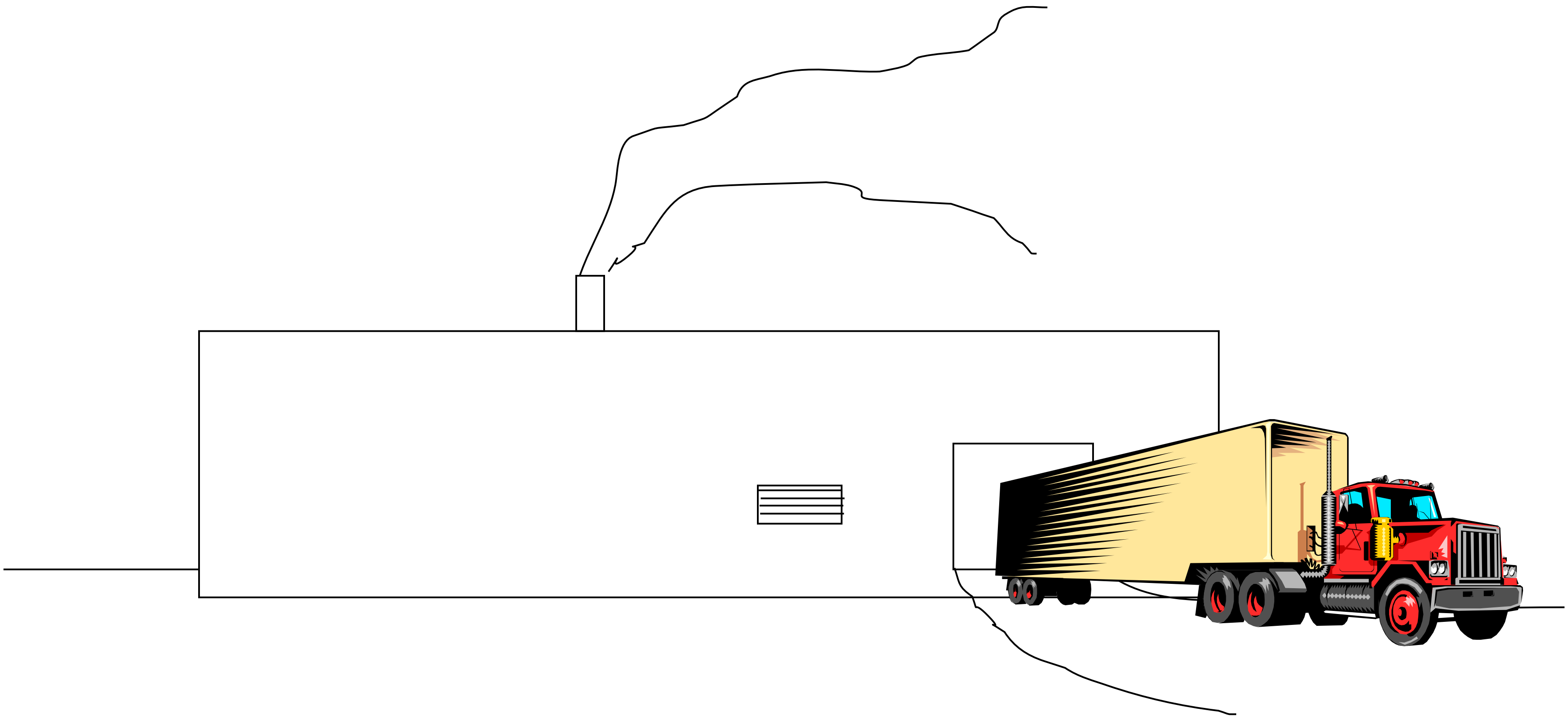


Hood Manifold Considerations

Hood Diversity = 33%



Ventilation Design: Avoid Exhaust Recirculation



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Lab Layout

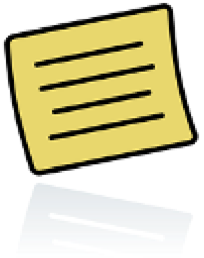
- Try to locate hoods, utilities and safety equipment in the same relative position in all labs.
- Locate sinks centrally
- Space between benches should allow people to pass each other (≥1.5 m).
- Details given in later presentations on:
  - Lab hoods
  - Safety showers / eyewashes
  - Chemical management

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

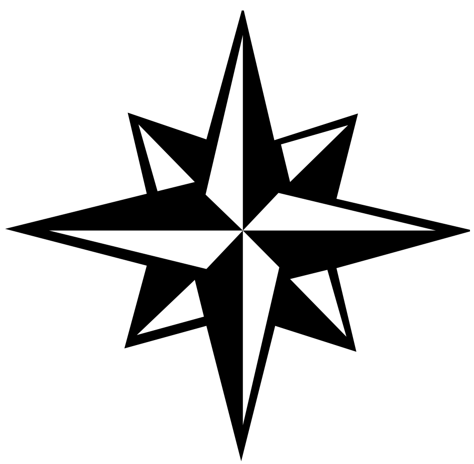
Together we can design, build, and operate safe/secure laboratories!

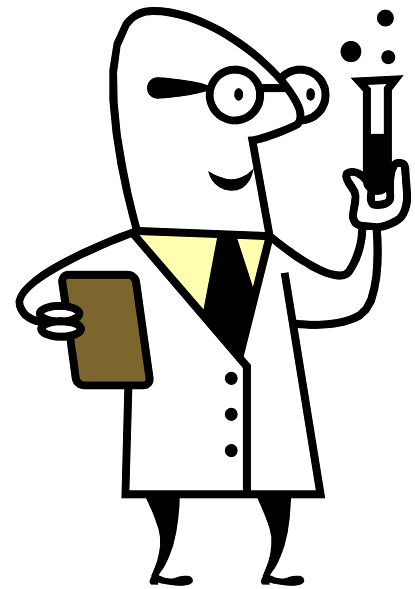
BREAK

Principles and Concepts of Laboratory Ventilation

Hazardous Exposure

SOURCE



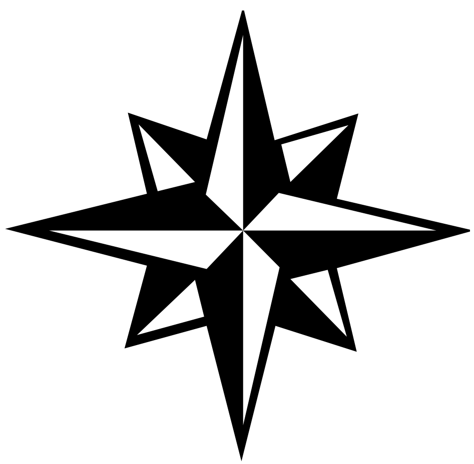


RECEIVER

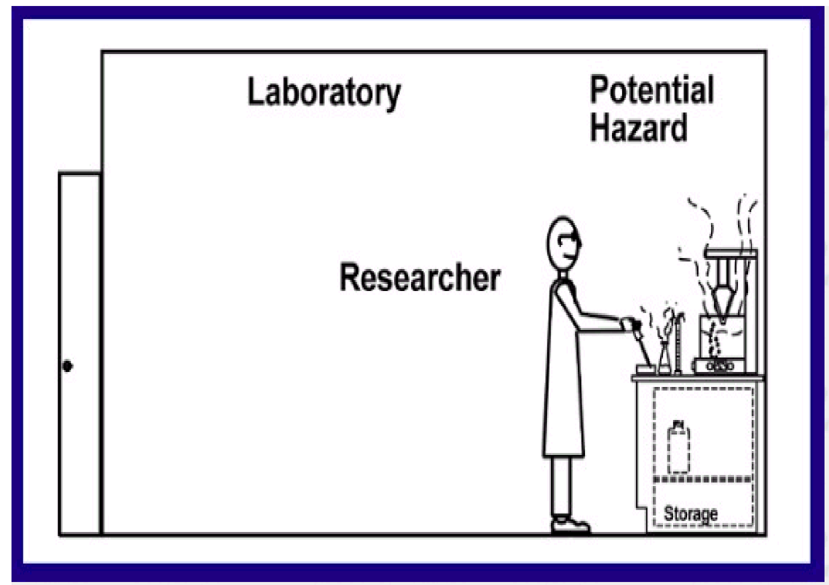
Enclose the Source

Hazardous Exposure

SOURCE



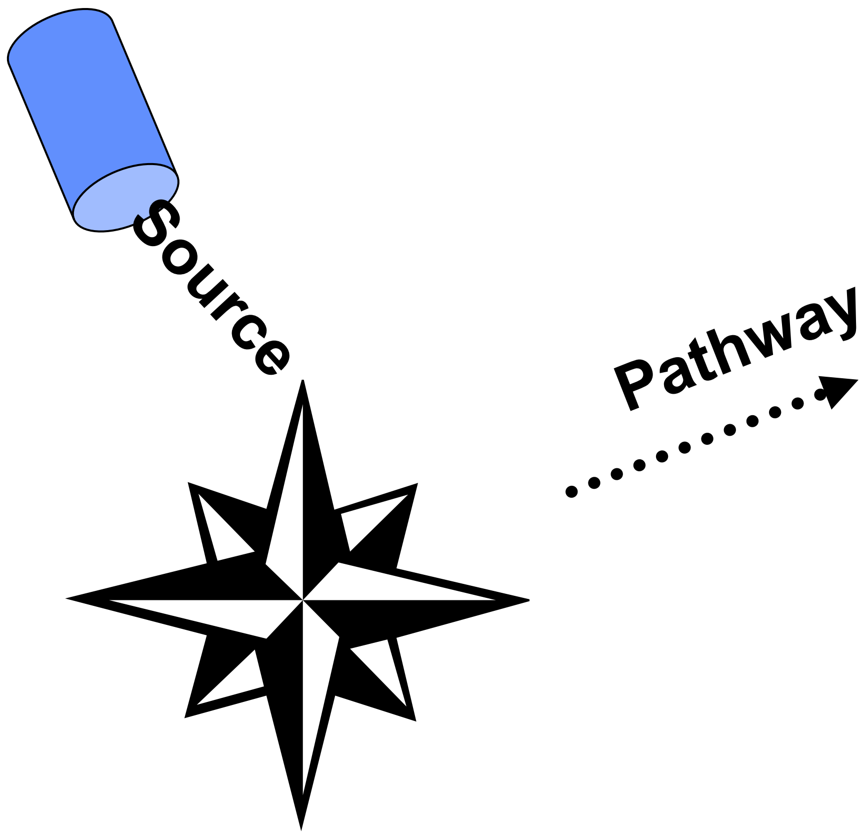
PATH

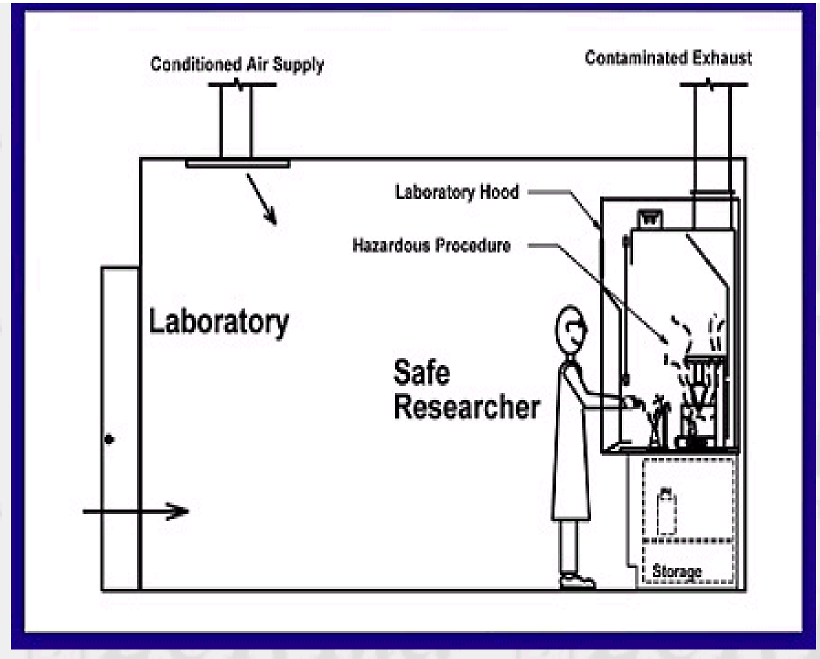


RECEIVER

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

Ventilation





Safe Worker

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

Prioritization of Controls

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

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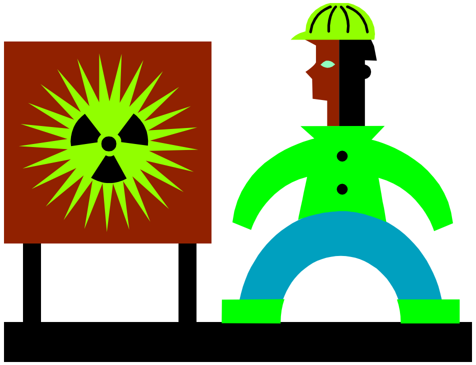
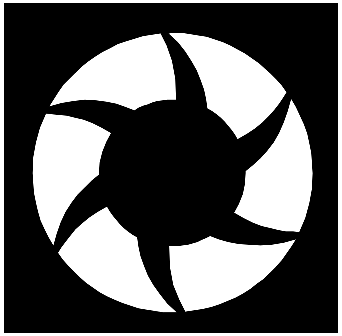
Engineering Controls

- **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**

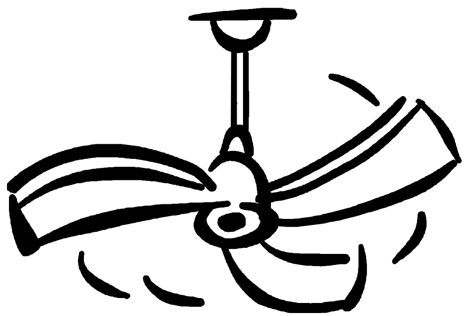


OEL = Occupational Exposure Limit

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 contaminate 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

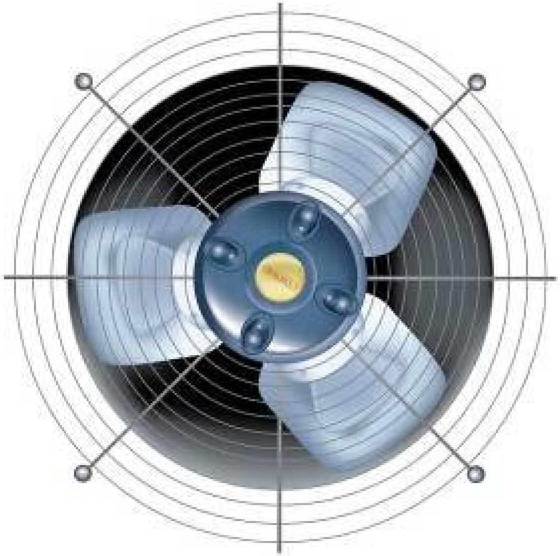
- Enclose source
- Capture contaminant near source
- Keep contaminant out of breathing zone
- Provide adequate make-up air
- Discharge away from air intake

Definitions

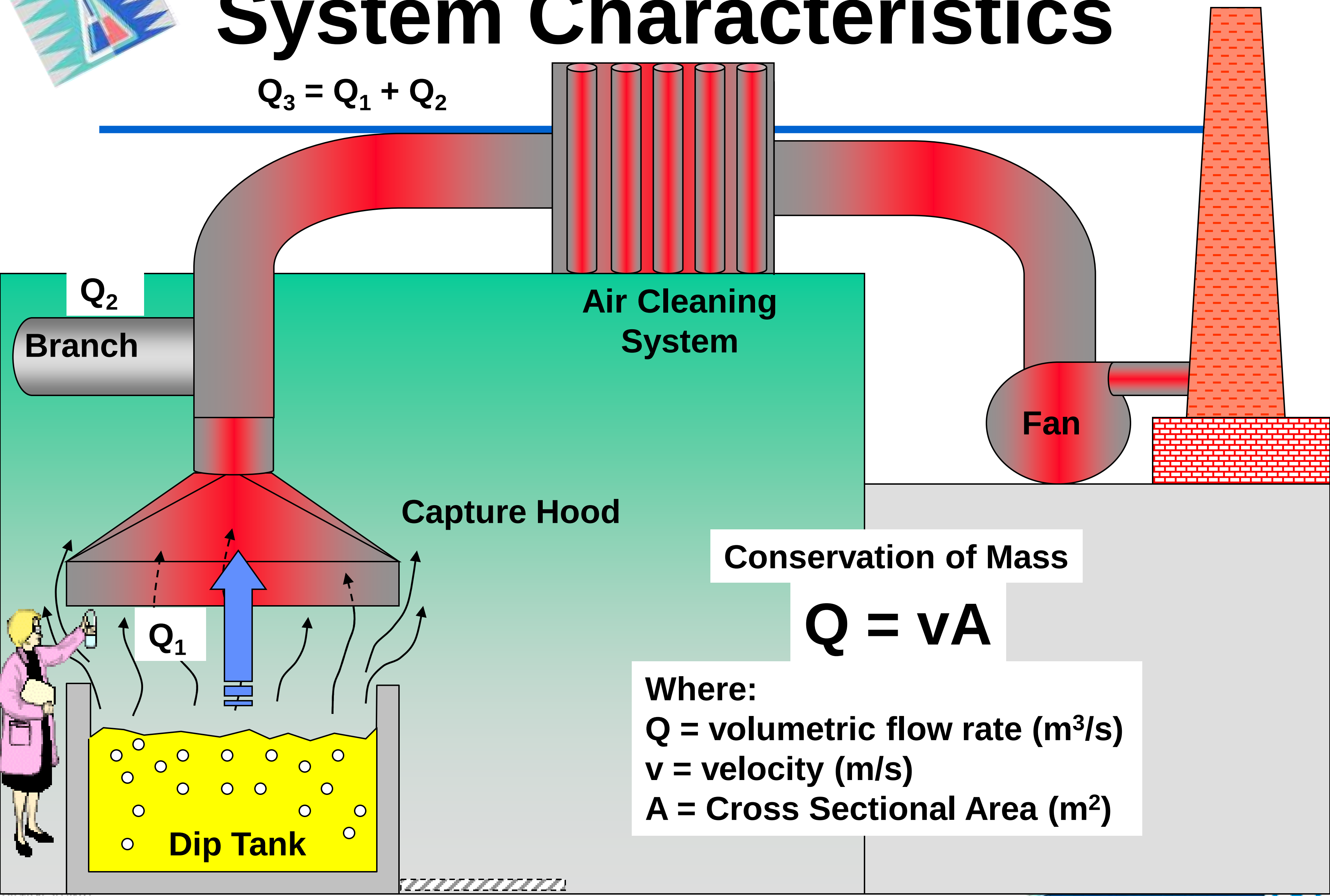
- **Hood** – includes any suction device, regardless of shape, that encloses, captures or removes contaminants.
- **Dilution Ventilation** – moves room air around by a fan that is sometimes exhausted to the outside.
- **Local Ventilation (LEV)** – ventilation system that captures and removes emitted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

System Components

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



System Characteristics



Q = vA

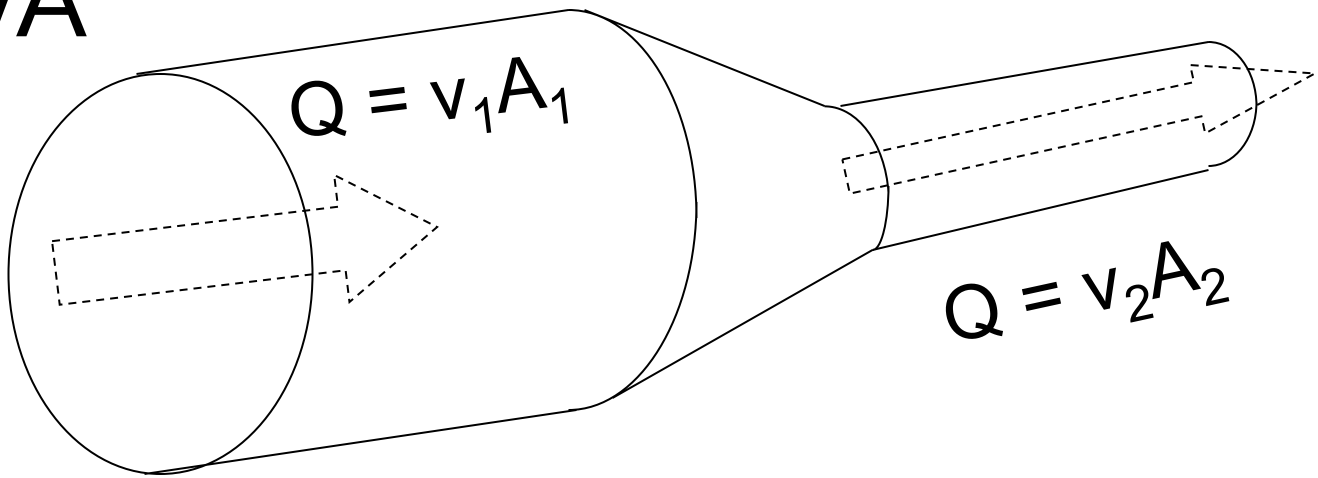
Q = volumetric flow rate of air (m^3/s)

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

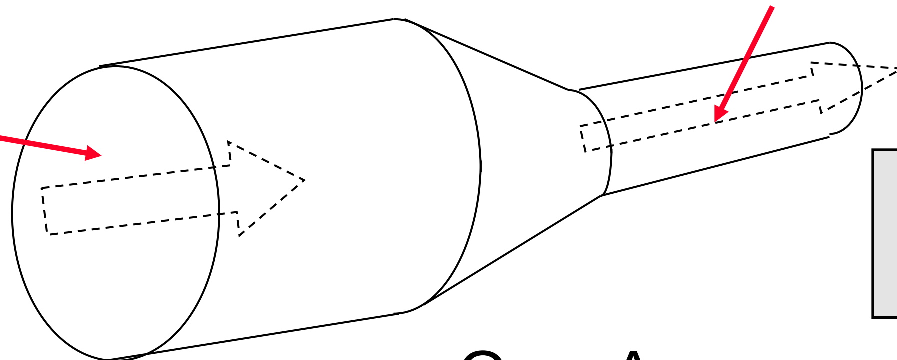
v = Average Velocity, m/s

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
$A = \pi d^2/4$

$Q = vA$

$Q = (600 \text{ m/s})(\pi[1\text{m}]^2/4)$

$Q =$ **471 m³/s**

$Q = vA$

471 m³/s $= v\,(\pi[0.5\text{m}]^2/4)$

v = 2403 m/s

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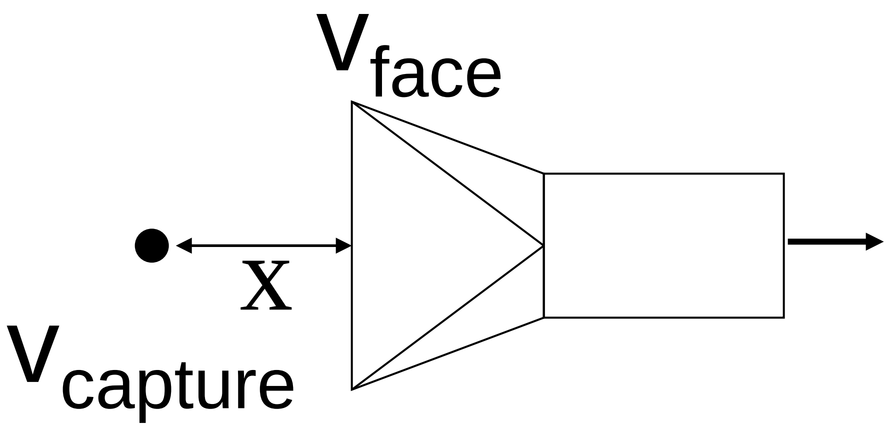
Press Room – Ventilation System

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.

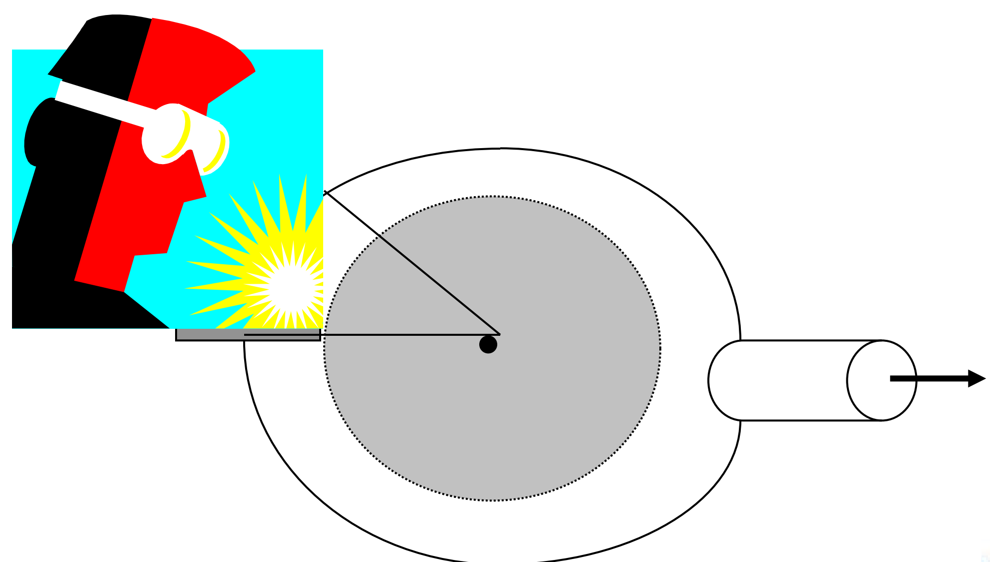
Local Exhaust Hoods

CAPTURE

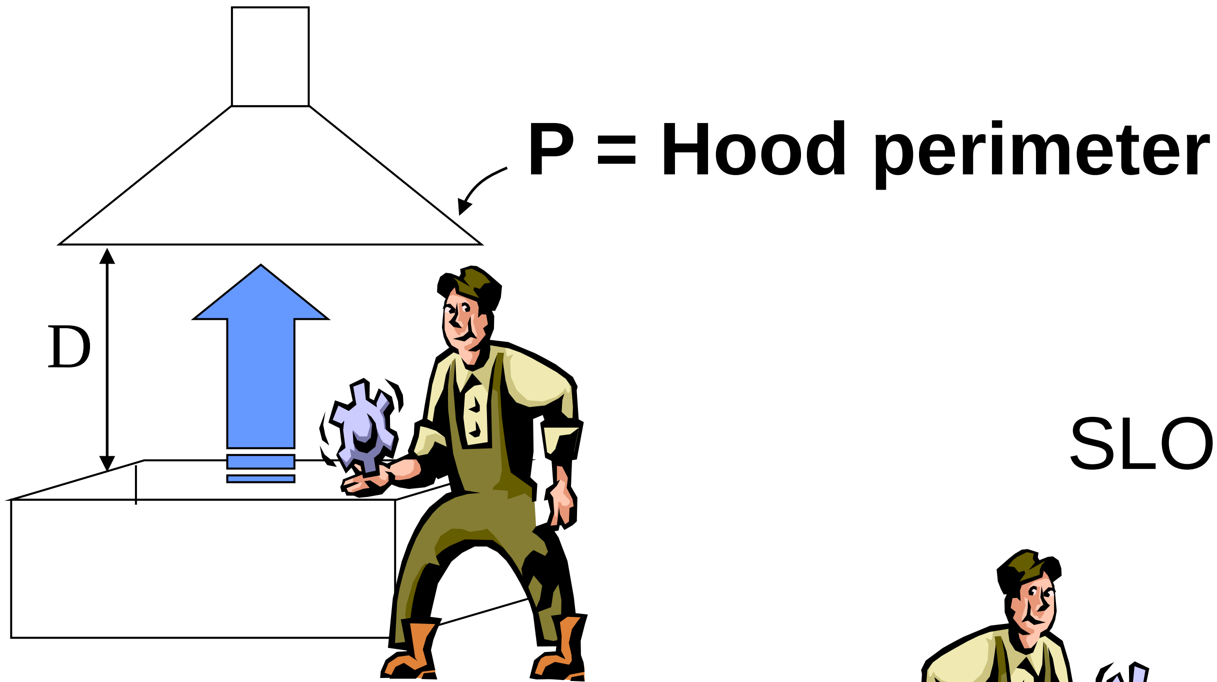


$$Q = vA$$

ENCLOSURE

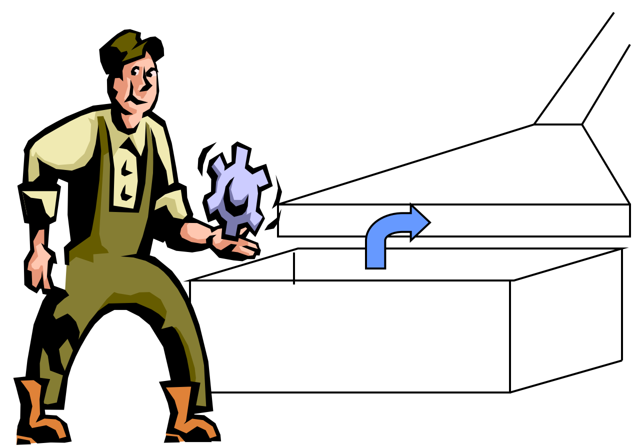


Local Exhaust Hoods



CANOPY HOOD

SLOT HOOD



Canopy Hood – Machine Shop

Portable Welding Hood

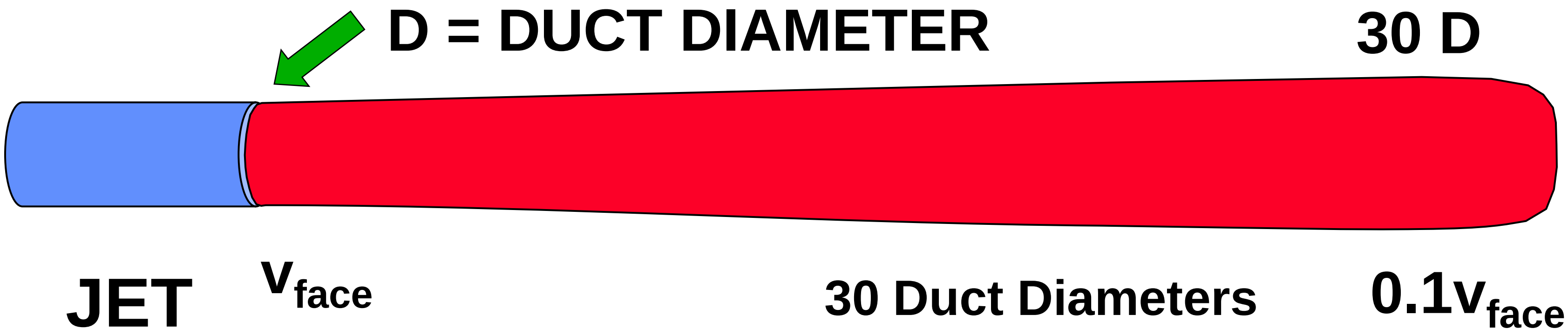
Traditional Laboratory Chemical Hood

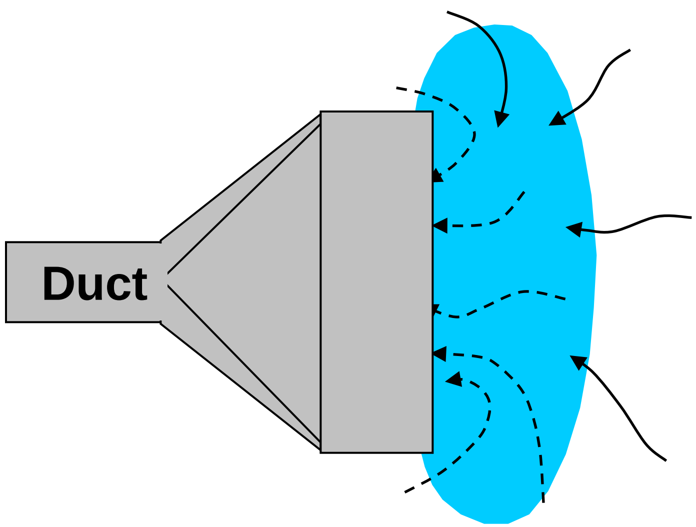
Special Purpose Hoods Vented to the Outside

Design Goals for Balance Enclosures

- High level of containment
- Stable balance readings
- Ergonomic design, visibility, comfort
- Task specific flexibility
- Energy efficient
  - 2’ enclosure = 100 CFM air, 6’ hood = 1200 CFM air
    1200 CFM = $5K/yr.

Flow at Exit and Entry



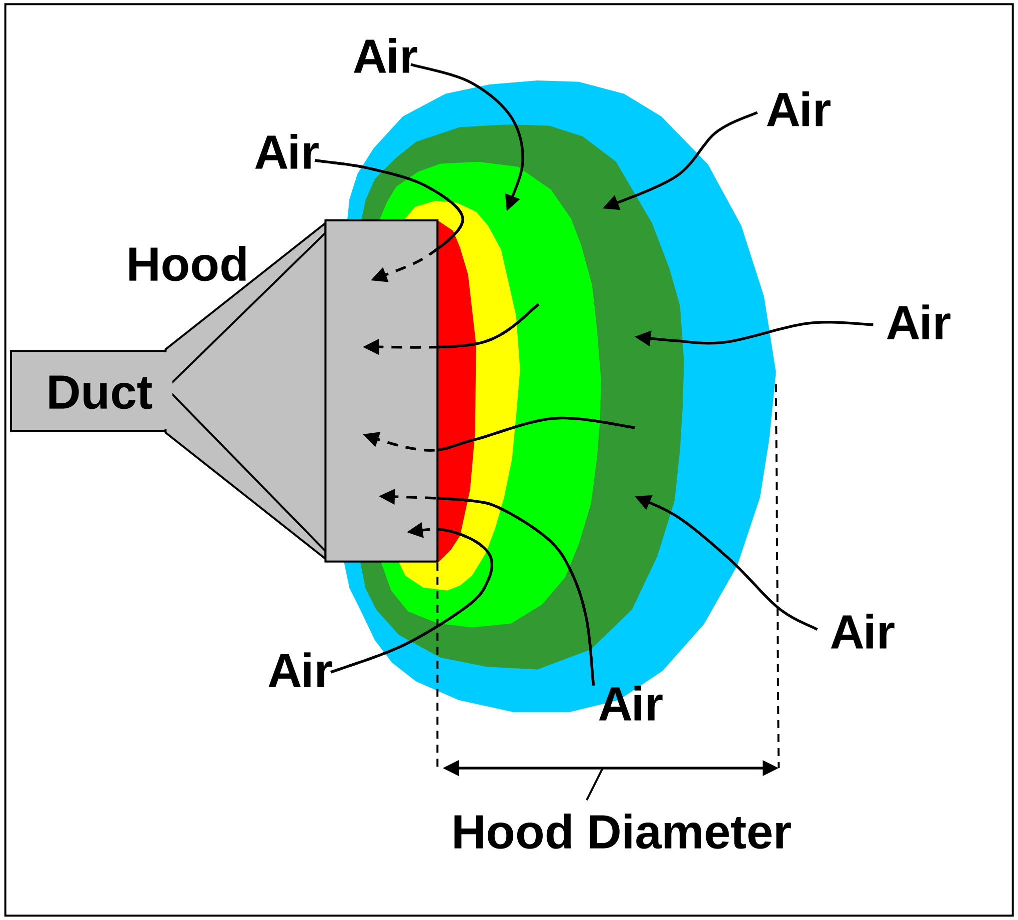


Capture of contaminant is only effective within <u>one (1) duct diameter</u>

Hood Capture Velocities

Equal Velocity Zones

% Hood Capture Velocity	
(red)	~100%
(yellow)	~60%
(light green)	~30%
(dark green)	~15%
(light blue)	~7.5%



Hood Capture Velocities

Equal Velocity Zones

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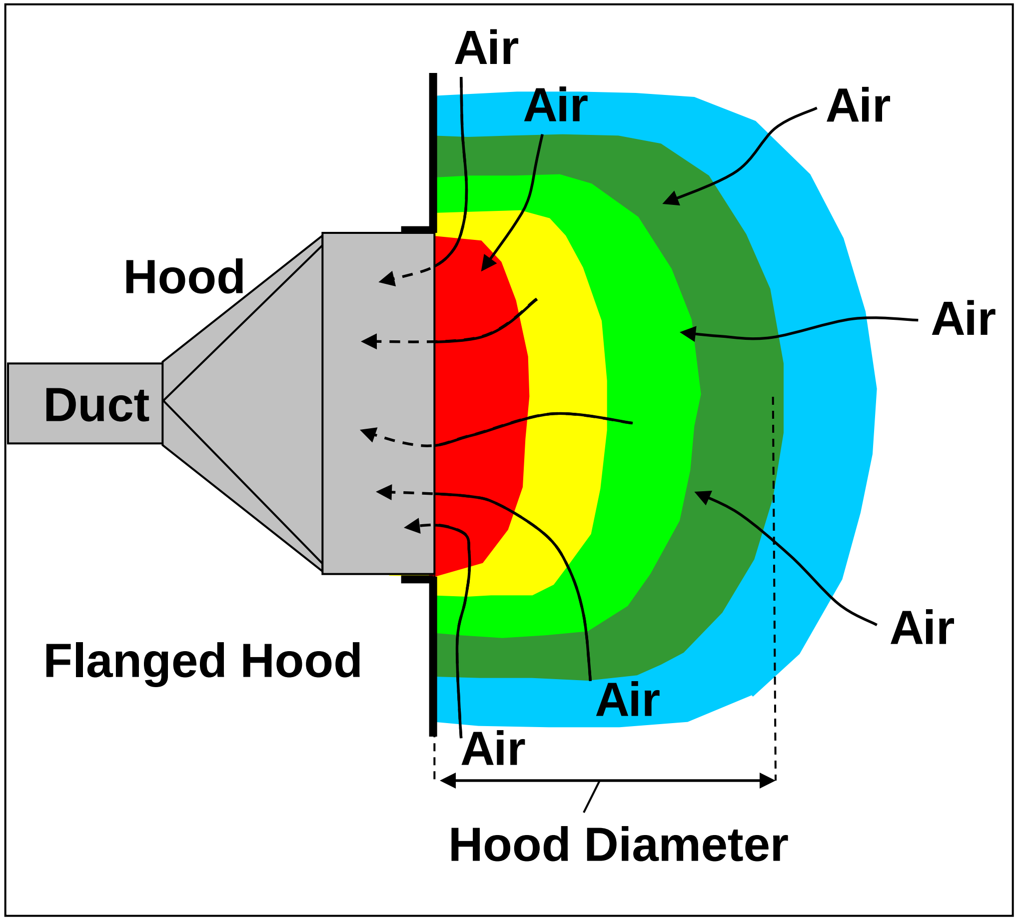
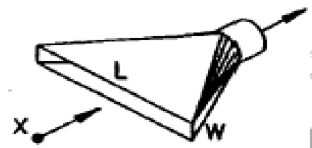
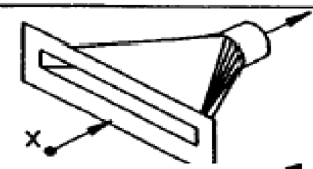
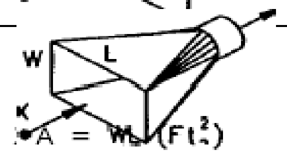
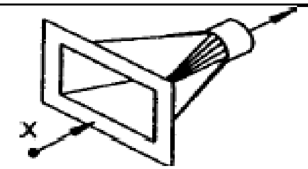
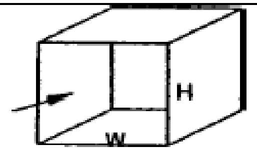
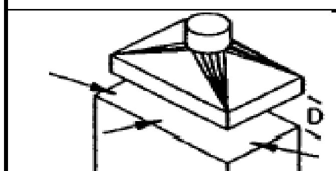
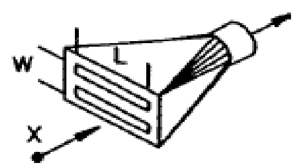
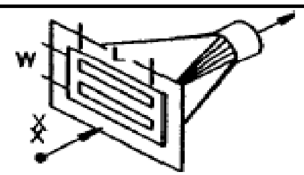


Recommended Capture Velocities

CONDITION	EXAMPLES	CAPTURE VELOCITY fpm (m/min)
No velocity, Quiet air	Evaporation from tanks, degreasers	50 – 100 (15 – 30)
Low velocity, moderately still air	Spray booths, container filling, welding, plating	100 – 200 (30 – 60)
Active generation into rapid air motion	Spray painting (shallow booths), crushers	200 – 500 (60 – 150)
High initial velocity into very rapid air motion	Grinding, abrasive blasting, tumbling	500 – 2000 (150 – 600)

Design Duct Velocities

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

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	$O = V(10X^2 + A)$
	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
- Flanged Opening
- Slot
- Flanged Slot
- Booth
- Canopy

- $Q = v(10X^2 + A)$
- $Q = 0.75v(10X^2 + A)$
- $Q = 3.7\ LvX$
- $Q = 2.6\ LvX$
- $Q = vWH$
- $Q = 1.4\ PvX$

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)

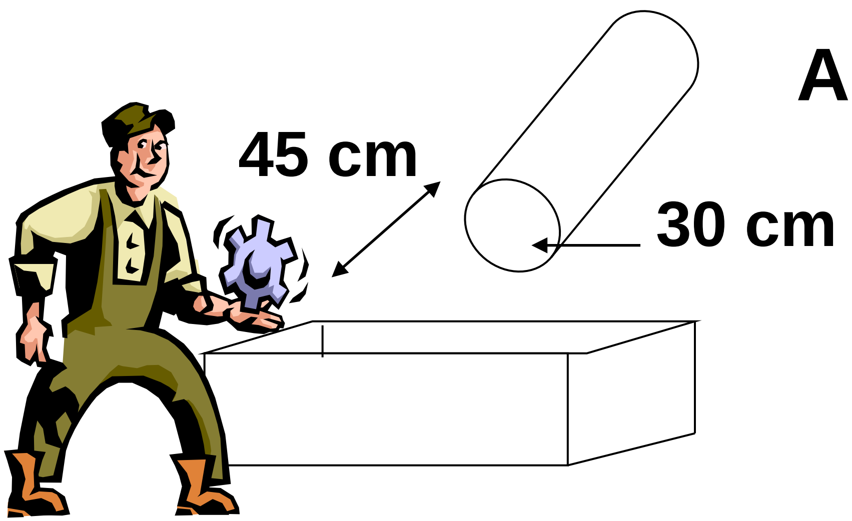
v = Velocity of air (m/s)

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.



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

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

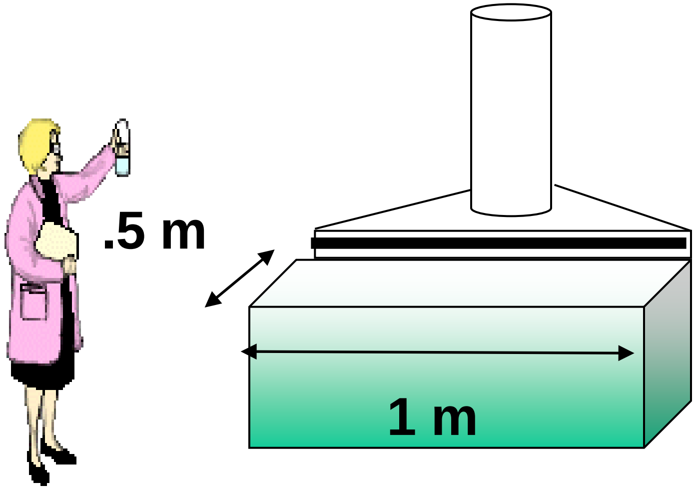
Assume a capture velocity = 30 m/min

$$Q = 30\ \text{m/min}\ [(10 \times 0.45^2) + 0.071\ \text{m}^2]$$

$$Q = 30\ \text{m/min}\ (2.096\ \text{m}^2) = 62.87\ \text{m}^3/\text{min}$$

Hood Calculations: Example

Determine the air flow required to capture Trichloroethlyene 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 30 m/min

$$Q = 2.6LvX$$

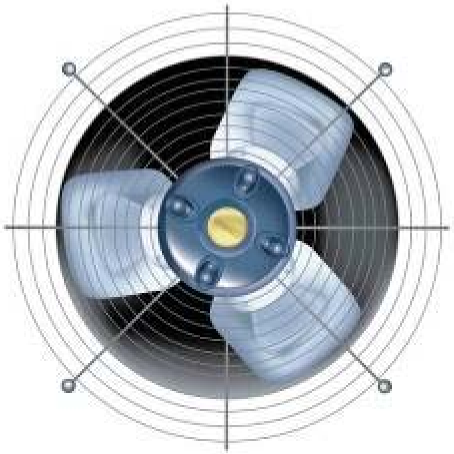
$$Q = 2.6(1\ m)(30\ m/min)(0.5\ m)$$

$$Q = 39\ m^3/min$$

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

Fan Speed and Air Flow

Fan rated to deliver 300 m^3/min of air running at 400 RPM. If fan speed increases by 25% to 500 RPM, what is the new air flow?



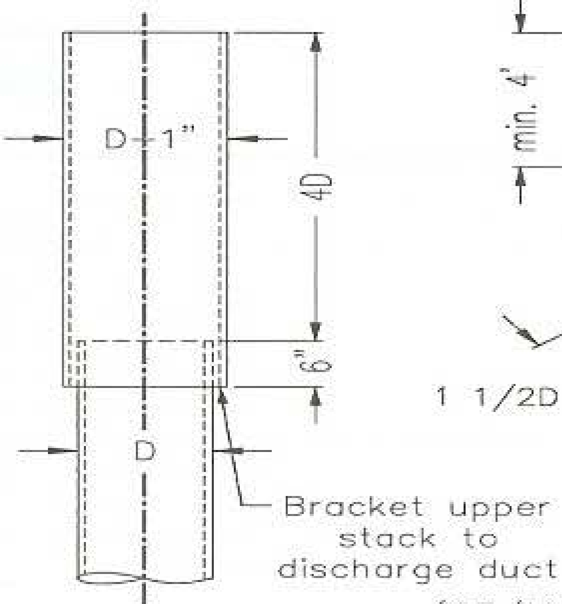
$$Q \propto RPM$$

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

$$Q_2 = 300 \left(\frac{500}{400} \right) = 375 \ m^3/min$$

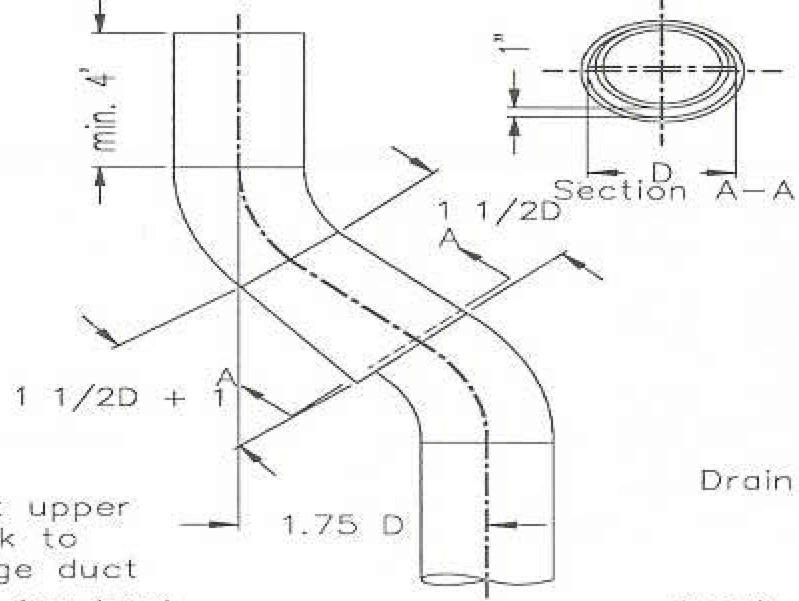
Hood Exhaust

- Height
- Discharge velocity
- Configuration

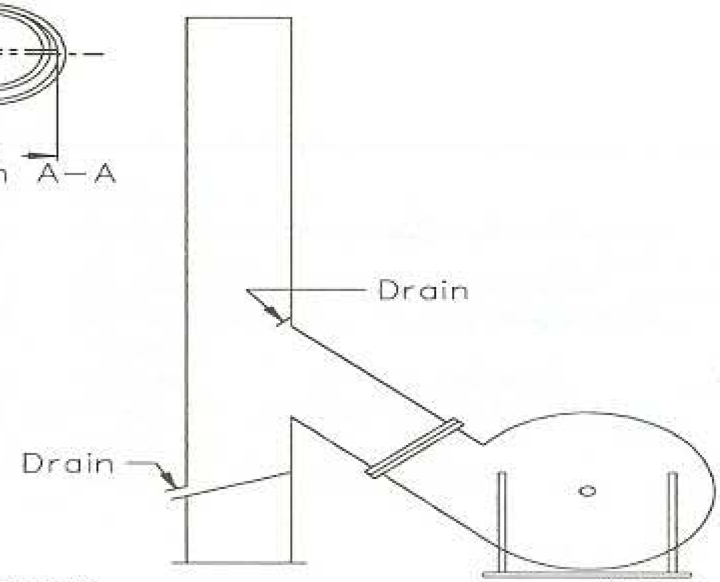


VERTICAL DISCHARGE (87/116)

NO LOSS



OFFSET ELBOWS (106)

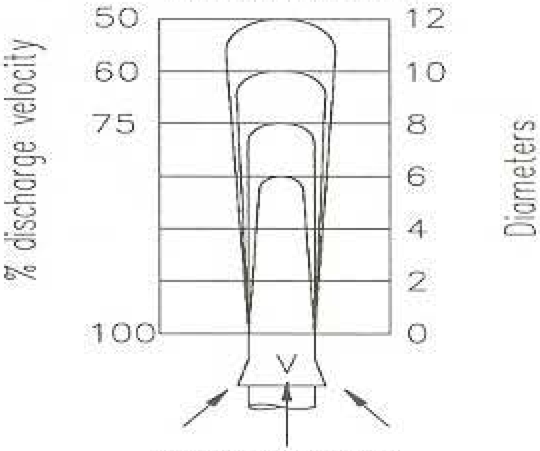


OFFSET STACK (106)

CALCULATE LOSSES DUE TO ELBOWS

1. Rain protection characteristics of these caps are superior to a deflecting cap located 0.75D from top of a stack.
2. The length of upper stack is related to rain protection. Excessive additional distance may "blowout" of effluent at the gap between upper and lower sections. (86)

STACKHEAD

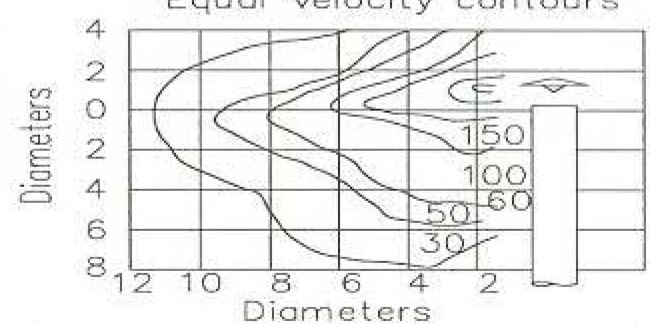


PREFERRED

Deflects air upward

WEATHER CAP

Equal velocity contours



NOT RECOMMENDED

Deflects air downward

AVOID


evapco
evapco

Engineering Controls: Avoid Exhaust Recirculation

Hood Exhaust

Air Intake

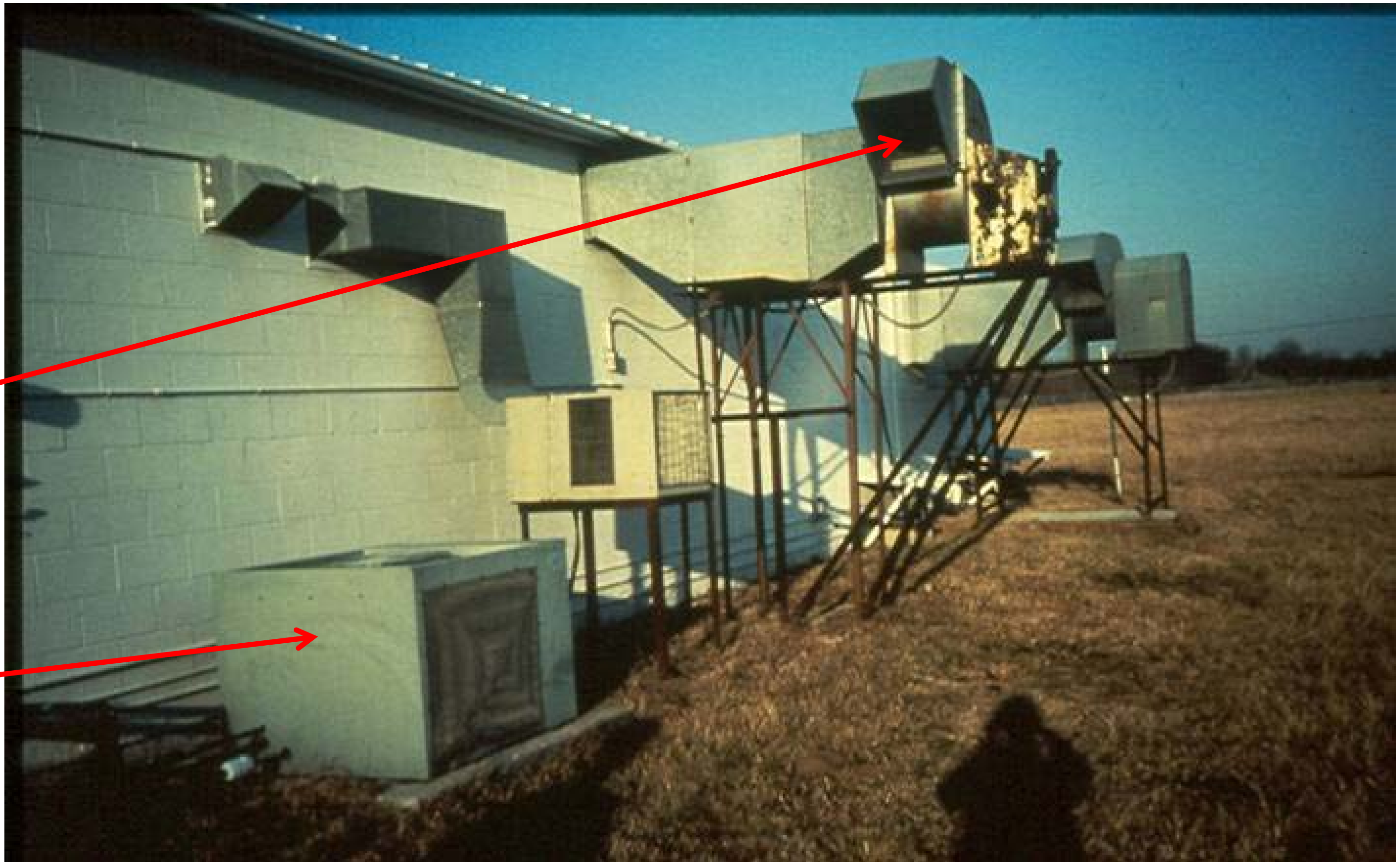
CSP CHEMICAL SECURITY ENGAGEMENT PROGRAM

Chemical SAFETY AND SECURITY TRAINING

Engineering Controls: Avoid Exhaust Recirculation

High Hazard Hood Exhaust

Air Intake

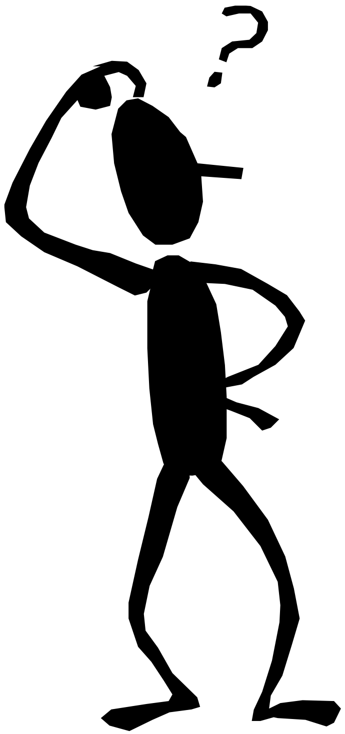


CSP CHEMICAL SECURITY ENGAGEMENT PROGRAM

Chemical SAFETY AND SECURITY TRAINING

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?

Laboratory Chemical Hoods:

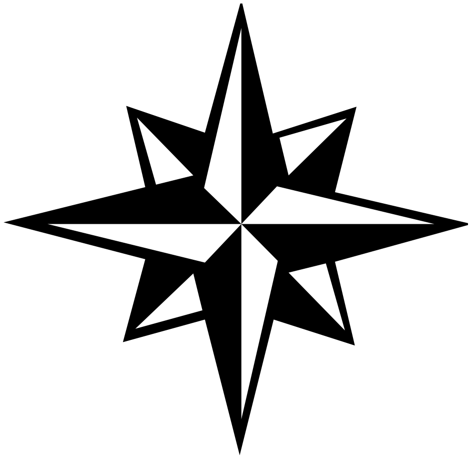
How they work & when they don't.

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



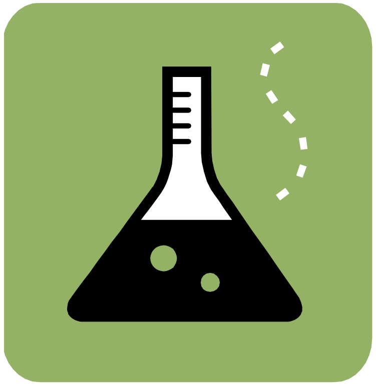
PATH

SOURCE

RECEIVER

LEV Objectives

- Maximize Containment
- Minimize Contamination
- Redundancy is the Key

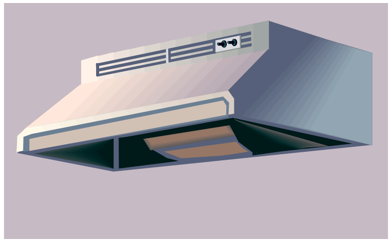


LEV Implementation

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

LEV Capture Ability

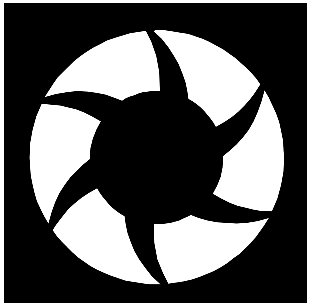
- Hood configuration (type of hood)



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

Duct Design

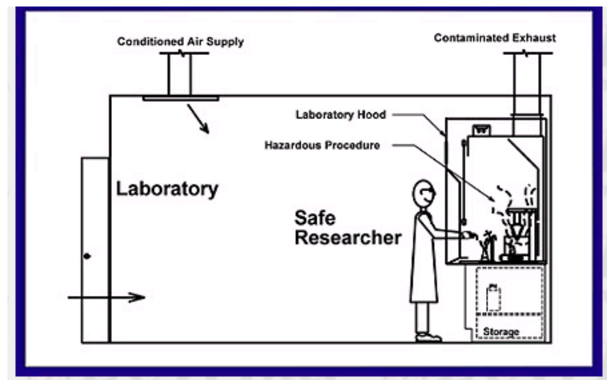
- **Provide adequate capture velocity**
  - **Usually 80-120 fpm (0.4 - 0.6 m/s)**



- **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

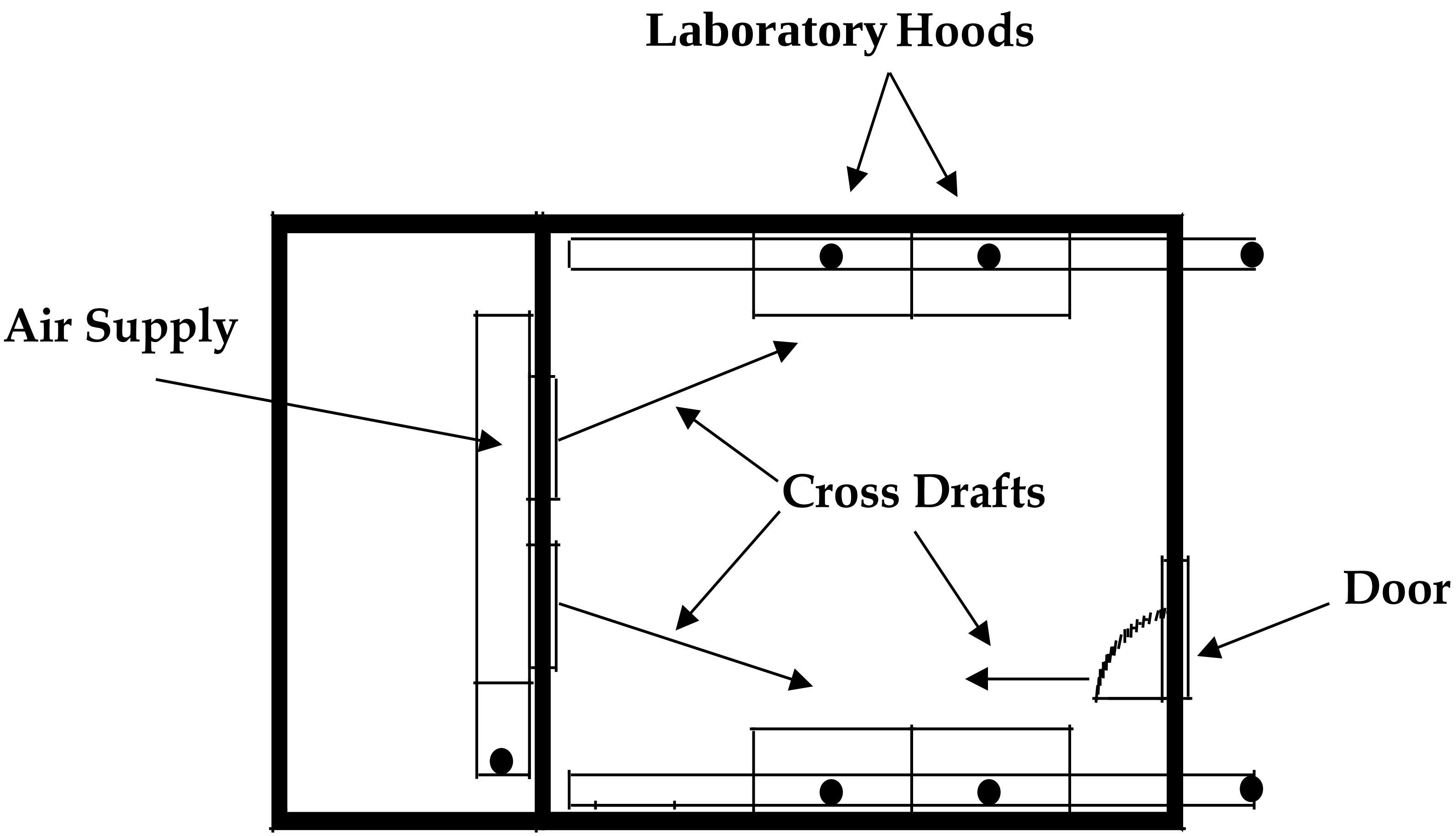
Laboratory hoods and ventilation are the basis of engineering controls.

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

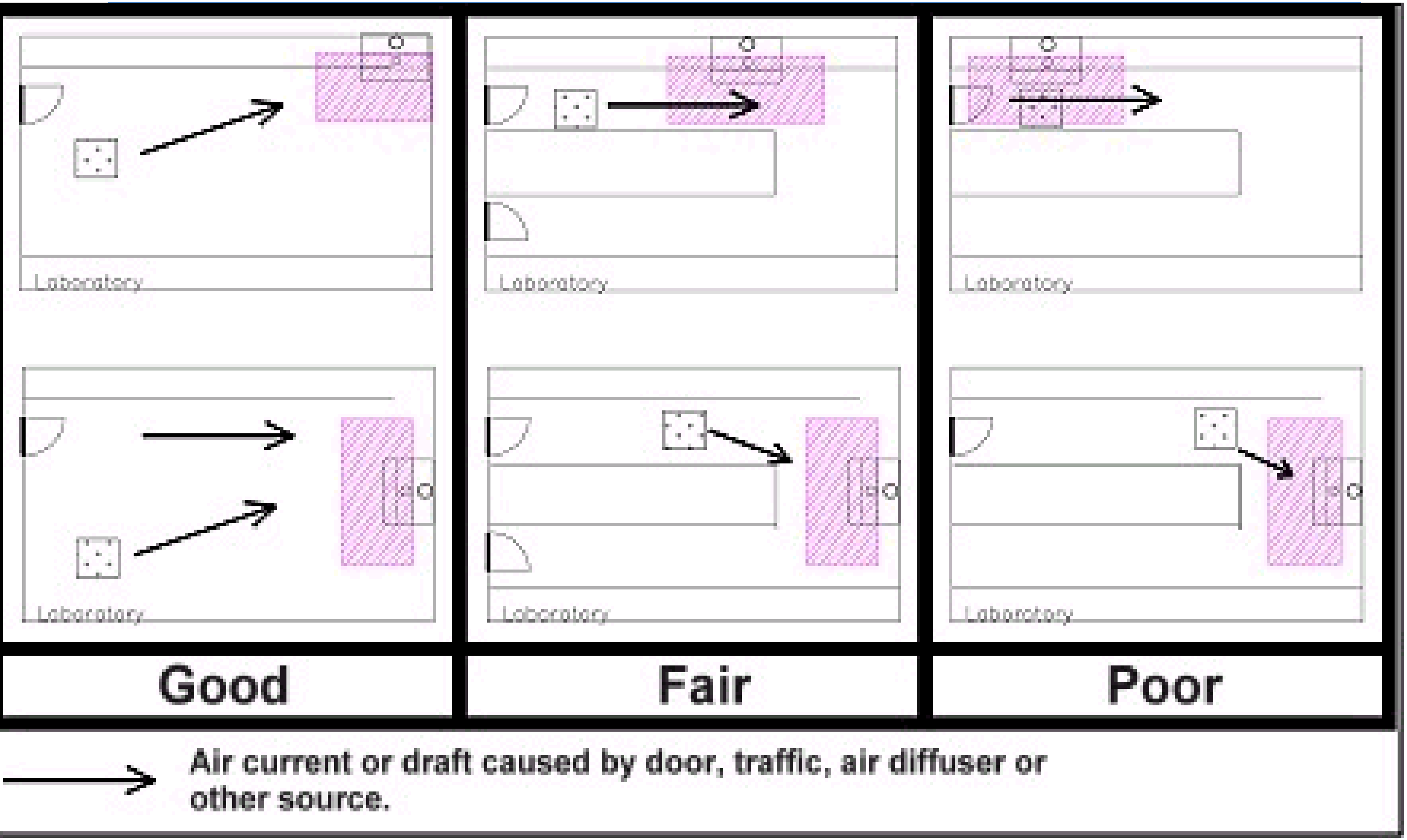
Hood Location Requirements

- 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.

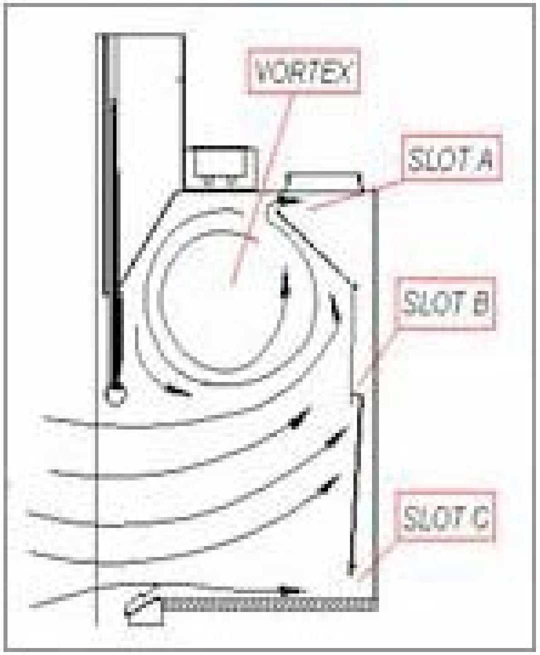
Laboratory Hood Types

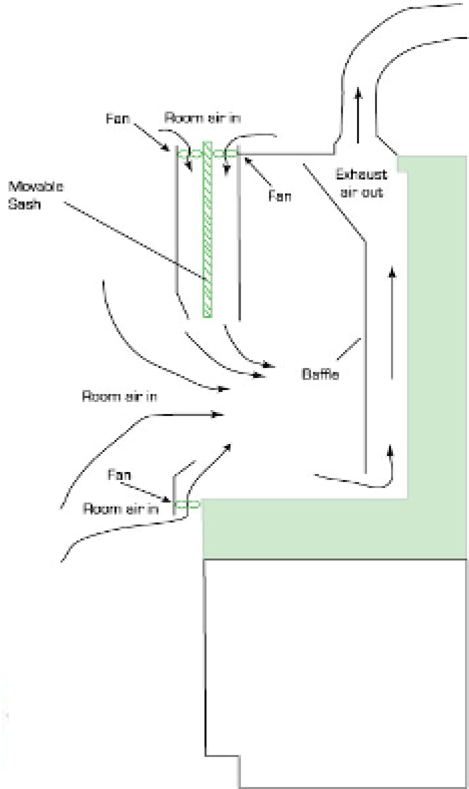
- **Constant Air Volume (CAV)**
  - **Traditional/Standard/Conventional**
  - **Bypass**
  - **HOPEC (horizontal/vertical sash)**
  - **Auxiliary Air (not recommended for Lab operations)**

- **Variable Air Volume (VAV)**

Traditional Constant Volume Hood

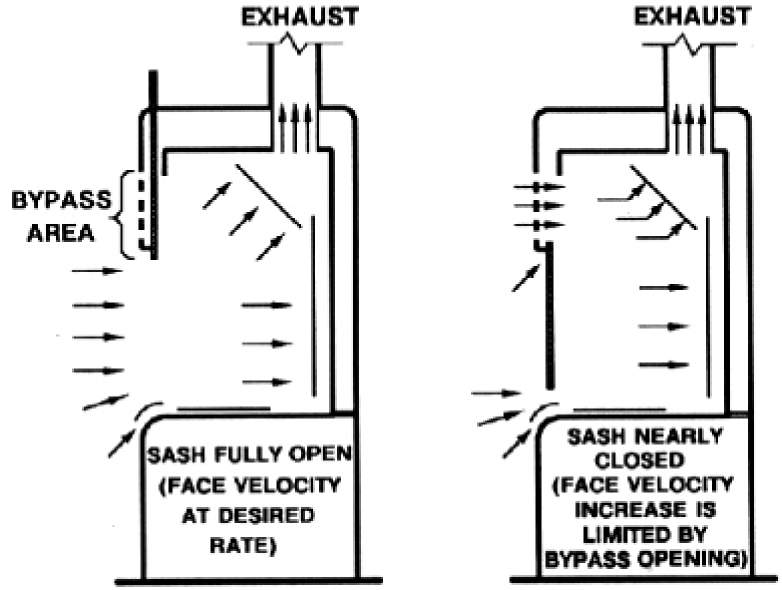
- All make up air enters through hood face.
- Air exhausted is constant regardless of size of face opening or sash height.
- Volume of air movement is constant but velocity varies with sash height.





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.



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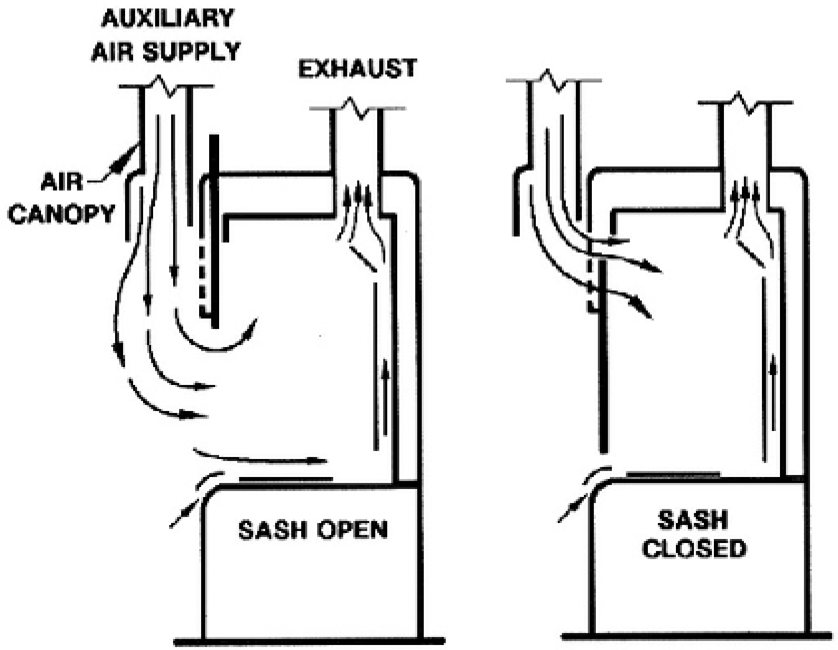
Chemical SAFETY AND SECURITY TRAINING

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.



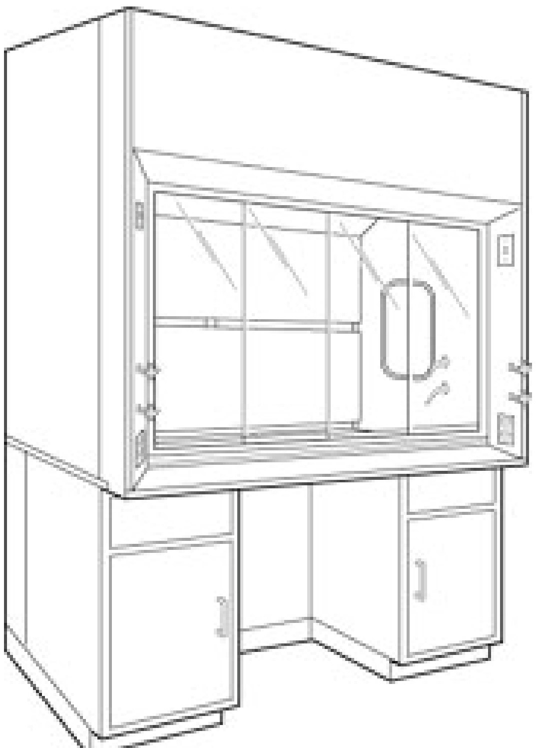
* According to ANSI Z9.5

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.

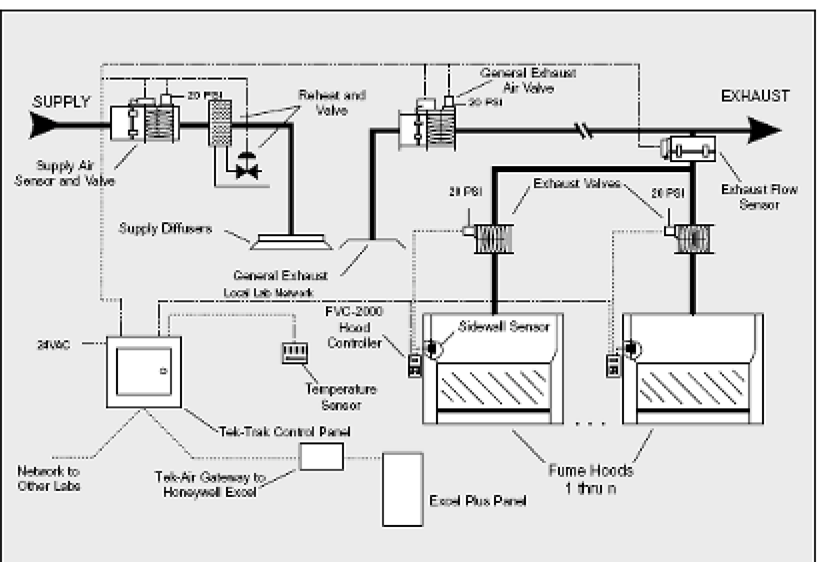


Variable Air Volume (VAV) Hood

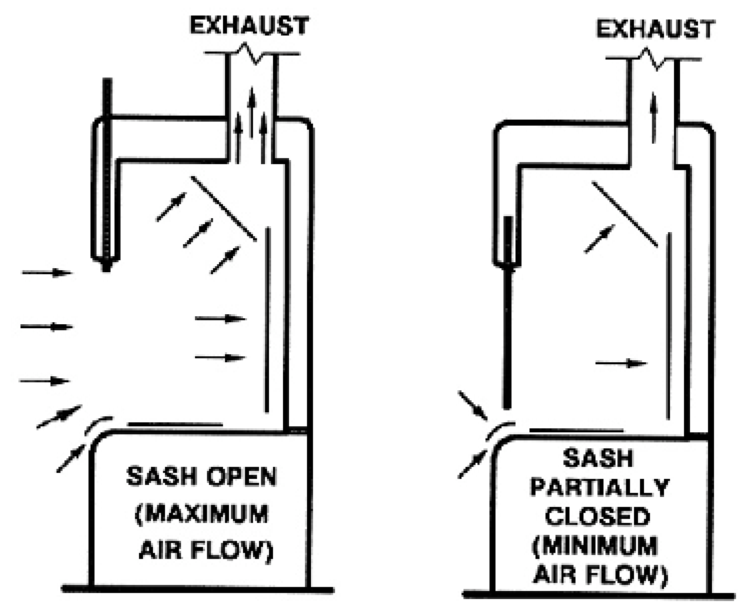
Uses mechanical and electronic controls to maintain constant air velocity.

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

Uses complicated electronic components that require special training to maintain.



RPI Walker Laboratory Typical Lab Layout



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

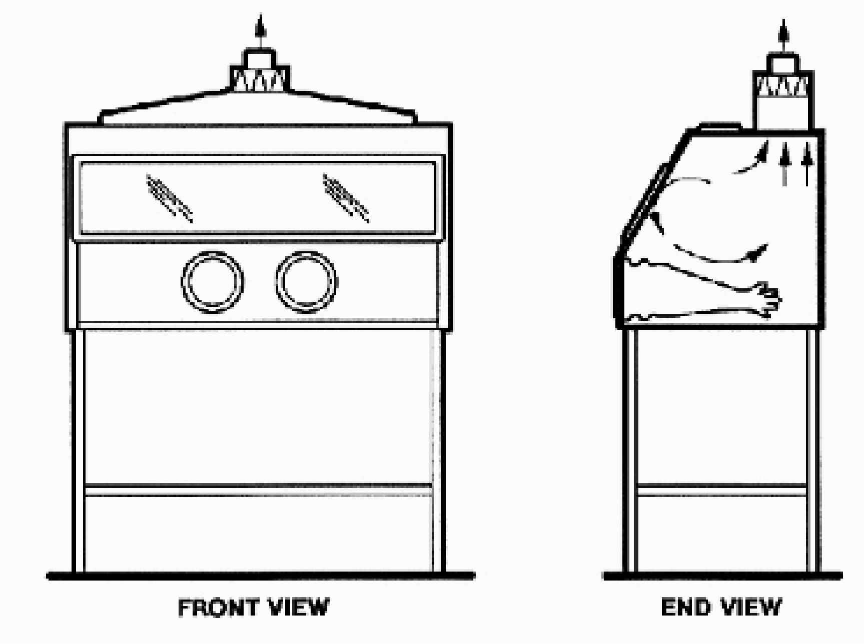
EXAMPLE: "Snorkel" Fume Extractor

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.

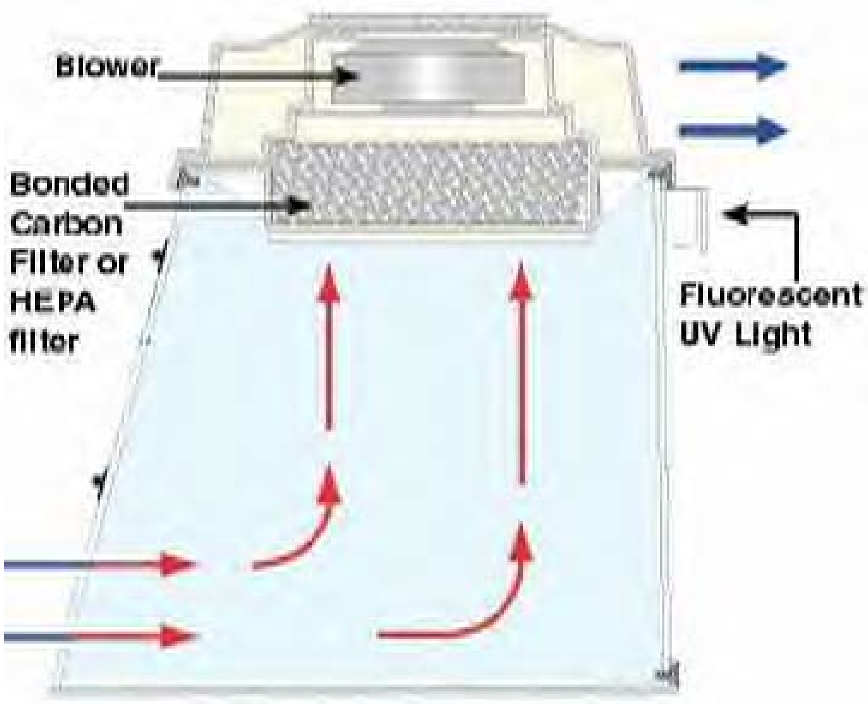


Special purpose vented hood

Chemical weighing station

Bulk powder transfer station

Ductless Hoods



Ductless Hoods

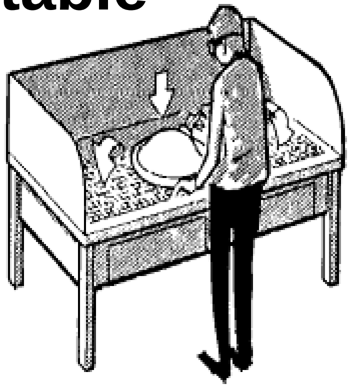
Should only be used in laboratories with:

- 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.

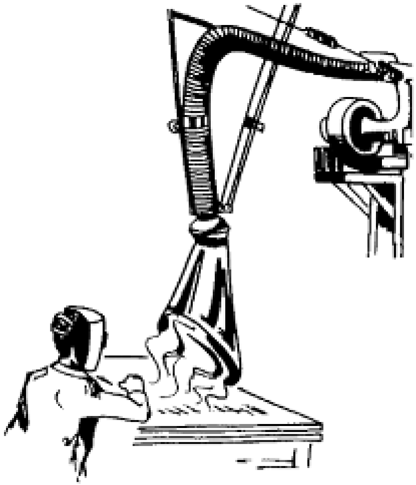
Specialized Hoods

Dust hood,
Animal feed

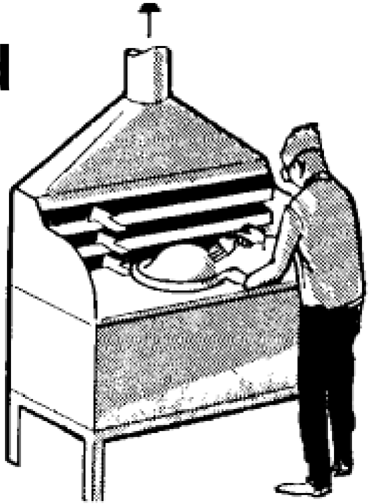
Downdraft table



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

CSP
CHEMICAL SECURITY ENGAGEMENT PROGRAM

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.

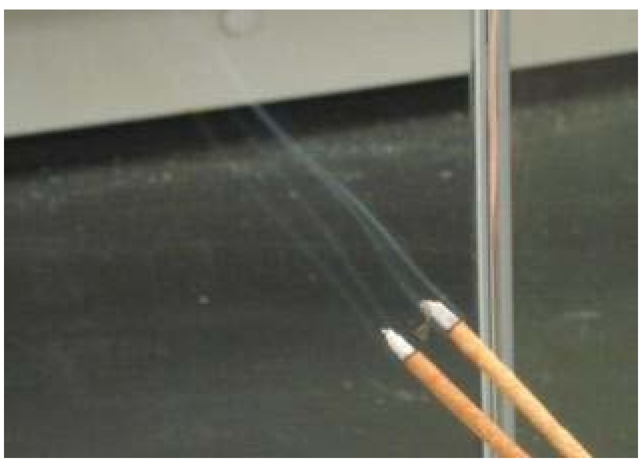
Hood Evaluation

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

$$PF = \frac{\text{Contaminant Concentration in Exhaust Air}}{\text{Contaminant Concentration in Breathing Zone}}$$

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
  - Anemometers (m/s)
    - Directional
  - Hot-wire anemometer (m/s)
    - Non-directional

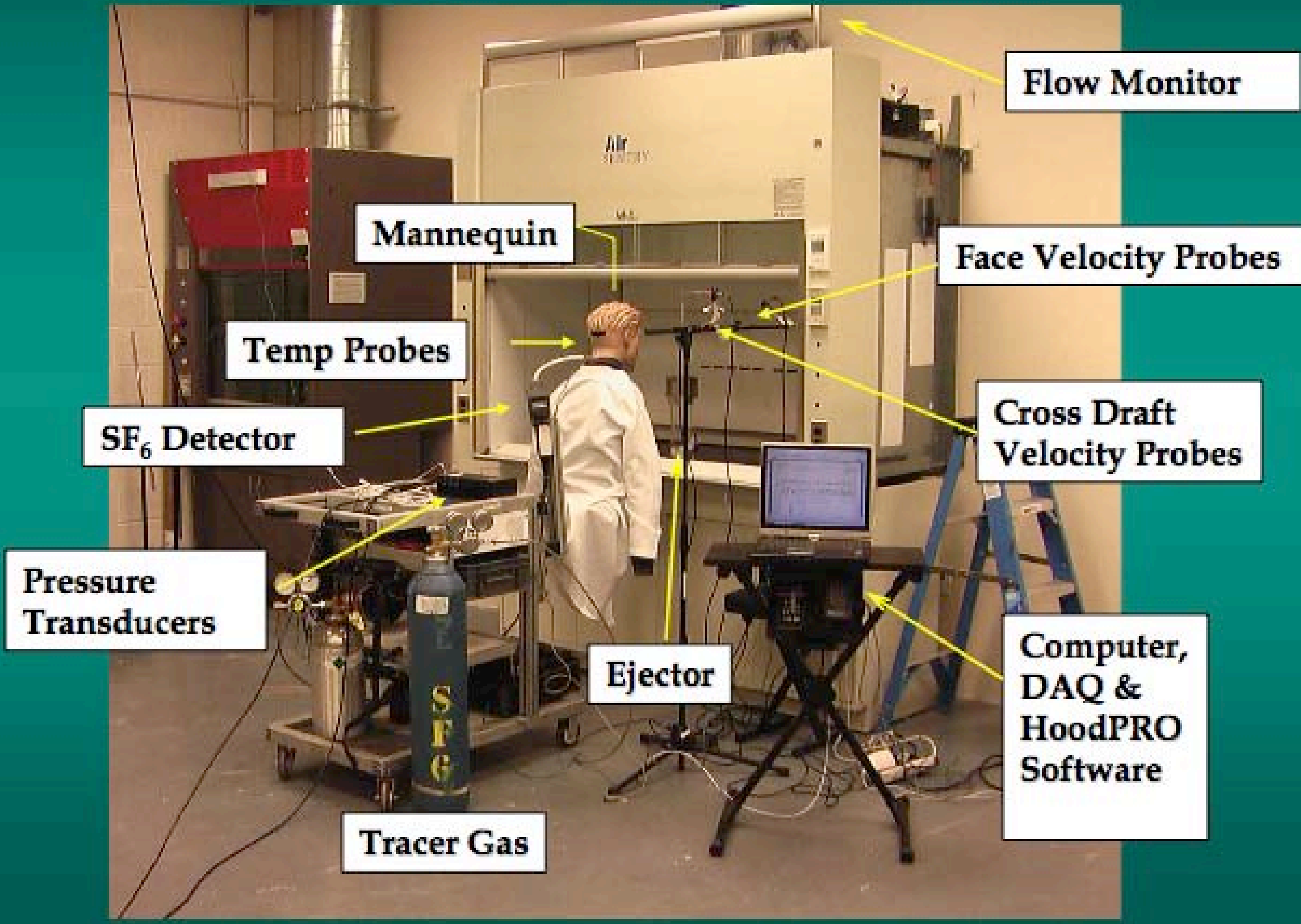
Hood Smoke Evaluation
Face velocity *vs.* Containment

- 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

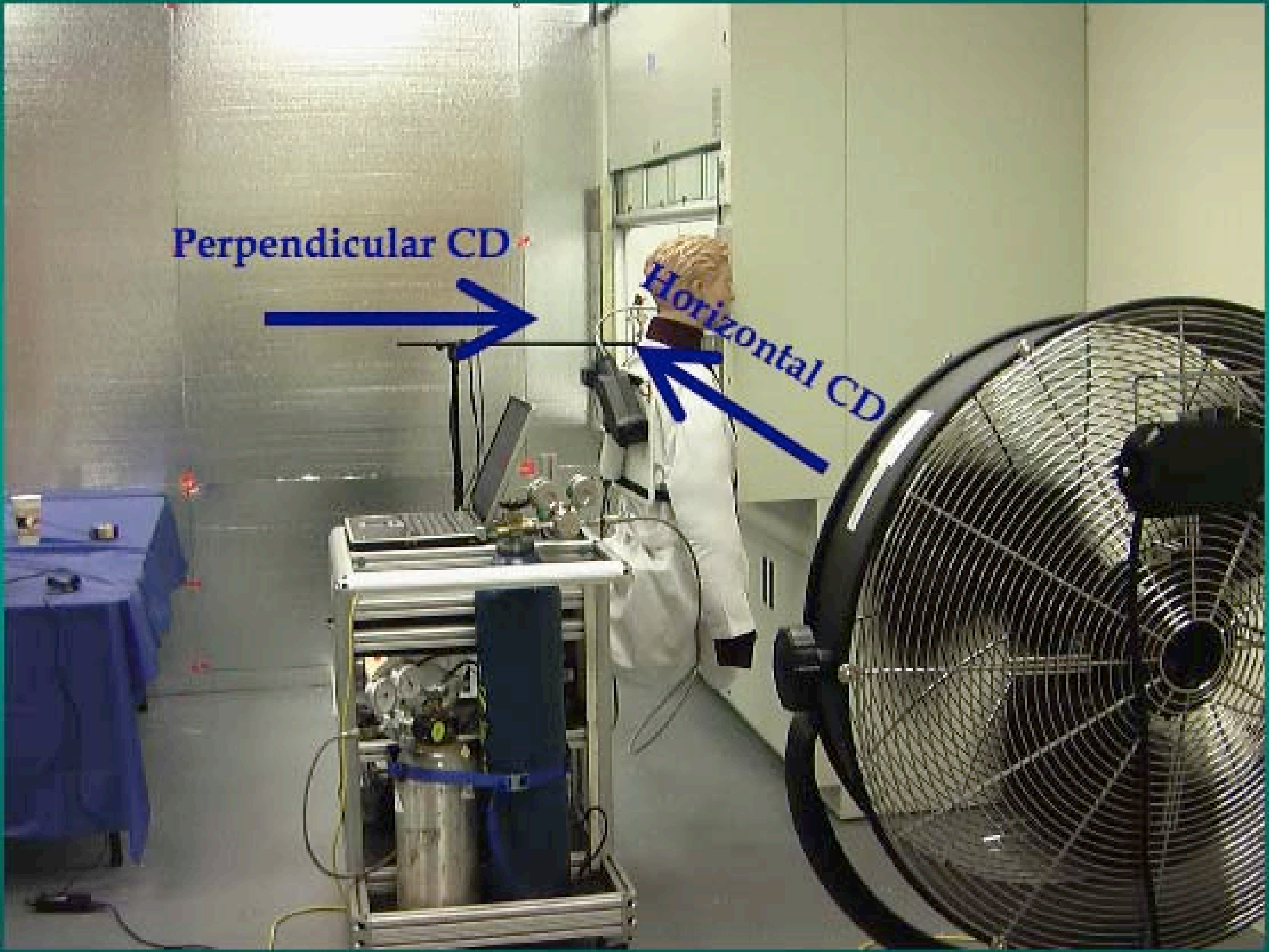
Chemical
SAFETY AND SECURITY TRAINING

CSP
CHEMICAL SECURITY
ENGAGEMENT PROGRAM

Hood Loading Challenge Test

Walk-By Challenge Test

Cross Draft Challenge Tests




Good sweeping flow

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

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LUNCH

Lab Visit