Personal Protective Equipment (PPE)

Limitations of PPE

- The least desirable control, but may be necessary if:
  - Engineering controls are being installed
  - Emergency response/spill cleanup
  - Non-routine equipment maintenance
  - To supplement other control methods

- Problems with PPE:
  - The hazard is still present with PPE
  - Use is very dependent on human behavior
  - Proper fitting is essential

- Can exposure be controlled by other means?

PPE Hazard Assessment

- Identify the hazard(s)
  - Chemical
  - Mechanical
  - Electrical
  - Light energy (lasers, welding)
  - Fire response
  - Hot processes

- Identify the potential exposure route
  - Inhalation
  - Skin contact
  - Eye contact
PPE Hazard Assessment

- Identify the type of skin contact
  - Immersion
  - Spray
  - Splash
  - Mist
  - Vapor (gaseous)
- Consider the exposure time
  - Incidental contact
  - Continuous immersion
  - Unknown/emergency response

Exercise

- List one work activity at your plant that uses PPE
- What is the hazard?
- What is the route of exposure? Inhalation, skin, eyes, or?
- Are there ways to control exposure to this hazard other than PPE?
  - What other ways?

Training

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, maintenance, useful life and disposal
- Involve workers in selection

Retraining is necessary when there is:

- A change in the hazards
- A change in the type of PPE required
- Inadequate employee knowledge or use of PPE

http://www.free-training.com/OSHA/ppe/Ppemenu.htm

http://www.free-training.com/OSHA/ppe/Ppemenu.htm
General Characteristics of PPE

Protective clothing and gloves:
- Act as a barrier to prevent contact with the skin
- Protect against:
  - Toxics
  - Corrosives
  - Irritants
  - Sensitizers (allergens)
  - Thermal injury (burns)
  - Physical Trauma

Permeation Rate (PR)

<table>
<thead>
<tr>
<th>PR</th>
<th>Permeation Rate Breakthrough (PB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>E: Excellent</td>
<td>&gt;Greater than (time - minutes)</td>
</tr>
<tr>
<td>VG: Very Good</td>
<td>&lt; Less than (time - minutes)</td>
</tr>
<tr>
<td>G: Good</td>
<td>F: Fair; fluid has moderate degrading effect.</td>
</tr>
<tr>
<td>F: Fair</td>
<td>P: Poor; fluid has pronounced degrading effect.</td>
</tr>
<tr>
<td>NR: Not recommended</td>
<td>NR: Fluid is not recommended with this material.</td>
</tr>
</tbody>
</table>

Permeation Degradation rate (DR)

- E: Excellent; fluid has very little degrading effect.
- VG: Very Good; fluid has minor degrading effect.
- G: Good; fluid has moderate degrading effect.
- F: Fair; fluid has moderate degrading effect.
- P: Poor; fluid has pronounced degrading effect.
- NR: Fluid is not recommended with this material.

Protective Clothing

- Special Applications
  - Hot processes
  - High voltage/arc flash
  - NFPA 70E
  - Foundries/molten metal
  - Refineries
- Select flame resistant clothing
- Chemical resistant coating may be added to flame resistant clothing
Gloves

• Evaluate the work task
  ▪ Chemical immersion or incidental contact?
  ▪ Consider ergonomics/dexterity required
• Use glove charts
  ▪ Charts recommend gloves for specific chemicals
    ▪ Evaluate permeation rates and breakthrough time of
      selected glove for the specific task
  ▪ Consider several glove manufacturers data before final
    selection.
    ▪ http://www.mapaglove.com
    ▪ http://www.ansellpro.com
    ▪ http://www.bestglove.com/site/chemrest/

Laminated Gloves: 4H®, Silver Shield®
• Useful for a wide range of chemicals.
  ▪ NOT HYDROGEN FLUORIDE!
• Can use with a nitrile over glove to improve dexterity.

Butyl Rubber
• Highest permeation resistance to gas or water vapors.
• Uses: acids, formaldehyde, phenol, alcohols.

General Types of Glove Material

Types of Gloves

Neoprene
• Protects against acids, caustics.
• Resists alcohols, glycols.

Nitrile
• Good replacement for latex
• Protects against acids, bases, oils, aliphatic hydrocarbon solvents and esters, grease, fats
• NOT ketones
• Resists cuts, snags, punctures and abrasions
Eye and Face Protection

- Each day, 2000 U.S. workers have a job-related eye injury that requires medical treatment.
- Nearly three out of five U.S. workers are injured while failing to wear eye and face protection.


<table>
<thead>
<tr>
<th>Hazard Type</th>
<th>Common related tasks</th>
<th>Protective Eyewear</th>
</tr>
</thead>
<tbody>
<tr>
<td>Impact</td>
<td>Chipping, grinding, machining, abrasive blasting, sawing, drilling, riveting, sanding,…</td>
<td>Safety glasses with sideshields or goggles</td>
</tr>
<tr>
<td>Heat</td>
<td>Furnace operations, smelting, pouring, casting, hot dipping, welding,…</td>
<td>Face shield with infrared protection</td>
</tr>
<tr>
<td>Chemicals</td>
<td>Pouring, spraying, transferring, dipping acids, solvents or other injurious chemicals</td>
<td>Goggles or face shield</td>
</tr>
<tr>
<td>Particles/Dust</td>
<td>Woodworking, metal working, and general dusty conditions</td>
<td>Safety glasses with sideshields</td>
</tr>
<tr>
<td>Optical Radiation</td>
<td>Welding, torch-cutting, brazing, and laser work</td>
<td>Welding helmet or laser glasses; must protect for specific wavelength of ultraviolet or infrared radiation.</td>
</tr>
</tbody>
</table>
Examples of Eye & Face Protection

- Goggles
- Face shield
- Safety glasses
- Welding helmet
- Hooded faceshield

Respiratory Protection

U.S. Respirator Requirements

- Written program
- Hazard assessment
- Air monitoring
- Medical clearance
- Fit testing
- Respirator selection
- Procedures
  - Cleaning, maintenance, repairing
  - Training (annual refresher)

Basic Types of Respirators

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

Air Purifying Respirators (APR)

- Work area must have at least 19.5% oxygen
- The contaminant must have adequate warning properties. Ex. ammonia
  - \textit{Never} use APR in oxygen deficient atmospheres
- APRs work by filtering, absorbing, adsorbing the contaminant or chemical reaction.
  - Filters, cartridges, canisters
- The contaminant concentration must NOT exceed the maximum use concentration.
- Some cartridges have “end of service life” indicators or can use change schedules
### Types of APR Cartridges

<table>
<thead>
<tr>
<th>Cartridge</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organic Vapor</td>
<td></td>
</tr>
<tr>
<td>Organic Vapor and acid gases</td>
<td></td>
</tr>
<tr>
<td>Ammonia, methylamine and P100 particulates filter</td>
<td></td>
</tr>
</tbody>
</table>

### 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

### APR Filter Efficiency

**National Institute of Occupational Safety and Health**

<table>
<thead>
<tr>
<th>Filter Class</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>N95</td>
<td>Filters at least 95% of airborne particles. Not resistant to oil.</td>
</tr>
<tr>
<td>N99</td>
<td>Filters at least 99% of airborne particles. Not resistant to oil.</td>
</tr>
<tr>
<td>N100</td>
<td>Filters at least 99.97% of airborne particles. Not resistant to oil.</td>
</tr>
<tr>
<td>R95</td>
<td>Filters at least 95% of airborne particles. Somewhat resistant to oil.</td>
</tr>
<tr>
<td>P95</td>
<td>Filters at least 95% of airborne particles. Strongly resistant to oil.</td>
</tr>
<tr>
<td>P99</td>
<td>Filters at least 99% of airborne particles. Strongly resistant to oil.</td>
</tr>
<tr>
<td>P100</td>
<td>Filters at least 99.97% of airborne particles. Strongly resistant to oil.</td>
</tr>
</tbody>
</table>

### 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)**

\[ \text{MUC} = \text{APF} \times \text{Occupational Exposure Limit} \]  
(e.g. PEL, TLV)
Workplace air sampling indicates the exposure to benzene is 15 ppm. The exposure limit is 0.5 ppm (ACGIH TLV). What respirator should you choose?

Maximum Use Concentration (MUC) = APF x OEL

- Half Face Mask: MUC = 10 x 0.5 ppm = 5 ppm
- PAPR (LFF): MUC = 25 x 0.5 ppm = 12.5 ppm
- Full Face Respirator: MUC = 50 x 0.5 ppm = 25 ppm
Respirator Fit Testing

• Qualitative
  – Irritant smoke
    • stannic chloride
  – Isoamyl acetate
    • banana oil
  – Saccharin
  – Bitrex
• Quantitative
  – Portacount

Respirator Fit Test

Positive / Negative pressure fit test

Supplied Air

• Supplies breathing air to worker
  – SCBA
  – Airline
• Must use Grade D Air
• Many 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 milligrams/cubic meter or less
  – CO $\leq$ 10 parts per million (ppm) or less
  – CO$_2$ of 1,000 parts per million (ppm) or less
  – Lack of noticeable odor
• Compressors may be equipped with in-line air-purifying sorbent beds and filters.
Maintenance and Storage Procedures

- **Disposable filtering face-piece:**
  - Dispose after use

- **Air purifying respirators:**
  - 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

- **SCBA:**
  - Inspected monthly
  - Accessible and clearly marked

Exercise

- A contractor has been hired to sweep out a work area that contains lead dust. The plant safety officer has recommended that the worker don a full-face air purifying respirator with a HEPA filter (P100) during this activity.

- Later that week the plant safety officer observes the worker sweeping without wearing the respirator. When asked why he is not wearing the respirator, the worker states “it is too uncomfortable to wear.”

- What approach should the safety officer take to ensure the worker wears a respirator?

PPE Exercise

- Worker A needs to transfer 10 liters of acetone into a hazardous waste drum.
- The safety officer has determined that due to the use of ventilation, the air concentration of acetone is below the exposure limit.
- The worker may have incidental skin contact with the acetone during pouring.
- Prolonged skin exposure to acetone causes dry and cracked skin, but acetone is not normally absorbed through the skin.
- There is also a possibility that the acetone may splash in the worker’s face during pouring.

PPE Exercise

- Worker B is walking back from the break room when he notices a yellow cloud of chlorine coming towards him from the chlorine storage area. He also notices that some of the chlorine has come into contact with water under one of the tanks and formed chlorine hydrate.
- He alerts the emergency response team who arrive at the emergency staging area.
  - Chlorine is a corrosive and toxic gas by inhalation.
  - Chlorine hydrate is corrosive to the skin and eyes.
  - The airborne concentration of chlorine is unknown in this situation.

- What PPE should the emergency response team use?
Worker C is tasked with adding zinc oxide pigment into a mixing bath by hand. This task will take 15 minutes. Worker C performs this task once every day. The safety officer has determined that the airborne concentration during this task is 20 milligrams/cubic meter. The short term exposure limit (15 minutes) for zinc oxide is 10 milligrams/cubic meter. Zinc oxide powder is mildly irritating to the skin and eyes, but not toxic or corrosive.

What PPE should Worker C wear?

Industrial Ventilation

• Definitions
• Common Terminology
• Purpose
• Hazard Assessment
• General Ventilation
• Local Exhaust Ventilation
• Ventilation Evaluation
• Troubleshooting
• Exercises

American Conference of Governmental Industrial Hygienists (ACGIH) Ventilation Manual 27th Edition
http://www.acgih.org/store/ProductDetail.cfm?id=1905

• Heating, ventilating and air conditioning (HVAC): refers to the distribution system for heating, ventilating, cooling, dehumidifying and cleansing air.
• Replacement/Supply air: refers to replacement air for HVAC and local exhaust ventilation.
• General ventilation: refers to ventilation that controls the air environment by removing and replacing contaminated air before chemical concentrations reach unacceptable levels.
• Local exhaust ventilation (LEV): refers to systems designed to enclose, capture and remove contaminated air at the source.
Common Terminology

\[ Q = \text{volume of air in cubic meters} \]
\[ V = \text{velocity of air in meters per second} \]
- Duct velocity-velocity required to transport the contaminant
- Face velocity-velocity on the front of an enclosing hood
- Capture velocity-velocity required to capture contaminant at point of generation

\[ A = \text{cross sectional area of hood opening in square meters} \]
\[ X = \text{distance of ventilation from the source in meters} \]

Purposes of Industrial Ventilation

- Protect workers from health hazards
  - Dilute, capture, or contain contaminants
- Protect workers from hot processes
  - Ovens, foundries
- Protect the product
  - Semiconductor
  - Electronics
  - Pharmaceuticals

Slot Hood
Canopy Hood
Laboratory Fume Hood

Hazard Assessment

- What are the airborne contaminants?
  - Particles
  - Solvent vapors
  - Acid mists
  - Metal fumes
- How do the workers interact with the source contaminant?
- Are workers exposed to air contaminants in concentrations over an exposure limit?
  *Requires air monitoring of the task
- Dilution or local exhaust ventilation?

Emergency ventilation
- Standalone fans
- Detectors connected to ventilation or scrubber systems
- Safe room
  - Positive pressure
- Enclosed vented rooms or cabinets
  - Gas cabinets
- Comply with health and safety regulations

*Photo credit: Advanced Specialty Gas Equipment
*Photo credit: Emergency Responder Products
*Photo credit: International Labor Organization
General Ventilation

- **Natural Ventilation:**
  - Useful for hot processes
  - Chimney effect
  - Windows and doors kept open
- Example: a warehouse opens the windows to create natural ventilation
  
  \[ Q = 0.2 \times AV \]
  
  \[ A = \text{square meters (area of open doors)} \]
  
  \[ V = \text{wind speed in kilometers/hour} \]
  
  \[ Q = \text{estimates the flow rate through the building (m/s)} \]

Dilution Ventilation

- Heat control
- Dilution of odors, flammables
- Not for control of toxics

Principles

- Contaminant emissions must be widely dispersed
- Exhaust openings must be near contaminant source
- The worker must not be downstream of contaminant
- Air flow over worker should not exceed 3.5 meters/sec

Local Exhaust Ventilation (LEV)

- Use when contaminant concentration cannot be controlled by dilution ventilation or other controls
- Select the type of LEV from hazard assessment
  - Which type is best to capture the contaminant?
    - Enclosed or capture hood?
    - Consider worker’s needs
  - What duct transport velocity is required to carry the contaminant? Heavy particles?
  - What face or capture velocity is required?
- Select duct material for the contaminant
- Ensure enough replacement air/adequate fan size
Local Exhaust Ventilation

Volumetric Flow Rate, \( Q = V A \) [Circular Opening]

\[ Q = V_A \]

- **Q** = Volumetric flow rate, in cubic meters/second
- **V** = Average velocity, in meters/second
- **A** = Cross-sectional area in square meters

For circular ducts:

\[ Q = \pi \frac{d^2}{4} \]

Local Exhaust Ventilation

Duct diameter = 1 meter
V = 600 meters/second
What is Q?

\[ Q = VA \]
\[ Q = (600 \text{ m/s}) \times (\pi \times [1 \text{ m}]^2/4) \]
\[ Q = 471 \text{ meters}^3/\text{second} \]

Duct diameter = 0.5 meter
What is the duct velocity (V)?

\[ Q = VA \]
\[ 471 \text{ meters}^3/\text{second} = V \times (\pi \times [0.5 \text{ m}]^2/4) \]
\[ V = 2400 \text{ meters/second} \]

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

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

<table>
<thead>
<tr>
<th>CONDITION</th>
<th>EXAMPLES</th>
<th>CAPTURE VELOCITY</th>
<th>Range in meters/second</th>
</tr>
</thead>
<tbody>
<tr>
<td>No velocity, Quiet air</td>
<td>Evaporation from tanks, degreasers</td>
<td>0.25 – 0.5</td>
<td></td>
</tr>
<tr>
<td>Low velocity, moderately still air</td>
<td>Spray booths, container filling, welding, plating</td>
<td>0.5 – 1.0</td>
<td></td>
</tr>
<tr>
<td>Active generation into rapid air motion</td>
<td>Spray painting (shallow booths), crushers</td>
<td>1.0 – 2.5</td>
<td></td>
</tr>
<tr>
<td>High initial velocity into very rapid air motion</td>
<td>Grinding, abrasive blasting, tumbling</td>
<td>2.5 – 10.1</td>
<td></td>
</tr>
</tbody>
</table>

Local Exhaust Ventilation

Capture Velocity \( (V_1) \): [Plain Opening]

\[
Q = V (10x^2 + A)
\]

\( V \): distance of source from hood face

Recommended Duct Velocities

<table>
<thead>
<tr>
<th>CONTAMINANT</th>
<th>EXAMPLES</th>
<th>DUCT VELOCITY</th>
<th>Meters/second</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vapors, gases, smoke</td>
<td>Vapors, gases, smoke</td>
<td>5.0 – 10.1</td>
<td></td>
</tr>
<tr>
<td>Fumes</td>
<td>Welding</td>
<td>10.1 – 12.7</td>
<td></td>
</tr>
<tr>
<td>Very fine dust</td>
<td>Cotton lint</td>
<td>12.7 – 15.2</td>
<td></td>
</tr>
<tr>
<td>Dry dusts &amp; powders</td>
<td>Cotton dust</td>
<td>15.2 – 20.3</td>
<td></td>
</tr>
<tr>
<td>Industrial dust</td>
<td>Grinding dust, limestone dust</td>
<td>17.8 – 20.3</td>
<td></td>
</tr>
<tr>
<td>Heavy dust</td>
<td>Sawdust, metal turnings</td>
<td>20.3 – 22.9</td>
<td></td>
</tr>
<tr>
<td>Heavy/moist dusts</td>
<td>Lead dusts, cement dust</td>
<td>&gt; 22.9</td>
<td></td>
</tr>
</tbody>
</table>
Local Exhaust Ventilation

**Canopy hood:**
- Best for controlling hot processes
- Not good for capturing dusts, or vapors
- Not good where cross-drafts exist
- Worker must not put head under canopy

**“Elephant trunk”:**
- Good for welding fumes, small process tasks, machining, disconnecting process lines
- Place close to contaminant
- Ensure adequate capture velocity at distance from contaminant
- Flanged opening captures contaminant better

**Downdraft hood:**
- Vapors pulled down through grill
- Capture velocity depends on source distance from grill
- Not for hot operations

**Slot ventilation:**
- Best for liquid open surface tanks
  - Acid baths
  - Plating tanks
- Pulls air across the tank away from worker
- Side enclosures prevent cross drafts
- Push-Pull design is optional (push jet)
Local Exhaust Ventilation

- **Fume hood:**
  - Laboratory use
  - Best for small amounts of chemicals
  - Sash must be kept at set level
  - **NO** storage of equipment in the hood!

Local Exhaust Ventilation

- **Enclosures:**
  - Example:
    - Paint booths
    - Control of exposure to liquid aerosols and vapors
    - Flammability hazard
    - Must have scheduled filter changeout
    - Operator must be upstream

Local Exhaust Ventilation

- **Other vented enclosures**
  - Glove boxes
  - Furnaces/ovens
  - Abrasive blasting

Local Exhaust Ventilation

- **Exhaust Systems:**
  - Do not place exhaust stack near air intakes
    - Re-enters contaminants into the building
  - Do not use rain caps
  - Stack height depends on:
    - Contaminant temperature
    - Building height
    - Atmospheric conditions
    - Discharge velocity
    - Ideal discharge velocity is **15 meters per second**
**Ventilation System Evaluation**

- Evaluate capture velocity
  - Quantitatively-anemometers, velometers
  - Qualitatively-smoke tubes, visualizes air movement
  - Use water vapor for clean rooms

- Air velocity measurements
  - Measure air velocities (meter/sec) at a number of points
  - Average the results and determine volumetric flow rate: \( Q = VA \)
  - All instruments must be calibrated periodically
  - Types:
    - Swinging vane velometer
    - Hot-wire anemometer

**Troubleshooting**

- Wrong hood for process
  - Example: canopy hood for toxics
- Insufficient capture velocity
- Insufficient duct velocity
  - \( \sim 14 \) meters/second for vapors
  - \( \sim 18 \) meters/second for dust
- Too much air flow = turbulence
- Traffic or competing air currents
- Insufficient make up air
  - Negative pressure
  - Can’t open doors

**Exercise**

- What is the preferred ventilation system for the following situation?
  - Dilute non-toxic odors in the warehouse

  A) General ventilation
  B) Local exhaust ventilation
Exercise

• What is the preferred ventilation system for the following situation?
  – Acid processing bath with open surface area
    A) Lab fume hood
    B) Slot ventilation
    C) Elephant trunk
    D) Canopy hood
    E) Paint booth

Exercise

• What is the preferred ventilation system for the following situation?
  – Welding table
    A) Lab fume hood
    B) Slot ventilation
    C) Elephant trunk
    D) Canopy hood
    E) Paint booth

Exercise

• What is the preferred ventilation system for the following situation?
  – Chemical analysis of small samples for quality control
    A) Lab fume hood
    B) Slot ventilation
    C) Elephant trunk
    D) Canopy hood
    E) Paint booth

Exercise

• What is the preferred ventilation system for the following situation?
  – Spray painting a large piece of equipment
    A) Lab fume hood
    B) Slot ventilation
    C) Elephant trunk
    D) Canopy hood
    E) Paint booth
US Standards & Guidelines

ACGIH
American Conference of Governmental Industrial Hygienists
Industrial Ventilation, A Manual of Recommended Practice

AIHA
American Industrial Hygiene Association

ASHRAE
American Society of Heating, Refrigeration and Air Conditioning Engineers
Standard 62.1-2010, Ventilation for Acceptable Indoor Air Quality

OSHA
Occupational Safety and Health Administration
Ventilation, 29 Code of Federal Regulations 1910.94
http://osha.gov/