Chemical

SAFETY AND SECURITY TRAINING

Amman, Jordan
23-27 October 2011

Sandia National Laboratories

Welcome and Introductions

Image credit: U.S. Environmental Protection Agency

Chemical Safety and Security Overview

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 under contract DE-AC04-4AL85000.

Why practice chemical safety?

- **Health and safety of the workers**
- **Prevent accidental releases**
  - **Potential regulatory fines, lawsuits**
- **Relationship with the local community**
- **Ensure a sustainable environment**

Industrial Safety Incidents

Catastrophic process incidents:
- 1976 Seveso Italy
- 1984 Bhopal India
- 2005 Texas City Texas

More recently:
- 2009-Fertilizer tank collapses
  - 2 critically injured
  - Responders exposed to ammonia
  - ~800,000 liters released
  - River contaminated
- 2007-Fire and Explosion
  - Filling ethyl acetate storage tank
  - Equipment not bonded and grounded

Photo credit. U.S. Chemical Safety Board. http://www.csb.gov/

U. S Chemical Safety Board Video

Center for Chemical Process Safety

Process Safety Beacon

- Anyone can subscribe
- Delivers monthly process safety messages to plant operators and other manufacturing personnel.
- Presents a real-life accidents, lessons learned, and practical means to prevent accidents at your plant.
- Published in 29 languages, including Arabic
  - http://www.aiche.org/CCPS/Publications/Beacon/index.aspx

Regulations and Standards

- Individual country regulations
  - EU REACH
  - U.S. OSHA Process Safety Standard
- International chemical & labor organizations
  - ICCA Responsible Care
  - International Labour Organization
- International standards
  - ISO 14001:2004
  - OHSAS 18001
  - United Nations-GHS

What about chemical security?

- Chemical theft
  - Precursors for drugs
  - Precursors for chemical weapons
  - Dual-use chemicals
    - Industrial chemicals
      - Flammable/toxic gases
      - Ammonium nitrate
      - Chlorine
      - Pesticides
- Plant sabotage
  - Deaths, injuries
  - Economic and environmental impact

Abandoned Bhopal Plant
Photo credit: AP/Saurabh Das

What are the threats to chemical security?

- Unlimited access to facilities
  - Chemical storage areas
  - Analytical laboratories
  - Waste storage
  - Construction sites
- No controls or security checks on chemical procurement
- Shipping and receiving areas not protected
- Recruit young chemists
  - Tokyo subway Sarin attack

Threats to Cyber Security

- SCADA control software is used by one-third of industrial plants
- Security technology may not work on plant proprietary networks
- Attacks may result in:
  - Loss of process control
  - Loss of production
  - Process safety incidents
- Examples
  - Insertion of Trojan program into SCADA causes explosion on Trans-Siberian pipeline
  - 2005-Zolob worm shuts down 13 Daimler Chrysler Plants

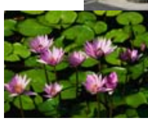
International Resolutions & Organizations

- UN Security Council Resolution 1540
- Australia Group
- Organization for the Prohibition of Chemical Weapons
- American Chemistry Council
  - *Responsible Care Security Code*

How are chemical safety and chemical security related?

Both Ensure Protection of:

- **Workers**
- **Plant facilities**
- **Plant processes**
- **Community**
- **Environment**
- **Economy**



Reflect and Consider

What chemical safety and security practices and controls does your plant require?

…Are they <u>effective</u>?

…Could they be <u>improved</u>?

…<u>How</u>?

Chemical Safety Principles

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Chemical Safety Defined

- **<u>Safety</u>: "**The condition of being safe from undergoing or causing hurt, injury, or loss"
  - **Merriam-Webster**

  http://www.merriam-webster.com/dictionary/safety
- **<u>Chemical Safety</u>: "**Practical certainty that there will be no exposure of organisms to toxic amounts of any substance or group of substances: This implies attaining an acceptably low risk of exposure to potentially toxic substances."
  - **IUPAC Glossary of Terms Used in Toxicology**

  http://sis.nlm.nih.gov/enviro/iupacglossary/glossaryc.html
- **<u>Also</u>**:
  - **Process Safety**
  - **Inherent Safety**

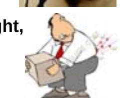
Hazard versus Risk

- **Hazard –** ***the inherent potential to harm***
- **Risk –** ***the probability that harm will result***

Photo credit. Proctor and Gamble

Chemical Hazards

- ***Chemical hazards***
  - Health hazards: toxics, corrosives, carcinogens
  - Physical hazards: flammables, explosives, reactives
- ***Other industrial hazards***
  - Mechanical-unguarded moving parts, belts, fans
  - Electrical
  - Pressure & temperature extremes
  - Elevated surfaces
  - Noise
  - Non-ionizing radiation-lasers, ultraviolet light, radiofrequency
  - Ergonomic hazards



Risk Assessment Process

Anticipation

Recognition

Evaluation

Control

} Hazards } Risks

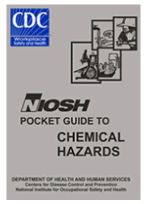
Anticipation

Anticipation = Advance Planning:

- **Team with process engineers, plant facility team leaders, workers, environmental, health & safety professionals, fire protection engineers**
- **Acquire process information, drawings, equipment requirements and specifications, chemical information, safety data sheets, plant safety procedures, and regulatory requirements**

Recognition/Identification

- Identify each chemical hazard
  - Quantity of each process chemical
  - Identify intermediates, by-products
  - Acquire toxicity information
  - Solid, liquid, or gas?
  - Flashpoint
  - Vapor pressure
  - Air or water reactivity
- Identify process hazards
  - Upper and lower limits of temperature, pressure, flow
  - Mechanical hazards
  - Electrical hazards



http://www.ilo.org/safework/info/databases/lang--en/WCMS_145760/index.htm

Evaluation

- What are the tasks in the process? How are chemicals used?
  - --Filling, spraying, reacting, mixing?
- What are the controls for over-pressurization or elevated temperature conditions?
- Process equipment inspected & maintained?
- Barriers and guards in place?
- Workers properly trained?
- What are the consequences of process deviations?
- Emergency shut-down equipment or ventilation?

Controls

How are the risks controlled?

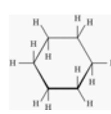
- Eliminate the hazard
- Substitute process materials
- Engineering controls
- Administrative controls/operational practices
- Personal Protective Equipment (PPE)

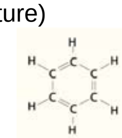
Controls

Change the process

eliminate the hazard

(e.g. Lower process temperature)





Substitution

less-hazardous substance

(e.g. - cyclohexane for benzene)

Engineering Controls

Enclose the hazard,

Use a barrier,

Or,

Ventilate

-Dilution ventilation

-Local exhaust ventilation (LEV)

Administrative Controls

Organizational safety policies,
Standard operating procedures,
Task-specific procedures

Personal Protective Equipment PPE

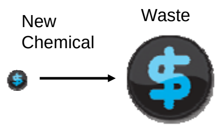
- **PPE is the *least* desired control**
- **Does not eliminate the hazard**
- **Depends on worker compliance**
- **May create heat stress**

Chemical Management

- **Benefits**
- **Cradle to Grave Model**
- **Procurement**
- **Storage**
- **Use**
- **Disposal**

Chemical Management Benefits

- Reduces cost of:
  - Raw materials
  - Hazardous waste disposal
- Facilitates plant sustainability
- Protects the environment
- Improves security
  - Theft
  - Sabotage



Chemical Management Cradle-to-Grave Model

Procure → Store →

Use → Disposal

Chemical Procurement

- Institute a ***procurement approval system***
  - Written procedure
    - Document who orders chemicals
    - Document what chemicals require approval
    - Who approves
  - Link ordering to a product review system
    - Engineering, Environmental Health & Safety, Facility & Fire Protection Staff
  - Track "chemicals of concern"

Discussion

- How are chemicals procured at your facility?
  - Are there rules about who can order chemicals?
- How do you track purchasing of highly toxic, flammable, or reactive chemicals?

Chemicals Storage

- Where are chemicals stored?
- Consider unusual storage sites
  - Loading docks
  - Outside locations
  - Waste storage facility
  - Chemicals contained in equipment
- Resource
  - *Guidelines for Safe Warehousing of Chemicals*, Center for Chemical Process Safety,
  - ISBN: 978-0-8169-0659-8

Chemical Storage

Design and Construction:

- Building and fire codes are specific for each country
- U.S. uses International Code Council http://www.iccsafe.org/
- Combines many building, fire, and energy codes
- Incorporates by reference
  - National Fire Protection Association
    - (NFPA) Codes
  - NFPA Electric Code (70)

Chemical Storage

Best Practices:

- Safe path during normal and emergency conditions
- Determine travel distance to exits
- Separate personnel areas from chemical storage
- Adequate aisle spacing
- Exit signage
- Emergency lighting

Chemical Storage

Design and Construction:

- Spill containment
  - Maximum probable spill plus fire sprinkler water
  - Primary containment
    - Drains, trenches
  - Secondary containment
    - Recessed loading dock
    - Concrete berms, grates
- Separate incompatible chemicals
  - Oxidizers, corrosives, flammables

Chemical Storage

Chemical Storage

Gas Cylinders:

- Separate incompatible gases
- Secure all gas cylinders
- Store in well-ventilated area
- Provide protection from direct sunlight
- Screw down cylinder caps when not in use

Chemical Storage

CSB Video: Compressed Gas Cylinder Fire

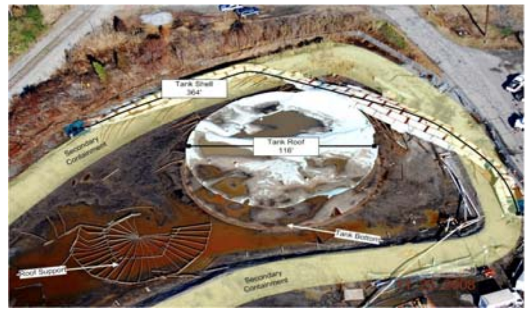
Chemical Storage

Tank Storage:

- **Tank material compatible with the chemical stored**
  - **Mild Steel**
  - **Stainless steel**
  - **Cross-linked high density polyethylene**
- **Spill containment**
  - **Double walled or lined tanks**
  - **Berms**
- **Security/Impact protection**

Photo credit: Bailiff Enterprises, Inc. Houston, Texas

Collapsed Fertilizer Tank



Discussion

What safeguards does your facility have in place to prevent, mitigate, or respond to a release in a chemical storage area?

Chemical Inventory Systems

- **Home made** – Access or Excel programs
- **Commercial** – Chemical inventory linked to Safety Data Sheets (SDS)
- **Freeware** – Web-based, Hypertext Preprocessor (PHP) software
- **Radiofrequency Identification** (RFID) tracking

Chemical Inventory Systems
Barcode Systems

- System of tracking is container-based or static inventory
- Each container, tank, or cylinder is provided with a barcode sticker
- Barcode labels may be printed using a direct thermal printer

123456

Photo credit: Fabian M. Dayrit and Jaclyn Elizabeth R. Santos

Chemistry Department
Ateneo de Manila University
Loyola Heights, Quezon City

Chemical Inventory Systems
Barcode Systems

<u>Advantages:</u>
- **Query for container location**
- **Link a chemical container to safety data sheet**
- **Track chemicals of concern**
- **Document disposal or waste transfer**

- **<u>Recommendations</u>:**
  - **Perform a periodic site inspection**
    - **-Assures accuracy of the inventory**
    - **-Provides visual inspection of container condition**

Photo credit: Fabian M. Dayrit and Jaclyn Elizabeth R. Santos

Chemical Inventory Systems

- **System should be able to query for the following:**
  - **Barcode number**
  - **Trade or IUPAC name**
  - **Chemicals in a mixture**
  - **CAS number**
  - **Location (process unit)**
  - **Quantity**
  - **Shelf life/expiration date**
    - **Lab chemicals**

Example: Barcode System for Static Inventory

Barcode	Location	Depart.	Quantity	Purchase Date	Expiration Date	Name	State	Waste Disposal
XX00187	110/1111	02712	40 liters	8/01/2007		BKC 20121	Liquid	
XX00172	110/1111	02712	80 liters	7/31/2007		DIETHANOLAMINE	Liquid	
XX00173	110/1111	02712	20 liters	11/18/2010	1/30/2011	ACETONE	Liquid	x
XX00174	110/1111	02712	28 liters	12/15/2010		ACETONE	Liquid	
XX00175	110/1111	02712	40 liters	10/17/2010		ISOAMYL ACETATE	Liquid	
XX00176	110/1111	02712	20 liters	11/18/2010		SOLVENT 25	Liquid	

Commercial Inventory Systems

- Commercial systems typically include:
  - Barcode Scanner
  - Database
  - Link to safety data sheets
- May also include:
  - Link to chemical suppliers
  - Report function
    - Reportable chemicals
      - Community Right-to-Know, air emissions, etc.
    - Internal reports

Using Chemicals Hazard Communication

Globally Harmonized System (GHS)

- Hazard pictograms
- Signal words
- Hazard statements

U.S. OSHA

- Label all chemical containers
  - Product or chemical name
  - Supplier name/contact information
  - Hazard

Danger
Flammable Liquid

A Guide to The Globally Harmonized System of Classification and Labeling of Chemicals: http://www.osha.gov/dsg/hazcom/ghs.html

Using Chemicals Hazard Communication

- Pipe Labeling
  - 2007 ANSI/ASME A13.1 *Scheme for the Identification of Piping Systems*
  - Does not apply to buried pipelines or electrical conduit
  - Label must state contents, hazard, direction of flow
  - May use color coding

Photo Credit: Seton Identification Products. http://www.seton.com/catalog/product/view/

Using Chemicals Hazard Communication

Safety Data Sheet:

1. Identification
2. Hazard(s) identification
3. Composition information
4. First-aid measures
5. Fire-fighting measures
6. Accidental release measures
7. Handling and storage
8. Exposure control/personal protection

Using Chemicals
Hazard Communication

9. Physical/chemical properties
10. Stability and reactivity
11. Toxicological information
12. Ecological information
13. Disposal considerations
14. Transport information
15. Regulatory information
16. Other information

Discussion

- What chemical labeling system does your facility use?
- Is the labeling system the same for all containers?
- How do workers and emergency response staff access safety data sheets in the event of an incident?

Chemical Waste Management

- Substitute chemicals when process permits
- Recycle
- Dispose by incineration, if allowed in your country
- Injection wells used in U.S.
- Incineration is NOT the same as open burning

Tea Break

Chemical Safety and Security Program Organization and Responsibilities

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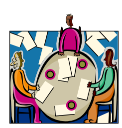
Chemical Safety and Security (CSS) Program Purpose

- Ensure a safe and secure workplace.
- Ensure a sustainable environment.
- Prevent/reduce release of hazardous substances in plant and in community.
- Prevent/reduce exposure to staff.
- Enhance community relations.
- Comply with regulations.
- Enable crisis management.

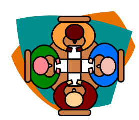
Crisis Management: Prevention & Response

- Facility crisis
  - Fire
  - Explosion
  - Chemical release
  - Evacuation
  - Remediation
- Natural disaster
  - Earthquakes
  - Hurricane/typhoon
  - Tsunami
- Security Incidents
  - Disgruntled personnel
  - Employees
  - Ex-workers
  - Contractors
  - Demonstrations, protests
  - Terrorism
  - Theft

Chemical Safety and Security Applies to Everyone



Administration
Management
Human Resources
Purchasing
Facilities
Construction
Police/Security
Employees
Contractors
All visitors



Senior Management

has the responsibility

to *teach*, *model* and *encourage* good Chemical Safety and Security practices

Plant Management Chemical Safety & Security (CSS) Responsibilities

- Develop procedures with Safety Officer for unique hazards and chemicals (toxic, flammable)
- Develop proper control practices with Safety Officer
- Participate in developing CSS Plan, CSS Committee, accident investigation procedure
- Ensure CSS documents and records are maintained
- Maintain plant chemical inventory
- Ensure Safety Data Sheets are available
- Facilitate compliance with policies, guidelines and regulations

Plant Management Responsibilities (cont'd.)

- Ensure workers know and follow policies and practices
- Ensure equipment and controls are properly maintained
- Ensure all workers received proper training and refreshers
- Ensure new workers receive proper training before starting work
- Inform Safety Officer of any accidents and incidents
- Follow-up on accidents and incidents

Employees

have a responsibility

to *actively* support and participate in the CSS Program.

Employee Responsibilities

- **Understand and act in accordance with policies/rules and practices.**
  - **Participate in and learn from required training**
  - **Learn about hazards of specific chemicals/processes**
  - **Read & understand related documents**
- **Follow good chemical safety practices**
  - **Wear and maintain Personal Protective Equipment (PPE)**
  - **Use engineering controls properly**
  - **Work safely/behave responsibly (i.e. don't put others at risk).**
- **Proactively encourage safety and security**
  - **Participate willingly in the CSS Program**
  - **Report accidents, incidents/near misses, problems**
  - **Suggest changes and improvements**

The Safety Officer

has the responsibility

to provide expertise and information so that a safe and healthy workplace is present and maintained.

Safety Officer Training, Experience, Skills

- **Chemistry**
  - Nomenclature
  - Physical properties
  - Reactive substances
  - Chemical compatibilities
- **Health and Safety (industrial hygiene)**
- **Security**
  - Facility
  - Chemicals
  - Equipment
  - Personnel
- **Psychology**
  - Interpersonal skills
- **Physics**
  - Ventilation
  - Electrical
- **Biology**
  - Biosafety
  - Blood borne pathogens
- **Administration**
- **Writing**
- **Speaking/presentations/training**

Safety Officer Duties and Responsibilities

- **Reports directly to higher management**
- **Provides leadership in safety and security**
  - **Advise administration, management, workers**
  - **Know legal regulations and ensure compliance**
  - **Establish Safety and Security Committee**
  - **Consult/advise project management on CSS concerns**
  - **Respond to problems and concerns of workers**
  - **Coordinate with facilities and security**
- **Writes and revises CSS Plan**
  - **Develop CSS training plans**
  - **Trains, documents and ensures training is performed**

Safety Officer
Duties and Responsibilities

- Ensures documentation, records and metrics are maintained.
  - Draft a safety budget
  - Set criteria for exposure levels
  - Coordinate and facilitate medical surveillance
  - Ensure plans and manuals are written and updated
- Oversees procurement, use, storage & disposal of hazardous materials
- Performs risk assessment and monitoring
  - Conducts audits and inspections
  - Interacts with staff to correct deficiencies
  - *Follows up* to ensure correction and resolution of issues
- Investigates accidents and incidents

Safety Officer
Duties

Surveys
Job Hazard Analysis
Inspections
Training
Medical Monitoring
Investigations

The Function of the Safety Officer is to Act as a Collaborator, *NOT* as a Policeman

The Safety Committee

has the responsibility

to oversee and monitor the CSS Program for management so that a safe and healthy workplace is maintained.

Safety Committee Responsibilities

- Reports directly to senior management
- Endorses policies
- Meets regularly (2 – 4 times/yr) with agendas
- Reviews accidents and incidents, may investigate, write reports with recommendations
- Establishes appropriate subcommittees on specific topics

Safety Committee Composition

- Chaired by committed staff
- Safety Officer is ex-officio member
- Includes representatives from:
  - Facilities Management
  - Security
  - Administration and General Management
  - Shops/Unions
- Representatives should rotate after a few years

Management Responsibilities

Commitment:

- Establish a formal CSS Program
- Announce formation of a CSS Program
- Create a written policy statement
- Designate a Safety Officer
- Endorse a written CSS Plan (Manual)
- Participate and intervene as needed

Support:

- Financial support (budget)
- Staffing
- Response/resolution of problems by
  - Establishing a CSS Committee
- Stipulates CSS is part of everyone's job
  - CSS applies to everyone
  - Specifies CSS orientation for new employees
- Supports CSS staff

Management Responsibilities

POLICY STATEMENT

Documents and describes
the commitment and support
from the highest management level
for the Chemical Safety and Security Program

Policy Statement Purpose

Establish and provide for maintenance of an effective Chemical Safety and Security Program to protect:

- Employees
- Facility
- Community
- Environment

…and to comply with all regulations.

Policy Statements

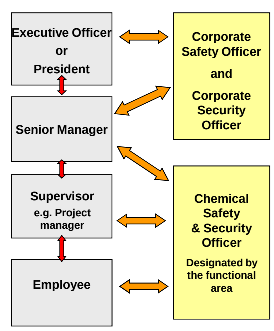
- Come from senior management
- Are typically brief
- Set clear goals
- Establish commitment
- Define employee role
- Identifies resources and staff
- Are signed by person in authority

Example Policy Statement

"It is the policy of XYZ Company to protect our workers and the public, prevent incidents, protect the environment through integration of environmental stewardship and sustainability throughout the life-cycle of its activities, and ensure regulatory compliance."

Chemical Safety and Security Program Ideal Roles

- Culture of Chemical Safety and Security should exist at all levels of the organization.
- Top management sets policy, provides resources.
- Workers must understand and implement.
- Many organizational interactions are important for chemical safety and security

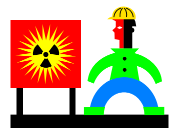


Program Evaluation

- Management leadership
- Employee involvement
- Administrative controls
- Security controls
  - Access to buildings, materials
- Engineering controls
- Accident/incident investigation
- Training
- Use of Personal Protective Equipment (PPE)
- Emergency Response Program
- Medical Surveillance Program
- Work site analysis
  - Inspections, hazard surveys

Hazard Survey

- **Baseline measurements**
- **Periodic inspections**
- **Identify potential job hazards, material hazards, and process hazards**



Hazard Survey Process

- **Prepare survey form**
- **Perform walk-through**
- **Take measurements**
  - Sample if necessary, monitor exposure (e.g., formaldehyde, radiation)
- **Perform data analysis**
- **Write and deliver report**

Periodic Inspections

- **Performed by Safety Officer**
- **Team may include:**
  - **Employees**
  - **Process Supervisor**
  - **Facilities representative**
- **Frequency determined by hazards present and local practices**
  - **2 - 4 times/yr**
- **Look for:**
  - **both good and bad practices**
  - **new hazards**
  - **new security issues**

Sample Plant Survey/Inspection Checklist

- **Date of Inspection:_______**
- **Conducted by:_______**
- **Location (room and building):_______**
- **Supervisor:_______**

- **Work Practices**
  - PPE available/properly used, stored, maintained
  - Work conducted under ventilation if airborne hazard
  - Housekeeping
  - Work instructions present and used

Survey/Inspection Checklist, cont'd.

- **Hazard Communication**
  - Warning signs ***posted.***
  - SDS available.
  - All chemical containers/tanks/piping labeled.
- **Personal Protective Equipment**
  - Available for each specific hazard.
  - Eye protection available, when & where required & *posted.*
  - Other PPE available as necessary.
  - Visitor requirements for PPE ***posted*****.**

Survey/Inspection Checklist, cont'd.

- **Plant Safety Equipment**
  - Fire pull stations & telephones appropriately placed and labeled
  - Adequate number of fire detection and control devices.
  - Emergency shut-down equipment present and routinely tested.
  - Emergency chemical release equipment available, maintained, labeled.
  - Eyewashes & safety showers present, unobstructed, in good working order, routinely tested and maintained.
- **General Facility**
  - Exits marked
  - Access controls
    - Hazardous areas
    - Proprietary processes

Survey/Inspection Checklist, cont'd.

- **Chemical Storage/Warehouse**
  - Area secured
  - Chemicals inventory list or database
  - All containers labeled
  - Incompatible chemicals segregated
  - Volatile, flammable material keep away from ignition sources
  - Fire protection
    - Barriers, sprinkler system, extinguishers, alarms
  - Emergency release equipment present
    - PPE
    - Spill equipment

Survey/Inspection Checklist, cont'd.

- **Ventilation**
  - Ventilation for airborne hazards available
  - Ventilation labeled with static pressure or airflow
  - Ventilation equipment intakes not blocked
- **General**
  - Aisles & exits unobstructed.
  - Work areas clean with no chemical contamination.
  - Mechanical hazards guarded with barriers

Training Program

- **Identify training needs**
- **Identify Goals & Objectives**
- **Develop training activities**
- **Identify resources**
- **Conduct training**
- **Evaluate effectiveness**
- **Continuous Improvement**

Employee Training Topics

- **New employee orientation**
- **Special processes and procedures**
- **Hazard communication/ labeling, Safety Data Sheets**
- **Occupational Exposure Limits (OEL) for hazardous chemicals;**
- **PPE use, storage and maintenance (especially respirators)**
- **Fire safety and fire extinguisher use**
- **Emergency plans, evacuation procedures & routes**
- **Confined space entries**
- **Lockout/tagout**
- **Hazardous waste procedures**
- **Facility security requirements**

Training Documentation: Sample

- **Employee name:** ____________________________
- **Department:** __________________________
- **Date:** ______
- **Training Subject:** _______________________________
- **Training Date:** ___________
- **Re-instruction date:** _________
- **Employee Signature:** _______________________________
- **Date Signed:** __________
- **Supervisor's signature:** ______________________________
- **Date:** __________

Standard Operating Procedures (SOP)

- An SOP explains *concisely and precisely* how, where and who performs a task.
- It does *not* explain why the task is done.
- The Safety and Security Plan explains policy and why a task is performed

Standard Operating Procedures (SOP), cont'd.

- SOPs are:
  - Dated
    - When issued
    - When reviewed
    - When revised
  - Have: subject, title and identification code
  - Officially reviewed by management
  - Written in a consistent and official format with numbered pages

LUNCH

Chemical Health Hazards Exposure Standards

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
under contract DE-AC04-94AL85000.

Chemical Health Hazards

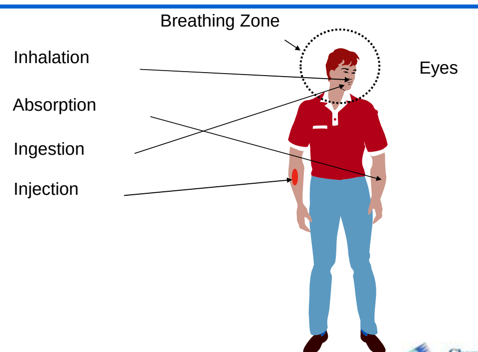
- Definitions
- Exposure
- Dose response
- Health effects
- Exposure limits
- Evaluating exposure
- Exercises

Definitions

- **Toxicology: the study of the adverse effects of chemicals (xenobiotics) on living organisms.**
- **Toxicity: ability of a chemical to produce an unwanted effect.**
- **Hazard: presence of an agent that has inherently hazardous properties and the potential to cause harm.**
- **Exposure: Contact with the chemical substance.**
- **Dose: the amount of the chemical that has the potential to produce injury or death.**

Klassen, C. (2001). Casarett and Doulls Toxicology
Plog, B. (2002). Fundamentals of Industrial Hygiene

Exposure



Exposure Inhalation

- **Most important route of exposure for workers**
  - Gases, solvent vapors, acid mists, dusts, particles, and metal fumes
- **Exposure is dependent on:**
  - Duration and frequency of task
  - Breathing rate
  - Concentration of the chemical
  - Particle size
    - Inhalable size = 0.1 μm to 10 μm
  - Solubility of gases & vapors
    - Formaldehyde versus chloroform

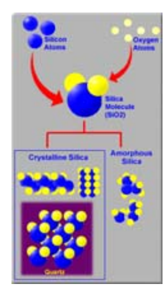
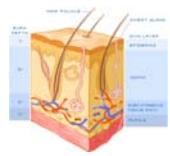


Photo Credit: US OSHA

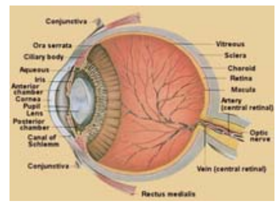
Exposure
Skin Absorption



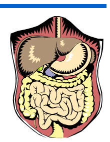
- Depends on skin location and thickness
  - Palms of the hands are thickest
  - Skin on abdomen is thin
- Depends on skin condition
  - Dry and broken skin more susceptible
  - Sweat increases absorption
- Duration of contact
- Properties of the chemical
  - Concentration
  - Solubility (in fat or water)
  - Molecular size (nanoparticles)

Exposure
Eyes

- **Corneal irritation or trauma**
  - Gases, particles
- **Corneal burns**
  - Acids, ammonia
  - Mustard agents
- **Optic nerve damage**
  - Thallium, methanol (ingested)



Exposure
Ingestion



- **Rare exposure route, but possible**
  - Swallow chemicals after inhaling
  - Eating, drinking, smoking in work areas
- **Factors affecting absorption**
  - Ionized versus nonionized form of compounds
  - Weak base absorbed in intestines
  - Weak acid absorbed in stomach

Pharmacokinetics

- **Absorption**
  - **Chemical enters the body by exposure route**
- **Distribution or storage**
  - **Distributed to organs, or**
  - **Stored in bone, proteins, fat**
- **Metabolism**
  - **Liver, kidney enzymes**
  - **May metabolize to a more toxic chemical**
- **Excretion**
  - **Sweat, urine, feces**

Dose Response

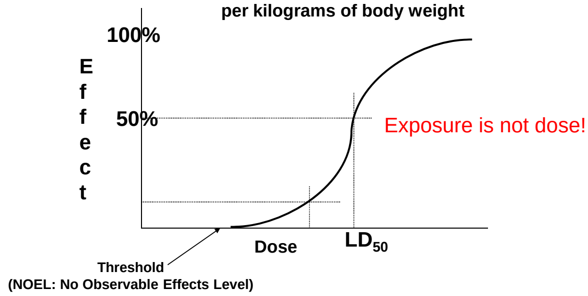
"All substances are poisons; There is none which is not a poison. The right dose differentiates a poison from a remedy…" – Paracelsus (1493-1541)

Dose Response Terminology

- TD_{lo} – Toxic dose low - lowest dose for effect
- LD_{50} – Lethal dose 50% - dose that causes death in 50% of the test population
- TC_{lo} – Toxic concentration low - used to express toxic concentration *via* inhalation
- LC_{50} – Lethal concentration 50% - concentration that causes death in 50% of the test population *via* inhalation

Dose Response

Dose is measured in milligrams of toxicant per kilograms of body weight

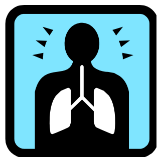


Health Effects

- **Acute Health Effects-severe injury or death**
  - High concentration of chemical over short time period
  - Chemicals with acute effects:
    - Toxic gases: hydrogen sulfide, phosgene
    - Asphyxiants gases: nitrogen, methane
    - Corrosive gases and liquids: chlorine, acids
- **Chronic Health Effects-chronic disease**
  - Low concentration over long time period
  - Chemicals with chronic effects:
    - Carcinogens: benzene, asbestos, arsenic
    - Reproductive agents: glycol ether acetates, lead, carbon disulfide
    - Sensitizers-glutaraldehyde, toluene diisocyanate

Health Effects

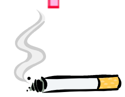
- **Local**
  - Effect occurs at site of contact
  - Skin rash, burns, coughing
  - Chemicals with local effects:
    - Cutting oils, solvents, acids
    - Cotton dust, aluminum oxide
- **Systemic**
  - Chemical distributed by circulation
  - Effect occurs in body organs
  - Chemicals with systemic effects:
    - Methylene chloride to heart muscle
    - Lead to bone and brain



Health Effects

Chemicals affect people differently:

- **Age**
- **Gender**
- **Genetic makeup**
- **Disease or stress**
- **Nutrition**
- **Lifestyle**
- **Interactions between chemical toxicants**



Health Effects
Chemical Interactions

- **Additive Effect**
  - **Combined effect of 2 chemicals equals sum of each agent alone…(2 + 3 = 5)**
  - **Example: Parathion, methyl-parathion pesticides**
- **Synergistic Effect**
  - **Combined effect of 2 chemicals is greater than sum of each agent alone…(2 + 3 = 20)**
  - **Example: Carbon tetrachloride & ethanol**

Health Effects
Chemical Interactions

- **Potentiation**
  - **One substance does not have toxic effect on certain organ or system, but when added to another chemical, it makes the latter more toxic…(0 + 2 = 10)**
  - **Example: Isopropanol & carbon tetrachloride**
- **Antagonism**
  - **2 chemicals, when given together, interfere with each other's actions or one interferes with the action of the other chemical…(4 + 6 = 8)**
  - **Example: BAL (chelating agent) and lead**

Industrial Exposures and Health Effects

Industrial Exposures Metals

Exposure primarily by inhalation:

- Particulates
  - Processes: grinding, cutting, sanding,
  - Examples: copper, nickel, zinc
- Fumes
  - Processes: welding, smelting
  - Examples: lead, manganese, hexavalent chromium, zinc
- Mists (soluble metal compounds)
  - Processes: spraying anticorrosives, metal plating

  Examples: hexavalent chromium, nickel chloride

http://www.millerwelds.com/

Health Effects Metals

- Sensitizers (skin and lungs)
  - Nickel, beryllium, chromium
- Metal fume fever
  - Oxides of zinc, magnesium, and copper
- Organ toxicity
  - Arsenic—neurotoxicity, liver injury
  - Cadmium—kidney, lung fibrosis
  - Lead-nervous system, blood, kidney, reproductive
- Carcinogens
  - Arsenic, soluble nickel, hexavalent chromium

Industrial Exposures Solvents

Exposure by inhalation and skin absorption:

- Process: transfer, mixing, spraying, high vapor pressure solvents
  - Examples: ethers, ketones, chloroform, methylene chloride
- Process: Heating solvents
  - Examples: styrene, dimethyl formamide
- Process: skin immersion in process baths, parts cleaning
  - Examples: acetone, trichloroethylene, dimethyl sulfoxide (DMSO)

Health Effects
Solvents

- Skin irritants, dermatitis
  - Acetone, alcohols
- Organ toxicity
  - N-hexane—neurotoxicity
  - Chloroform, vinyl chloride—liver toxicity
  - Methylene chloride—heart toxicity
- Carcinogens
  - Benzene, formaldehyde
- Reproductive toxicants
  - Glycol ether acetates

Occupational Exposure Limits

Evaluating Exposure

Occupational Exposure Limits (OELs)

- Government regulation or professional standard organizations set OELs
- OELS apply to workers only, NOT the general public
- Primarily limits for inhalation exposure
- Expressed in milligrams/cubic meter (mg/m^3) or parts per million (ppm)
- Exposure must be measurable for comparison with the OEL
- Some publish exposure standards for noise, lasers, non-ionizing radiation, heat & cold stress, as well as chemicals

International Occupational Exposure Limits

- Indicative OEL Values (IOELVs)
  - Specified by the Council of the European Union
  - Based on advice from Scientific Committee on Occupational Exposure Limits (SCOEL)
  - 2009 -Third list of IOELVs published
  - Member states have until 12/2011 to implement legislation
- European Union Reach
  - Worker derived no-effect levels (DNELs)
  - Must be calculated for quantities >10 tons/year
  - Safety margins higher than the IOELVs
- German Exposure Limits
  - DFG MAK – Maximum Workplace Concentrations

U.S. Exposure Limits

- **PEL – Permissible Exposure Limits**
  - Occupational Safety and Health Administration **(**OSHA)
  - **USA legal limits**
- **REL – Recommended Exposure Limits**
  - National Institute of Occupational Safety & Health (NIOSH)
  - Recommended, not legal limits
- **ACGIH TLV® – Threshold Limit Values®**
  - American Conference of Governmental Industrial Hygienists
  - Recommended, not legal limits
- **AIHA WEEL – Workplace Environmental Exposure Limits**
  American Industrial Hygiene Association (AIHA)
  - Recommended, not legal limits

Exposure Limits

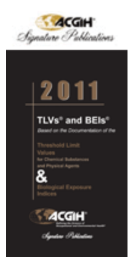
Permissible Exposure Limit (PEL)

- **Exposure limits are published by the U.S Occupational Safety and Health Administration (OSHA)**
- **Intended to control health effects from exposures to "air contaminants"**
- **Applies only to workplaces covered by OSHA**
- **Action Levels published for highly toxic chemicals**
  - **½ the PEL**
  - **Benzene, asbestos, vinyl chloride, formaldehyde**

Exposure Limits

ACGIH TLVs®:

- **ACGIH is a private, non-governmental corporation**
- **ACGIH TLVs are published as *guidelines***
- **Not legal standards**
- **ACGIH TLVs are usually lower than PELs**
- **Reviewed and revised annually**



Exposure Limits

ACGIH TLVS®:

- **8 Hour time-weighted average (TWA)**
- **15 minute short-term exposure limit (STEL)**
- **Ceiling value (C)**

- **TLV Examples:**
  - Carbon dioxide = 5000 ppm TWA
  - Osmium tetroxide = 0.0002 ppm TWA
  - Hydrogen chloride = 2 ppm ceiling
  - Ammonia = 35 ppm STEL

Time Weighted Average (TWA)

Average exposure for an individual over a working period of time, determined by taking one or more samples during the working period:

$$\text{TLV – TWA* } = \frac{C_1T_1 + C_2T_2 + \ldots + C_NT_N}{T_1 + T_2 + \ldots + T_N}$$

Where:

C = airborne concentration
T = time

* A TLV expressed as a TWA

8-Hr Time Weighted Average

Average exposure for an individual over an 8-hr working period of time, determined by taking one or more samples during the 8-hr working period:

$$\text{TLV – TWA}_8 = \frac{C_1T_1 + C_2T_2 + \ldots + C_NT_N}{8 \text{ hrs}}$$

Example 1

A degreaser operator is monitored for exposure to Stoddard solvent. The monitoring data is:

TIME PERIOD (NUMBER)	*CONCENTRATION (PPM)*	*TIME (HOUR)*
1	80	2
2	110	4
3	55	2

Solution

$$\text{TLV – TWA}_8 = \frac{C_1T_1 + C_2T_2 + \ldots + C_NT_N}{8 \text{ hrs}}$$

$$\text{TLV – TWA}_8 = \frac{(80 \times 2) + (110 \times 4) + (55 \times 2)}{8 \text{ hrs}}$$

EIGHT HOUR TLV-TWA = 89 ppm

Over exposed?
(TLV-TWA = 100 ppm)

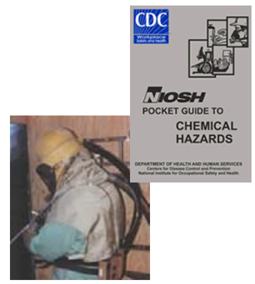
Other ACGIH TLV Notations …

- "Skin" potential exposure by the dermal route, including mucous membranes and the eyes
  - Examples: some solvents, phenol, pesticides
- "SEN" potential to produce sensitization
  - Example: toluene diisocyanate

Evaluating Exposure

- **Qualitative assessment**
  - **Observe task**
    - **Airborne contaminants?**
    - **Skin immersion ?**
  - **Evaluate toxicity**
    - **Safety data sheets**
    - **NIOSH Pocket Guide**

    http://www.cdc.gov/niosh/npg/
- **Quantitative**
  - **Model exposure**
  - **Perform air sampling**



Evaluating Exposure

- **Quantitative**
  - **Model the contaminant concentration in the room**
  - **__Example__: What concentration, in mg/m^3 would be produced by the release of 1 gram (g) of benzene in a 125 cubic meter room (m^3)?**

Mass of contaminant/volume of room

1 g/125 m^3 = 1000 milligrams/125 m^3 = 8 mg/m^3

Calculation for PPM Concentration

$$\frac{(8\ \text{mg/m}^3)\ (24.45)}{(78.11\ \text{MW})} = 2.5\ \text{ppm}$$

ACGIH STEL for benzene is 2.5 ppm
(15 minute short term exposure)

Evaluating Exposure

Air monitoring:

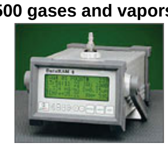
- Results must be analyzed
- Results are compared against a standard OEL
- Methods:
  - Air sampling pump and media or badges
    - Filters-for metals, particulates
    - Charcoal tubes-for solvents
    - Silica gel tubes-for acids

Photo credits: Sensidyne , SKC Inc.

Evaluating Exposure

Other air monitoring methods:

- Direct reading instruments
  - Photoionization detectors-solvents
  - Particle counters-dusts
  - Portable gas detection
    - Operate with hand pump
    - Color coded detector tubes
    - Detect 500 gases and vapors



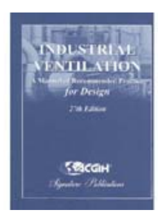
Chemical SAFETY AND SECURITY TRAINING

Industrial Ventilation

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 under contract DE-AC04-94AL85000.

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

Definitions

- **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, or capture and remove contaminated air at the source.

Common Terminology

Q = volume of air in cubic meters

V = velocity of air in meters per second

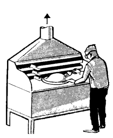
- **Duct velocity-velocity required to transport the contaminant**
- **Face velocity-velocity on the front of an enclosing hood**
- **Capture velocity-velocity required to capture contaminant at point of generation**

A = cross sectional area of hood opening in square meters

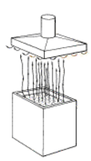
X = distance of ventilation from the source in meters

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

Purposes of Industrial 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

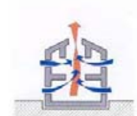
Hazard Assessment

- What are the airborne contaminants?
  - Particles
  - Solvent vapors
  - Acid mists
  - Metal fumes
- How do to 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?

Picture 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 AV

A = square meters (area of open doors)

V = wind speed in kilometers/hour

Q = estimates the flow rate through the building (m/s)

General Ventilation

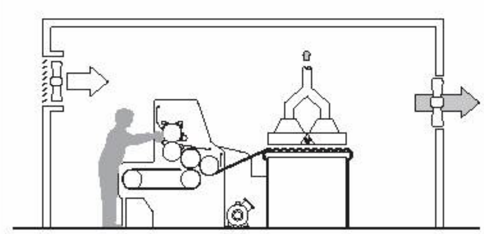
Dilution Ventilation

- Heat control
- Dilution of odors, flammables
- <u>Not</u> 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

General Ventilation

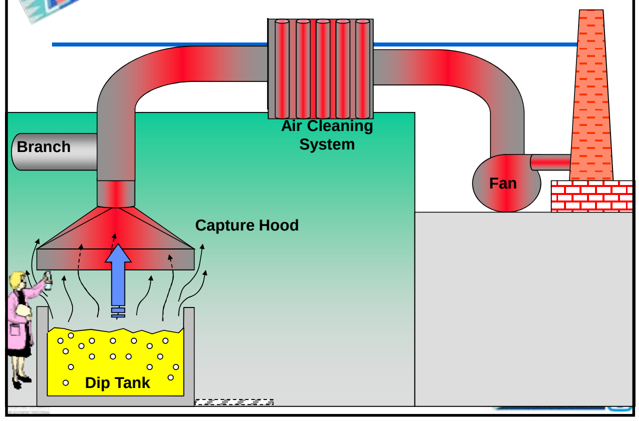


General ventilation for cleaning a printing press

Local Exhaust Ventilation (LEV)

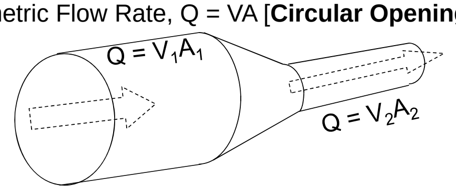
- Use when contaminant concentration cannot be controlled by dilution ventilation or other controls
- Select the type of LEV from hazard assessment
  - Which type is best to capture the contaminant?
    - Enclosed or capture hood?
    - Consider worker's needs
  - What duct transport velocity is required 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



Local Exhaust Ventilation

Volumetric Flow Rate, Q = VA [**Circular Opening**]

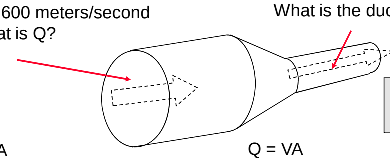


Q = Volumetric flow rate, in cubic meters/second
V = Average velocity, in meters/second
A = Cross-sectional area in square meters

Local Exhaust Ventilation

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

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



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

Q = VA

Q = (600 m/s)(π[1m]^2/4)

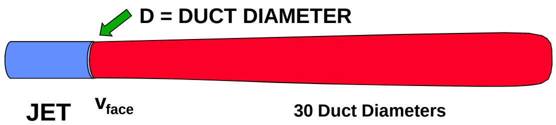
Q = **471 meters^3/second**

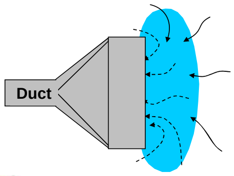
Q = VA

471 meters^3/s = V (π[0.5m]^2/4)

V = 2400 meters/second

Local Exhaust Ventilation





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

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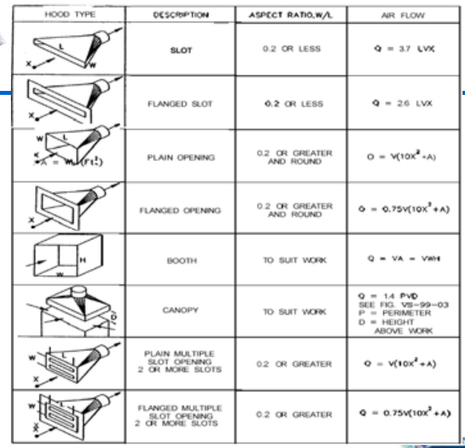
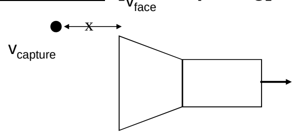


HOOD TYPE	DESCRIPTION	ASPECT RATIO, W/L	AIR FLOW
	SLOT	0.2 OR LESS	Q = 3.7 LVX
	FLANGED SLOT	0.2 OR LESS	Q = 2.6 LVX
	PLAIN OPENING	0.2 OR GREATER AND ROUND	$Q = V(10X^2 + A)$
	FLANGED OPENING	0.2 OR GREATER AND ROUND	$Q = 0.75V(10X^2 + A)$
	BOOTH	TO SUIT WORK	Q = VA = VWH
	CANOPY	TO SUIT WORK	Q = 1.4 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	$Q = 0.75V(10X^2 + A)$

ACGIH Ventilation Manual

Local Exhaust Ventilation

Capture Velocity (V) : [Plain Opening]



$Q = V(10x^2 + A)$
X = distance of source from hood face

Recommended Capture Velocities

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

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Recommended Duct Velocities

CONTAMINANT	EXAMPLES	DUCT VELOCITY Meters/second
Vapors, gases, smoke	Vapors, gases, smoke	5.0 – 10.1
Fumes	Welding	10.1 – 12.7
Very fine dust	Cotton lint	12.7 – 15.2
Dry dusts & powders	Cotton dust	15.2 – 20.3
Industrial dust	Grinding dust, limestone dust	17.8 – 20.3
Heavy dust	Sawdust, metal turnings	20.3 – 22.9
Heavy/moist dusts	Lead dusts, cement dust	> 22.9

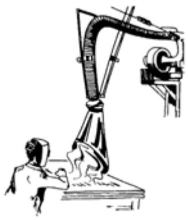
ACGIH Ventilation Manual

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

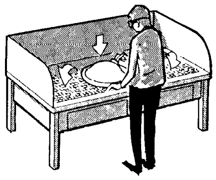
Local Exhaust Ventilation

- **"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



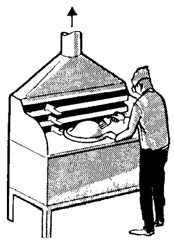
Local Exhaust Ventilation

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



Local Exhaust Ventilation

- **<u>Slot ventilation:</u>**
  - 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

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

Local Exhaust Ventilation

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

Photo Credit: Spray Shield Industries

Local Exhaust Ventilation

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

Photo credit: Borel Furnaces and Ovens

Photo credit: U. S. Department of Labor. OSHA

Local Exhaust Ventilation

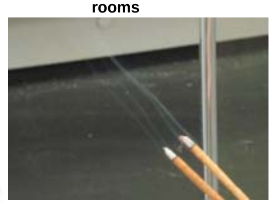
Exhaust Systems:

- Do not place exhaust stack near air intakes
  - Re-entrains 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

Photo Credit: All Products Inc.

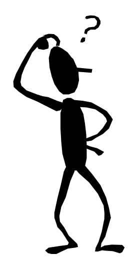


Ventilation System Evaluation

- 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
  - ~14 meters/second for vapors
  - ~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
Standard Z9.2, Fundamentals Governing the Design and Operation of Local Exhaust Ventilation Systems

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/

Tea Break

Chemical
SAFETY AND SECURITY TRAINING

Personal Protective Equipment (PPE)

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
under contract DE-AC04-94AL85000.

Personal Protective Equipment (PPE)

- Limitations of PPE
- Hazard assessment
- Training
- Characteristics of PPE
- Protective clothing
- Gloves
- Eyewear
- Respirators
- Exercise

Limitations of PPE

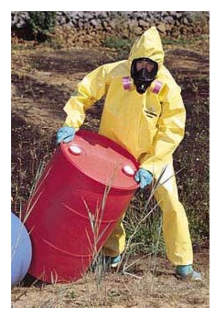
- The least desirable control, but may be necessary if:
  - Engineering controls are being installed
  - Emergency response/spill cleanup
  - Non-routine equipment maintenance
  - To supplement other control methods
- Problems with PPE:
  - The hazard is still present with PPE
  - Use is very dependent 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

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

Training

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

General Characteristics of PPE

<u>Protective clothing and gloves:</u>

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

General Characteristics of PPE

Protective clothing and gloves

- When selecting consider:
  - Permeation
    - Breakthrough time
    - ASTM F739 Standard
  - Penetration
  - Degradation
  - Comfort
  - Heat stress
  - Ergonomics
  - Cost

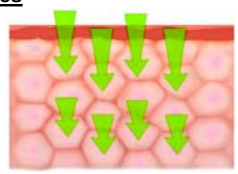


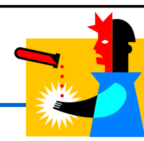
Photo credit: Permeation, http://www.cdc.gov/niosh/topics/skin/

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

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 manufactures data before final selection.
    - http://www.mapaglove.com
    - http://www.ansellpro.com
    - http://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.

	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*		
CHEMICAL	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	P	—	—	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

General Types of Glove Material

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.

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

Latex Allergy

Proper Steps for Removing Gloves

1

2

3

4

5

6

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.

NIOSH. (2010). http://www.cdc.gov/niosh/topics/eye/

Types of Eye Hazards

Hazard Type	Common related tasks	Protective Eyewear
Impact	Chipping, grinding, machining, abrasive blasting, sawing, drilling, riveting, sanding,…	Safety glasses with sideshields Goggles
Heat	Furnace operations, smelting, pouring, casting, hot dipping, welding, …	Face shield with infrared protection
Chemicals	Pouring, spraying, transferring, dipping acids, solvents or other injurious chemicals	Goggles Faceshield
Particles/ Dust	Woodworking, metal working, and general dusty conditions	Safety glasses with sideshields
Optical Radiation	Welding, torch-cutting, brazing, and laser work	Welding helmet Laser glasses -Must protect for specific wavelength of ultraviolet or infrared radiation.

Examples of Eye & Face Protection

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

Respiratory Protection

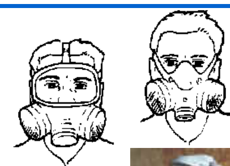
U.S. Respirator Requirements

- 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. <u>ammonia</u>
  - <u>Never</u> use APR in oxygen deficient atmospheres
- APRs work by <u>filtering</u>, <u>absorbing</u>, <u>adsorbing</u> the contaminant or <u>chemical reaction</u>.
  - 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

Cartridge	Description
	Organic Vapor
	Organic Vapor and acid gases
	Ammonia, methylamine and P100 particulates filter

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
Filter Efficiencies

Filter Class	
N95	Filters at least 95% of airborne particles. Not resistant to oil.
N99	Filters at least 99% of airborne particles. Not resistant to oil.
N100	Filters at least 99.97% of airborne particles. Not resistant to oil.
R95	Filters at least 95% of airborne particles. Somewhat resistant to oil.
P95	Filters at least 95% of airborne particles. Strongly resistant to oil.
P99	Filters at least 99% of airborne particles. Strongly resistant to oil.
P100	Filters at least 99.97% of airborne particles. Strongly resistant to oil

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. PEL, 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 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

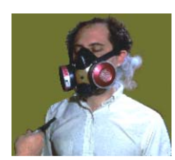
Full Face Respirator: MUC = 50 x 0.5 ppm = 25 ppm

Filtering Facepieces

Filtering Facepiece Use

Respirator Fit Testing

- **Qualitative**
  - **Irritant smoke**
    - **stannic chloride**
  - **Isoamyl acetate**
    - **banana oil**
  - **Saccharin**
  - **Bitrex**
- **Quantitative**
  - **Portacount**



Respirator Fit Test

Positive / Negative pressure fit test

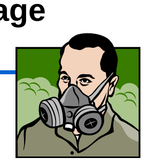
Supplied Air

- 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 ≤ 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

Discussion

- 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.

What PPE should Worker A wear?

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?

PPE Exercise

- 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?

Chemical

SAFETY AND SECURITY TRAINING

Behavior Based Safety (BBS)

SAND No. 2011-0487C
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 under contract DE-AC04-94AL85000.

What is Behavior Based Safety?

Behavior is "the manner of conducting oneself."*

Therefore, behaviors are <u>observable</u> acts.

Behavior Based Safety focuses on behaviors that promote safety.

* Merriam-Webster dictionary

Behavior Based Safety is <u>NOT</u>:

- **A fully-developed safety program.**
  - **It is a process designed to eliminate behaviors that put workers at risk and enhance existing safety protocols.**
- **A process used to enforce safety rules, nor to correct hazardous conditions.**
  - **Safety rule violations and hazardous workplace conditions must be corrected outside of the BBS process.**
- **A process for assigning blame or criticizing workers.**

How does BBS differ from traditional safety?

Traditional Safety…

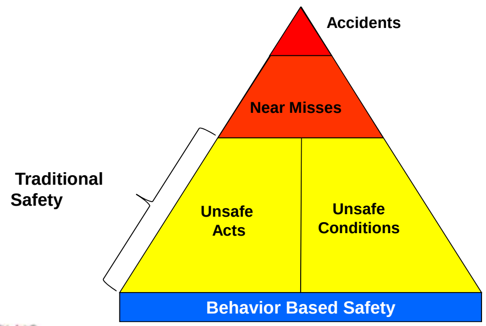
- **Is *reactive* – focuses on correcting problems only after they have occurred.**
- **Searches for "root cause" of accidents**
  - **Using incident/accident data from investigations**
    - e.g. Incident and Severity rate
- **Focuses on making the working environment less hazardous.**
- **Sometimes assigns blame to individuals.**
  - **Emphasis on negative reinforcement.**

How does BBS differ from traditional safety?

Behavior Based Safety…

- Is proactive – discourages ‘at-risk’ behaviors.
- Focuses on observing worker behavior.
  - Common behaviors that place employees at risk are noted and adjustments are made.
  - Data come from behavioral observations.
- Has a holistic understanding of worker behavior.
  - Notes the environment in which behavior occurs, the behavior itself, and consequences of this behavior.

Behavior Based Safety underlies and benefits Traditional Safety



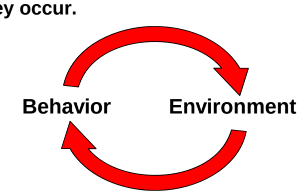
Always Keep in Mind…

BBS is focused on two concepts:

- BEHAVIOR
  - What is behavior?
  - What are the factors influencing “at-risk” behavior?
  - How can this behavior be discouraged?
- RISK
  - What is risk?
  - Why do people take risks?
  - What are the consequences of taking these risks?

Remember: Behavior is “the manner of conducting oneself”

Behaviors cannot be isolated from the environment in which they occur.



Therefore, if employees are expected to promote safe practices the working environment must encourage this behavior.

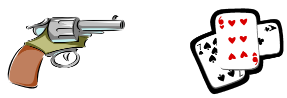
Risk = exposure x probability

Exposure – extent a person is involved in an activity.

Direct

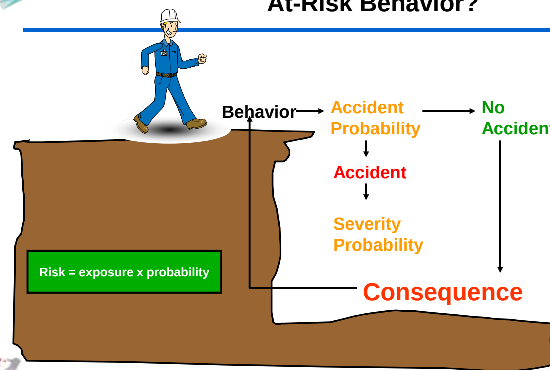
Indirect

Probability – the chances of an accident occurring during activity.



1 in 6 — 1 in 52

How do Consequences Affect At-Risk Behavior?



Positive Consequences Influence At-Risk Behavior

- **Convenience**
- **Time savings**
- **Increased productivity**
- **Getting away with it**
- **Feeling bullet-proof**
- **More comfortable (no PPE)**

How does cheaper/better/faster influence taking risks?

Worker's reasons for taking a risk:

In my opinion . . .
In my experience . . .
I don't think it's a problem because . . .
I've done it before and not gotten hurt.
What's wrong with it?

That's the way I always do it!
I don't know.
I didn't think about it.
It's the way we always do it around here.

Obstacle

I can't do it any other way because . . .
It would be difficult to do it that way because . . .
If I do it that way, (this would happen).

Implementing Behavior Based Safety

Prior to Implementation

Important to develop a BBS Committee and working structure that persists after implementation:

- Designs the BBS process.
- Develops the implementation strategy.
- Implements the BBS process.
- Steers the BBS process.
  - Assures observation and data quality through a Quality Assurance Plan.
  - Champions worker involvement and completion of observations.
  - Analyzes observation data to identify the causes of at-risk behaviors and develops recommendations.
  - Facilitates removal of barriers to workers being able to easily perform work safely.
  - Reports the results of data analysis.

Responsibilities of Managers & Supervisors

- Understand the process (receive training)
- Establish BBS as a part of the job
- Help identify and correct systems issues
- Remove barriers
- Support:
  - Time for:
    - Training
    - BBS Committee duties and meetings
    - Observations
- Encourage and provide positive reinforcement: workers, observers, BBS Committee members

4 Steps of Implementation

The BBS implementation process consists of four steps we will discuss in further detail:

1. Establish Feasible Goals
2. Develop Observation Checklists
3. Take observations
4. Provide Feedback

Step 1: Establish Feasible Goals

The overall purpose of BBS is to establish a culture of safety in the working environment. However, attainable goals need to exist in working toward this. **Make goals SMART:**

Specific – **M**otivational – **A**ttainable – **R**elevant – **T**rackable

e.g. A goal of "zero-injuries" is <u>NOT</u> SMART, but a goal of 95 % participation in appropriate safety training is SMART.

Goals should focus on outcomes, NOT behaviors.

Step 1: Establish Feasible Goals

Employee participation in the goal-setting process is important, and must continue throughout the BBS process to ensure success. There are two broad reasons for this:

1. "Employee buy-in" – verbal and nonverbal support for change from those directly affected.

2. Interpersonal trust – trust among employees, and trust between employees and management.

Step 2: Develop Observation Checklists

In looking for behaviors that encourage safe practice, there are several options:

- Review past accident/incident reports to identify behavior that could have prevented them.
  - Focus on those that could have prevented the largest number of accidents.
- Consult with employees and managers.
  - It is important for employees to take responsibility for their actions.
  - Beneficial for developing trust.
- Observe workers for a period of time.

Step 2: Develop Observation Checklists

Remember in developing the list that positive reinforcement is better for employee participation (i.e. specify criteria for good performance).

SHARP BE SHARP STAY SHARP

Sandia Hazard & Accident Reduction Program

Division 2000 Behavior Based Safety—Electrical Lab Workers

Observer: ______ Date: ______ Time: ______

No. Observed: ______ Bldg: ______ Org: ______

Behavior	Safe	Concern	What	Why
Eyes on Path/Task (26%)				
Line of Fire (19%)				
Repetition (16%)				
Alignment (9%)				

Observer Comments: ______

Employee Comments: ______

Step 3: Observing

There are several decisions to be made when selecting an observation method or methods:

- Who will observe?
  - Self-observation
  - Peer-to-peer
  - Top-down
  - Working groups
- Frequency of observations?
  - Daily, bi-weekly, monthly
- How will feedback be given?
  - Immediately
  - Within a week

Observers Have…

Three main responsibilities:

- Gather data
  - Observation data (Safe/Concern)
  - Discussion data (What/Why)
- Give feedback
  - Positive reinforcement for safe behaviors
  - Provide coaching on concerns
- To remain objective/unbiased

Step 3: Observing

As an example, Sandia's method of observation is:

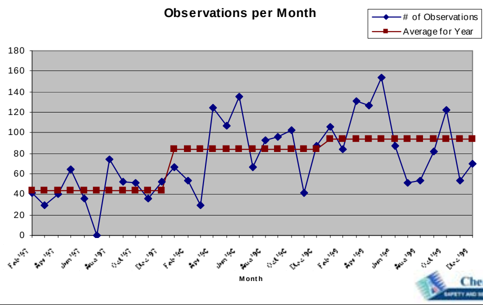
- Peer-to-peer
- Anonymous (No Names/No Blame)
- Announced
- 5 minutes or less
- Provide feedback:
  - Positive reinforcement for safe behaviors
  - Coaching for behaviors of concern
- Identify obstacles
- Foster safety communication

An Observer's Job is NOT:

- Ambush or spy on workers
- "Catch" people doing activities unsafely
- Criticize worker performance
- "Safety cop" (risks vs. rules; right vs. wrong; safe vs. unsafe)
- Watch a whole task or job
- Force people to change
- Turn people in for discipline
- Identify conditions that don't directly impact critical behaviors

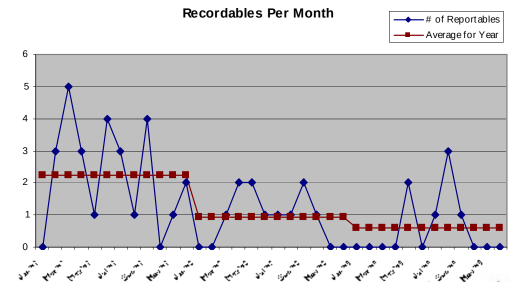
What happens with more observations?

Feedback Changes Behaviors



Fewer injuries!

Changed Behaviors Reduce Accidents



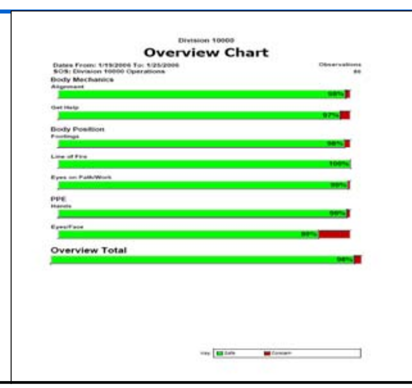
Step 4: Providing Feedback

Providing feedback to workers in a timely manner is important. Using multiple methods has proven beneficial:

- **Verbal - Immediate feedback during observations.**
- **Through reports written after observation data collected.**
- **Posting graphs/charts where all can see.**
- **Having celebrations for milestones or providing other incentives.**

NOTE: It is important that workers are allowed time to adjust their performance before being observed again.

An example of a “Green/Red” Chart from the Observations of a Division at Sandia



Why Implement Behavior Based Safety?

The BBS Process Closes the Gap to "Nobody Gets Hurt"

- Focuses on the critical few precautions that would prevent the most injuries
- Prioritizes actions to remove barriers
- Generates actionable data
- Provides positive reinforcement of safe behaviors
- Engages workers and management:

  Worker driven/Management supported

BBS is proven to reduce injuries

- At 850+ companies injuries were reduced by an average of:
  - 37% after 1 year
  - 66% after 2 years
  - 87% after 3 years
- Multisite Success – See case study of BP's Fabrics and Fibers Business Unit (FFBU) included in your extra materials.

The Benefits Outweigh the Costs

- What is the Return on Investment for BBS?
  - Saves time, money, energy, and can improve morale among employees and between employees and managers.
  - Costs of accidents/incidents are both direct and indirect:
    - Direct costs: investigation, production downtime, medical expenses, damage to equipment or product, repairs, legal costs, fines, etc.
    - Indirect costs: employer/public liability, business interruption, training replacements, loss of goodwill/employee morale, negative public image.

Why Implement Behavior Based Safety?

Remember:

The Iceberg Theory

For every accident, there are many "near misses" that go unnoticed.

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Questions?