Chemical
SAFETY AND SECURITY TRAINING

Alushta, Ukraine
31 October -4 November 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 Russian
  - 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

ICCA

International Labour Organization

ISO International Organization for Standardization

## 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 effective?**

**…Could they be improved?**

**…How?**

# Chemical Safety Principles

SAND No. 2009-8395P
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## Chemical Safety Defined

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

  http://www.merriam-webster.com/dictionary/safety
- **Chemical Safety: "**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
- **Also**:
  - **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

**A**nticipation
**R**ecognition
**E**valuation
**C**ontrol

→ 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?

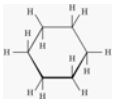
- **Eliminate the hazard**
- **Substitute process materials**
- **Engineering controls**
- **Administrative controls/operational practices**
- **Personal Protective Equipment (PPE)**

## Controls

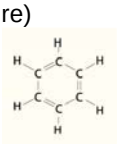
### Change the process

**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


## Personal Protective Equipment PPE

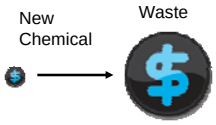
- **PPE is the *least* desired control**
- **Does not eliminate the hazard**
- **Depends on worker compliance**
- **May create heat stress**

## 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

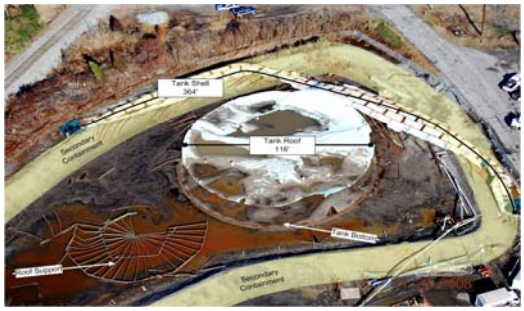
## Chemical Storage

**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

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

**Advantages:**

- **Query for container location**
- **Link a chemical container to safety data sheet**
- **Track chemicals of concern**
- **Document disposal or waste transfer**

- **Recommendations:**
  - **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

Danger
Flammable Liquid

**U.S. OSHA**

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

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

## OHSAS 18001: International Occupational Health and Safety Assessment Specification and Management System

SAND No. 2011-0549C
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.

## OHSAS 18001 Requirements

- Identify OHS hazards
- Assess the risks associated with OHS hazards identified
- Determine the controls necessary to reduce OHS risks to acceptable levels

## OHSAS 18001 Relationships to ISO

- Uses same principles as ISO 9001/14001
  - Document and data control
  - Auditing
  - Process controls
  - Record controls
  - Training
  - Corrective and preventive action and statistics
  - Structure about identical to ISO 14001

## ISO 9001 and OHSAS 18001

- ISO 9001, the world's most widely established quality standard, focuses on satisfying customer requirements.
  - However, neither ISO 9001 nor ISO 14001 explicitly address risk management.
- OHSAS 18001 expands customer requirements of ISO 9001 and:
  - Includes regulatory and other mandatory OHS requirements
  - Is a system for monitoring, controlling and improving performance regarding current regulations and legislation.
    - Does NOT replace these regulations and legislation.

## BS (British Standard) 8800

- Written by industry, safety practitioners and the Health and Safety Executive (HSE) Board to:
  - Minimize risk to employees by developing good working practices to prevent accidents and ill health
  - Improve business performance and responsible image
  - Assist in continuous improvement beyond legal compliance
  - Help organizations comply with its OHS policies and objectives


## BS 8800 (2004)

- New and improved annexes:
  - Promoting an effective OHS management system
  - Hazardous event investigation
  - Risk assessment and control
  - Integration with other management systems into an overall management system

## OHSAS 18001 Integration with ISO Standards

- Can be partially of fully integrated with ISO 9001/14001 programs.
- Some elements are common to ISO; others have no common basis.
- Successful integration requires a mature ISO 9001/14001 program(s).
- Can be run in parallel with ISO; integration not for all.

## Relationships

- OHSAS 18001 sets OHS specifications.
- OHSAS 18002 provides guidelines for implementation of OHS 18001.
- BS8800 explains various elements in developing and maintaining an OHS management system.
  - Offers guidance in promoting safety management system, risk assessment and hazardous event investigation.

## Applicability of OHSAS 18001

- Applies to any organization, regardless of:
  - Size
  - Process
  - Regulatory requirements
  - Economic situation
  - Geographic location

## Why Implement OHSAS 18001?

There are costs to implementing OHSAS 18001, but if they can be justified the benefits (both tangible and intangible) exceed the costs:

- Safety of workers
- Quality of product
- Increased efficiency
- Good for business

## Benefits of OHSAS 18001

- Tangible
  - Reduce lost time
  - Reduce litigation risk
  - Adequate health & safety insurance provisions
  - Regulatory flexibility

## Benefits of OHSAS 18001

- Intangible
  - Continuity of operations
  - Operational efficiency
  - Quality work force
  - Improved community goodwill
  - Competitive advantages
  - Employee motivation and pride

## OHSAS 18001 Management Plan

- Integrated with other business activities
- Dedicated to continuous improvement
- Develops corporate commitment
- Establishes emergency preparedness response
- Satisfies legislative requirements
- Not intended to address product or services safety

## OHS Management Program

- Designates responsibility and authority
- Defines means through which objectives are to be achieved, and timeline for achieving them.
- Must be reviewed at regular, planned intervals
- Must be amended to address relevant changes in activities, products/services or operating conditions
- Top management must provide necessary resources

## OHSAS 18001 Requirements

- Must establish and maintain procedures for ongoing identification of hazards, risk assessment and control measures for:
  - Routine and non-routine activities
  - Activities of all personnel having access to the facility
  - For all facilities, regardless whether provided by the organization or others

## Proactive, Not Reactive

- Consistent with operating experiences and capabilities of risk control measures and provide input into:
  - Determination of facility requirements
  - Identification of training needs
  - Development of operational controls
  - Monitoring of actions to ensure effectiveness and timeline to implementation
  - Classification of risks (LOW-HIGH)

## Regulations

- Specific to the activity (e.g. site operating permits)
- Specific to the organizations products and/or services
- Specific to the industry; general OHS safety laws and authorizations, licenses and permits
- Must consider the legal and regulatory requirements of ALL activities (not just high risk).

## Objectives

- Should be quantified whenever possible
- There must be a continuous improvement commitment
- Consider:
  - Legal requirements
  - OHS hazards and risks
  - Technological options
  - Financial, operations and business requirements
  - Views of interested parties


## Employee Awareness

- Employees must understand:
  - Importance of conforming to OHS management system
  - OHS consequences of their work activities
  - Individual roles & responsibilities
  - Potential consequences of non-conformance to operating procedures
- Employees should be involved in review of policies/procedures for managing risks and consulted on changes that affect workplace.
- Employees should be aware of organization's OHS representative.

## Employee involvement is KEY.

- Employees must take responsibility for conforming to OHS standards on a daily basis.
  - Therefore, it is important that they respect the process.
- More likely to follow procedures they are involved in designing, and will have greater respect for the process if they are recognized as active participants/encouraged to share opinions.
- Interaction between management and employees, as well as with OHS representative, should be encouraged.

## Authorization of OHS Management System by Top Management is Crucial

- Appropriate to nature and scale of OHS risks
- Include commitment to continuous improvement
- Documented and communicated to all employees
- Available to interested parties
- Reviewed periodically
- At least comply with current OHS legislation

## Document Control

- Procedures established and maintained such that all documents and data required by OHSAS specifications:
  - Can be readily located.
  - Are reviewed periodically and updated if necessary.
  - Are available at all locations where the OHS management system operates.
  - Documents may be integrated with other corporate documents where appropriate .
    - e.g. org charts, site emergency plans, etc.

## Document Control (continued)

- Applies to documents including records, audits and reviews:
  - Must be legible, identifiable and traceable
  - Must be stored as to be readily retrievable and protected against loss or damage
  - Retention time must be established and recorded

## Records and Reviews

- Compliant records
- Training records
- Accident Information
- Inspection, maintenance and calibration records
- Contractor and supplier information
- Incident reports
- Risk information
- Audit results
- Management review records

## Emergency Situations

- Identify potential emergency situations and response measures.
- There must be review of response measures after any incidents occur.
- Emergency response measures must be tested periodically.

## Responsibility and Authority

- Procedures must be defined for response to and investigation of accidents and incidents
- Procedures must be in place for taking action to mitigate consequences from accidents and incidents
- Corrective and preventive action procedures must be initiated and completed
- There must be confirmation of effectiveness of corrective and preventive actions taken

## Audit Program and Procedures

- Determines whether OHS management plan has been properly implemented and maintained and meets policy and objectives
- Reviews results of previous audits
- Provides audit information to (top) management
- Should be conducted by independent (not necessarily external) personnel

## Management Reviews

- Should be at specified periodic intervals, documented, and cite any need for changes to policy or objectives
- Should include:
  - Audit results
  - Extent to which objectives are met
  - Confirmation of continued suitability of OHS management system
  - Concerns from any relevant interested parties

## OHSAS 18001 Certification

**Steps to certification are similar to those for ISO 9001/14001:**

- **Commit to developing OHSAS 18001 system.**
- **Develop plan for implementation.**
  - **Understand legal/regulatory requirements.**
  - **Identify risks/hazards, and controls for them.**
- **Implementation and training.**
  - **Training for management/employees can be done in-house or through consultants.**
  - **Allow enough time for system to be correctly/effectively implemented.**
- **Once system is in place, consider options for certification.**

## OHSAS 18001 Certification

**Developing a program can be done with or without consultation:**

- **Without – literature can be purchased to help guide through the process of designing/implementing.**
  - Hiring a consultant to check progress may be beneficial.
- **With – Groups like SGS and BVQI, who were involved in the creation of OHSAS 18001, offer in-depth consulting services.**
  - SGS offers its services from the initial set-up, through development and implementation, all the way to certification.
  - BVQI offers preliminary audits to diagnose implementation problems, and audits post-certification to monitor progress.

## Chemical Safety and Security Program Organization and Responsibilities

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 Safety and Security (CSS) Program Purpose

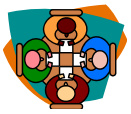
- **Ensure a safe and secure workplace.**
- **Ensure a sustainable environment.**
- **Prevent/reduce release of hazardous substances in plant and in community.**
- **Prevent/reduce exposure to staff.**
- **Enhance community relations.**
- **Comply with regulations.**
- **Enable crisis management.**

## 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

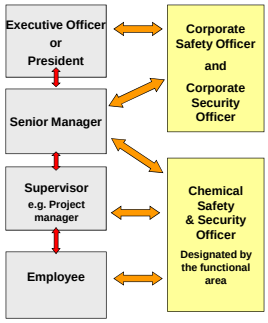
- Come from senior management
- Are typically brief
- Set clear goals
- Establish commitment
- Define employee role
- Identifies resources and staff
- Are signed by person in authority

## 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**

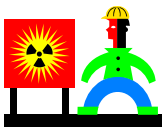



## Program Evaluation

- **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

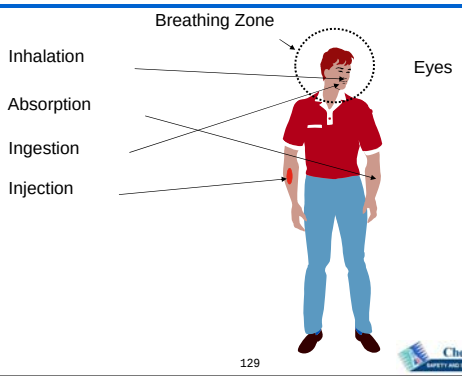


## Definitions

- 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

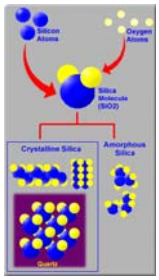
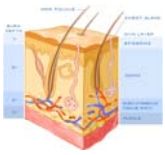



Photo Credit: US OSHA



## Exposure
## Skin Absorption

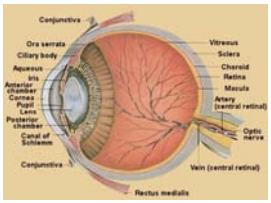
- **Depends on skin location and thickness**
  - Palms of the hands are thickest
  - Skin on abdomen is thin
- **Depends on skin condition**
  - Dry and broken skin more susceptible
  - Sweat increases absorption
- **Duration of contact**
- **Properties of the chemical**
  - Concentration
  - Solubility (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**

- Worker swallows 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



## Pharmakokinetics

- **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

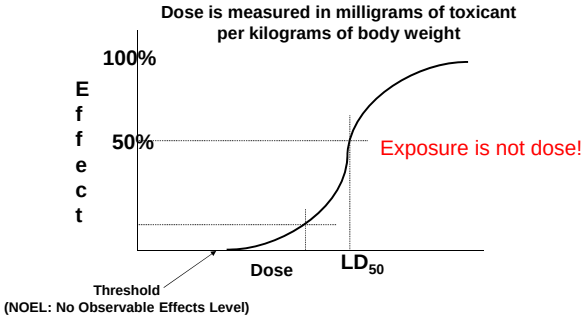
**"All substances are poisons; There is none which is not a poison. The right dose differentiates a poison from a remedy…" – Paracelsus (1493-1541)**



## 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






## 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--heart muscle
    - Uranium--kidney damage



## 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
  - Uranium-kidney and lung damage
  - 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:**

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

**Where:**
C = airborne concentration
T = time

*** A TLV expressed as a TWA**



## Example

**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

$$TLV - TWA_8 = \frac{C_1T_1 + C_2T_2 + \ldots + C_NT_N}{8 \text{ hrs}}$$

$$TLV - TWA_8 = \frac{(80 \times 2) + (110 \times 4) + (55 \times 2)}{8 \text{ hrs}}$$

**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
  - Sensitizers produce allergic reactions
  - 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
  - Exercise: 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

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

**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



## Process Safety Overview

SAND No. 2011-0548P
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.

## Key acronyms

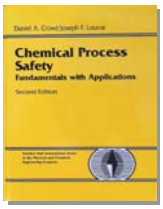
**PSM** = *process safety management*

**SDS** = *safety data sheet*

**RAGAGEPS** = *recognized and generally accepted good engineering practices*

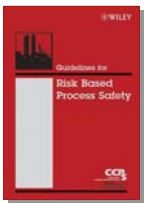
## Process safety resources

D.A. Crowl and J.F. Louvar 2001. ***Chemical Process Safety: Fundamentals with Applications, 2nd Ed.,*** Upper Saddle River, NJ: Prentice Hall.




## Process safety resources

CCPS 2007a. Center for Chemical Process Safety, ***Guidelines for Risk Based Process Safety***, NY: American Institute of Chemical Engineers.

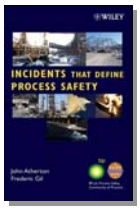



## Process safety resources

CCPS 2008a. Center for Chemical Process Safety, ***Guidelines for Hazard Evaluation Procedures, Third Edition***, NY: American Institute of Chemical Engineers.

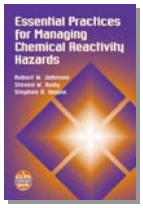
## Process safety resources

**CCPS 2008b.** Center for Chemical Process Safety, ***Incidents that Define Process Safety***, NY: American Institute of Chemical Engineers.




## Process safety resources

**Johnson et al. 2003.** ***Essential Practices for Managing Chemical Reactivity Hazards,*** NY: American Institute of Chemical Engineers, accessible free after registration on www.knovel.com.




## Process safety resources

**CCPS 2001.** Center for Chemical Process Safety, **"Reactive Material Hazards: What You Need To Know,"** NY: American Institute of Chem. Engineers, www.aiche.org/uploadedFiles/CCPS/Resources/SafetyAlerts/reactmat.pdf.


## Process Safety Overview

1. What is *process safety*?
2. Opposite of process safety: Major incidents
3. The basic anatomy of process safety incidents
4. Overview of process safety strategies
5. Taking advantage of past experience
6. Defense in depth / layers of protection
7. Elements of process safety management

## Process Safety Overview

1. **What is *process safety*?**

## *Process safety*

**= the absence of loss and harm resulting from fires, explosions and hazardous material releases at process facilities.**

*(Event-focused definition)*

## *Process safety*

**= the absence of loss and harm at process facilities by**
**(a) identifying process hazards,**
**(b) containing and controlling them,**
**(c) countering abnormal situations with effective safeguards.**

*(Activity-focused definition)*

## Process Safety Overview

1. What is *process safety*?
2. **Opposite of process safety: Major incidents**

## Some major process incidents

- **Flixborough**, UK (June 1974)
  - Partial oxidation of cyclohexane
  - Catastrophic failure of temporary piping
  - 30 tonnes of hot cyclohexane released in 30 s
  - Vapor cloud explosion
  - 28 fatalities, 53 injuries; 1800+ houses damaged; plant destroyed
  - 18 of those fatally injured were in control room
  - Hastened passage of UK "Health and Safety at Work Act"

See CCPS 2008b for details of these incidents

## Some major process incidents

- **Seveso**, Italy (July 1976)
  - Runaway reaction
  - 2 kg of dioxin release from relief system
  - Over 17 $km^2$ affected
  - Locally grown food banned for several months
  - Several inches of topsoil removed, incinerated
  - 80,000 animals died or slaughtered
  - Plant shut down and destroyed
  - EU "Seveso Directive" prompted

## Some major process incidents

- **Mexico City**, Mexico (November 1984)
  - Large LPG / fuels storage facility
  - Fires, vessel ruptures, boiling-liquid-expanding-vapor explosions (BLEVEs)
  - Initiating cause unknown
  - 600 fatalities, 7000 injuries
  - Horizontal tanks rocketed as far as 1200 m away
  - Fixed fire protection destroyed by blasts
  - Fuels terminal destroyed

## Some major process incidents

- **Bhopal**, India (December 1984)
  - Pesticide production facility
  - Water introduced into methyl isocyanate storage
  - MIC toxic vapor release from vent system
  - 2000 to 3000 early fatalities; ~200,000 injuries
  - Plant shut down; Union Carbide eventually sold
  - Seveso II, EPA Risk Management Program prompted

## Some major process incidents

- **Toulouse**, France (September 2001)
  - Ammonium nitrate storage at fertilizer plant
  - Explosive decomposition initiated; cause unknown
  - Equivalent blast energy 20-40 tons of TNT
  - 30 fatalities; 2500+ injuries; US$ 2 billion in losses

## Some major process incidents

- **Texas City**, Texas (March 2005)
  - Refinery isomerization unit
  - One valve not opened during unit re-start
  - Release of hot flammable material from blowdown
  - Ignition and vapor cloud explosion
  - 15 fatalities, 170+ injuries; BP losses and impacts

Photo credit: U.S. Chemical Safety & Hazard Investigation Board

## Some major process incidents

- **Buncefield**, UK (December 2005)
  - Petrol (gasoline) tank farm
  - Storage tank overflow
  - Ignition, vapor cloud explosion and fires
  - 40+ injuries; 20+ tanks destroyed
  - Consequences could have been much worse

See www.buncefieldinvestigation.gov.uk/index.htm for details

## DISCUSSION

**When "major chemical incidents" is mentioned, what come first to your mind?**

- 
- 
- 
- 
- 

## Process Safety Overview

1. What is *process safety*?
2. Opposite of process safety: Major incidents
3. **The basic anatomy of process safety incidents**

## *Process safety incident anatomy*

**Preface**

This presentation is adapted from course materials and from presentations used for several years for process safety lectures at the University of Cincinnati and The Ohio State University, with updates to reflect terminology used in the Third Edition of *Guidelines for Hazard Evaluation Procedures* (CCPS 2008a).

## Incident - Definition

***Incident:***

**An unplanned event or sequence of events that either resulted in, or had the potential to result in, adverse impacts.**

## Major process industry incidents

- Fires
- Explosions
- Toxic Releases

→

- Fatalities
- Injuries
- Environ. Damage
- Property Damage
- Evacuations
- Business Losses
- Plant Closings
- Fines, Lawsuits

## Major process industry incidents

***Loss Events***

→

- Fatalities
- Injuries
- Environ. Damage
- Property Damage
- Evacuations
- Business Losses
- Plant Closings
- Fines, Lawsuits

## Major process industry incidents

***Loss Events***

→

**Impacts**

## Key definition

**Loss event:**

***Point of time in an abnormal situation when an irreversible physical event occurs that has the potential for loss and harm impacts.***

– CCPS 2008a Glossary

## Key definition

**Loss event:**

***Point of time* in an abnormal situation when an *irreversible physical event* occurs that has the potential for loss and harm impacts.**

– CCPS 2008a Glossary

**Examples:**

- Hazardous material release
- Flammable vapor or dust cloud ignition
- Tank or vessel overpressurization rupture

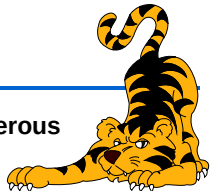
## Key questions

- **Why** do loss events happen?
- **How** do loss events happen?
- **What** must be done to avoid them?

## WHY do loss events happen?

- We choose to handle dangerous process materials and energies
  - To make a living
  - To provide society with desirable products
- As long as we choose to handle them, a potential for loss events exists

## Analogy



- We choose to handle dangerous animals at the Zoo
  - To make a living
  - To provide society with desirable experiences
- As long as we choose to handle them, a potential for loss events exists
  - Things can be done to reduce their likelihood and severity to negligible or tolerable levels

## *Process safety*

**The absence of loss and harm at process facilities by**

**(a) identifying process hazards,**

**(b) containing and controlling them,**

**(c) countering abnormal situations with effective safeguards.**

## Process hazard - Definition

***Presence** of a*
***stored or connected***
***material or energy** with*
***inherent characteristics***
*having the **potential** for*
***causing loss or harm.***

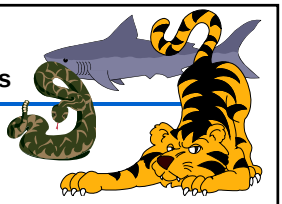
## Three types of process hazards

- **Material hazards**
- **Energy hazards**
- **Chemical interaction hazards**

## Three types of process hazards

- **Material hazard: A contained or connected process material with one or more hazardous characteristics**
- Energy hazard
- Chemical interaction hazard

## Inherent characteristics



***Presence** of a*
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*having the **potential** for*
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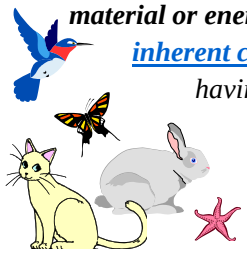


## Material hazards

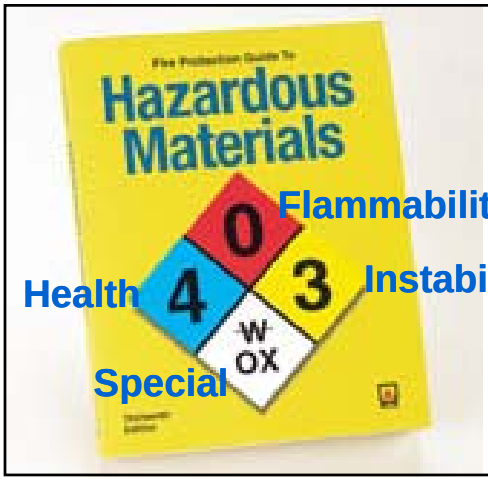
***Inherently hazardous characteristics*:**

- Flammability
- Instability
- Toxicity
- Corrosivity

## E.g., Flammable/combustible materials

***Inherent characteristics:***

- **Flash point (volatility)**
- **Heat of combustion**
- **Ease of ignition**
  - **Flammability limits**
  - **Minimum ignition energy**
  - **Autoignition temperature**




**NFPA 704**
**Summary of material hazards for emergency response**

## SDSs

**Safety Data Sheets**

- More complete summary of hazards
- Required to be accessible in workplace
- All hazardous materials on-site
- Available from suppliers, internet sources
- Give only basic chemical reactivity info
- Often inconsistent from source to source

## Limitations

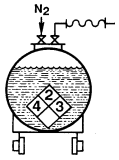
- **NFPA 704 diamonds and SDSs only give properties of individual hazardous materials**
  - **Hazardous energies not identified**
  - **Some hazardous chemical interactions not identified**
  - **Connected hazards may not be identified**

## Three types of process hazards

- Material hazard
- **Energy hazard: Some form of physical energy contained within or connected to the process with the potential for loss or harm**
- Chemical interaction hazard

## Process hazard

***Presence** of a*
***stored or connected***
***material or energy** with*
***inherent characteristics***
*having the **potential** for*
***causing loss or harm.***



## Form of Energy with Injury Potential (examples)

- Electrical (voltage, capacitance)
- Mechanical (spring, machine parts)
- Kinetic (moving or rotating mass)
- Positional (elevated part or equipment)
- Hydraulic (liquid under pressure)
- Pneumatic (gas/vapor under pressure)
- Chemical–Health Hazard (NFPA 2 to 4)
- Chemical–Flammables (NFPA 3 or 4)
- Chemical–Combustibles (NFPA 2)
- Chemical–Reactive (NFPA 2 to 4)
- Thermal–Hot Material (steam, hot oil)
- Thermal–Cryogenic Fluid (liquid $N_2$)

**LOCKOUT/TAGOUT ENERGY CONTROL PROCEDURE** Page 1 of 1

**Drawing No.** X-100-101
**Equipment Name** Methanol Flowmeter
**Location** Bldg 1, Inside dike wall

| Form of Energy with Injury Potential (examples) | Connected Energy Source and Magnitude | Residual and/or Stored Energy? |
|---|---|---|
| Electrical (voltage, capacitance) | | |
| Mechanical (spring, machine parts) | | |
| Kinetic (moving or rotating mass) | | |
| Positional (elevated part or equipment) | | |
| Hydraulic (liquid under pressure) | MeOH pump discharge, 3 bar g | |
| Pneumatic (gas/vapor under pressure) | | |
| Chemical–Health Hazard (NFPA 2 to 4) | MeOH, up to 10,000 liters | Yes |
| Chemical–Flammables (NFPA 3 or 4) | MeOH, up to 10,000 liters | Yes |
| Chemical–Combustibles (NFPA 2) | | |
| Chemical–Reactive (NFPA 2 to 4) | | |
| Thermal–Hot Material (steam, hot oil) | | |
| Thermal–Cryogenic Fluid (liquid $N_2$) | | |

**ISOLATE CONNECTED ENERGY SOURCES**
**Energy Isolating Device #1** Ball Valve
**Location** Between MeOH transfer pump and flowmeter
**Use of Device** Close valve
**LOTO** Lockout and tagout **Initials**_____

**LOCKOUT/TAGOUT ENERGY CONTROL PROCEDURE** Page 1 of 1

**Drawing No.** X-100-101
**Equipment Name** Methanol Flowmeter
**Location** Bldg 1, Inside dike wall

...

**ISOLATE CONNECTED ENERGY SOURCES**
**Energy Isolating Device #1** Ball Valve
**Location** Between MeOH transfer pump and flowmeter
**Use of Device** Close valve
**LOTO** Lockout and tagout **Initials**_____

...

**BLEED OFF RESIDUAL OR STORED ENERGIES**

**Bleed-Off Procedure:**
Drain residual flammable liquid into grounded catch pan.
**Initials**_____

**VERIFY ISOLATION AND DEENERGIZATION**

**Verification Procedure:**
Visually check for pockets of flammable liquid while disassembling.
**Initials**_____

## Three types of process hazards

- Material hazard
- Energy hazard
- **Chemical interaction hazard:**
  **Presence of materials with the potential for loss or harm upon their interaction in an unintentional or uncontrolled manner**

## Reactive interactions

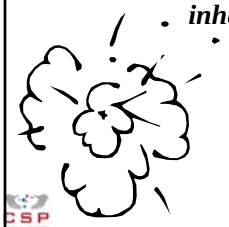
Example Compatibility Chart for an Acetic Anhydride Handling Facility

| *Will These Two Materials React?* | Acetic Acid | Acetic Anhydride | Cooling Water | Sulfuric Acid | 50% Caustic | Lube Oil | Cleaning Solution |
|---|---|---|---|---|---|---|---|
| Acetic Acid | | | | | | | |
| Acetic Anhydride | *Reactive* | | | | | | |
| Cooling Water | *Not reactive* | *Reactive* | | | | | |
| Concentrated Sulfuric Acid | *Reactive* | *Reactive* | *Reactive* | | | | |
| 50% Caustic | *Reactive* | *Reactive* | *Reactive* | *Reactive* | | | |
| Lube Oil | *Not reactive* | *Not reactive* | *Not reactive* | *Reactive* | *Reactive* | | |
| Cleaning Solution | *Find out what the cleaning solution contains, then determine reactions* | | | | | | |

From CCPS 2001

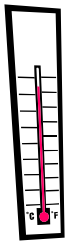
## Process hazard

***Presence** of a*
***stored or connected***
***material or energy** with*
***inherent characteristics***
*having the **potential** for*
***causing loss or harm.***



## Degree of hazard

- More hazardous material
  → *greater degree of hazard*
- Farther from zero energy state
  → *greater degree of hazard*



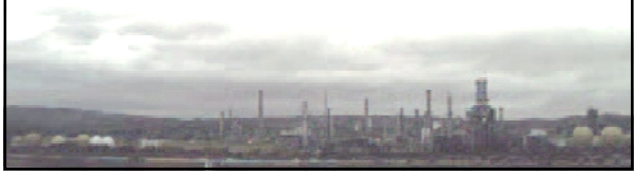

## EXERCISE

**Which has more available energy?**

**1 t heptane at 98 °C**

***or***

**2 t heptane at 20 °C** (ambient temperature)



## EXERCISE

**1 t heptane, 98 °C**

**Chemical energy = 44,600 MJ**
**Thermal energy = 200 MJ**
**Total = 44,800 MJ**

**2 t heptane, ambient temperature**

**Chemical energy = 89,200 MJ**
**Thermal energy = 0 MJ**
**Total = 89,200 MJ**

| Form of Energy with Injury Potential (examples) | Zero Energy State |
|---|---|
| Electrical (voltage, capacitance) | 0 volts |
| Mechanical (spring, machine parts) | Sprung |
| Kinetic (moving or rotating mass) | At rest |
| Positional (elevated part or equipment) | Ground level |
| Hydraulic (liquid under pressure) | 0 bar gage |
| Pneumatic (gas/vapor under pressure) | 0 barg, 0 $m^3$ |
| Chemical–Health Hazard (NFPA 2 to 4) | Nontoxic |
| Chemical–Flammables (NFPA 3 or 4) | Non-flammable |
| Chemical–Combustibles (NFPA 2) | |
| Chemical–Reactive (NFPA 2 to 4) | Nonreactive |
| Thermal–Hot Material (steam, hot oil) | Ambient |
| Thermal–Cryogenic Fluid (liquid $N_2$) | Ambient |

## Key questions

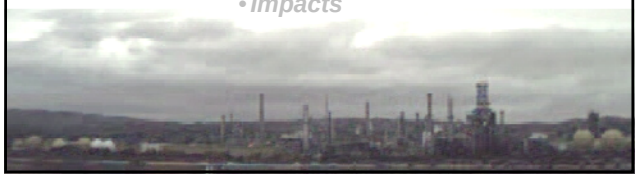
- **Why** do loss events happen?
- **How** do loss events happen?
- **What** must be done to avoid them?

## HOW do loss events happen?

- **Anatomy of an incident**
- **Unsafe act & condition precursors**

## Incident sequence: *Initiating cause*

- *(Hazard)*
- ***Cause***
- *Deviation*
- *Loss event*
- *Impacts*



## Process hazard

***Presence** of a*
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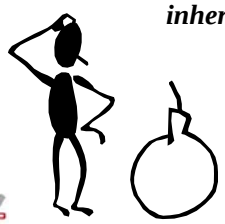


## Normal operation

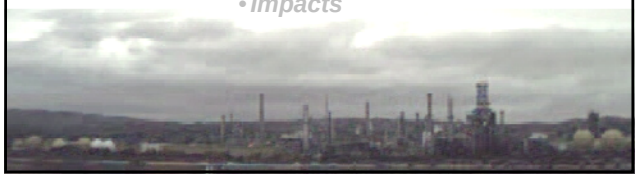

During **normal operation**, all hazards are contained and controlled…

## Normal operation


During normal operation, all hazards are contained and controlled, ***but they are still present.***

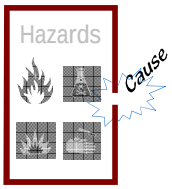
## Incident sequence: *Initiating cause*

- *(Hazard)*
- ***Cause***
- *Deviation*
- *Loss event*
- *Impacts*



## Initiating cause

Every incident starts with an ***initiating cause*** *(also called an **initiating event** or just a "**cause**".*



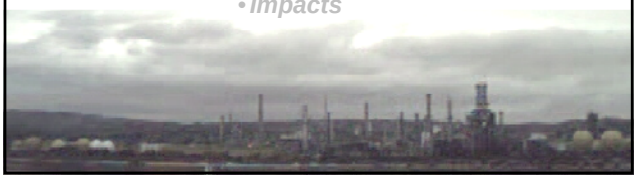

*Example initiating causes:*
- Feed pump fails off
- Procedural step omitted
- Truck runs into process piping
- Wrong raw material is received
- Extreme low ambient temperature

## Initiating cause

Once an ***initiating cause*** occurs, normal operation cannot continue without a process or operational response.


## Incident sequence: *Deviation*

- *(Hazard)*
- *Cause*
- ***Deviation***
- *Loss event*
- *Impacts*



## Deviation

The immediate result of an initiating cause is a ***deviation.***


- **No Flow**
- **Low Temperature**
- **High Pressure**
- **Less Material Added**
- **Excess Impurities**
- **Transfer to Wrong Tank**
- **Loss of Containment**
- **etc.**

## Abnormal situations

- Most engineering focuses on designing a process to ***work****:*

  (**normal situation**)

- We must also consider how a process can ***fail***, starting with an

  "**abnormal situation**"

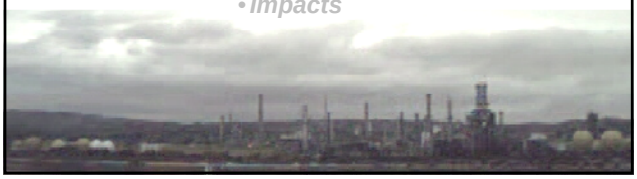
## Deviation

A ***deviation*** is an abnormal situation, outside defined design or operational parameters.


- No Flow
- Low Temperature
- **High Pressure** *(exceed upper limit of normal range)*
- Less Material Added
- Excess Impurities
- Transfer to Wrong Tank
- Loss of Containment
- etc.

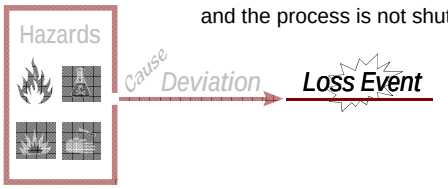
## Incident sequence: *Loss event*

- *(Hazard)*
- *Cause*
- *Deviation*
- ***Loss event***
- *Impacts*



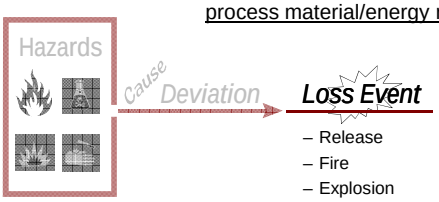
## Loss event

A ***loss event*** will result if a deviation continues uncorrected and the process is not shut down.



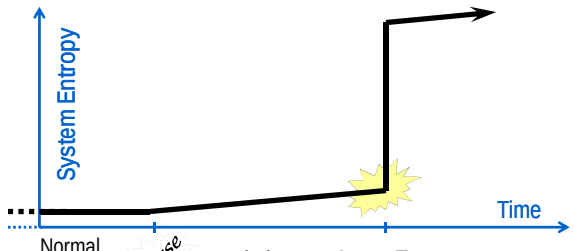

## Loss event

***Loss events*** are generally irreversible process material/energy releases.




– Release
– Fire
– Explosion

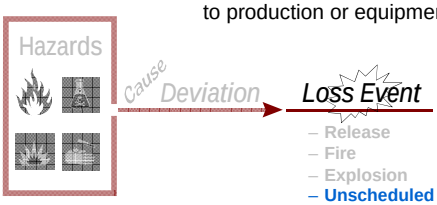
## **Loss event:** Step change in system entropy




– Release
– Fire
– Explosion

## Loss event

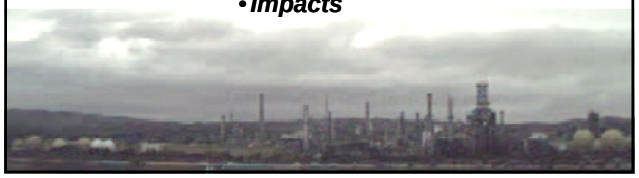
**Loss events** may also be related to production or equipment failures.




– Release
– Fire
– Explosion
– **Unscheduled shutdown**
– **Ruined batch**
– **Compressor failure**

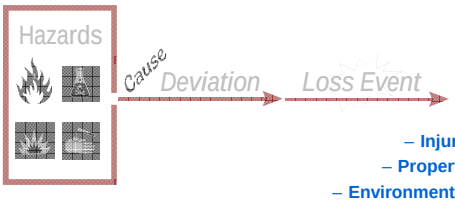
## Incident sequence: *Impacts*

- *(Hazard)*
- *Cause*
- *Deviation*
- *Loss event*
- ***Impacts***



## Impacts

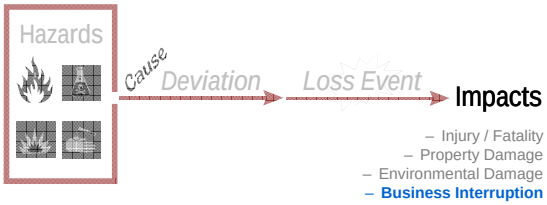
***Impacts*** are the losses and injuries that can result from a loss event.




- Injury / Fatality
- Property Damage
- Environmental Damage

## Impacts

There are often other, less tangible impacts as well.




- Injury / Fatality
- Property Damage
- Environmental Damage
- **Business Interruption**
- **Market Share Loss**
- **Reputation Damage**

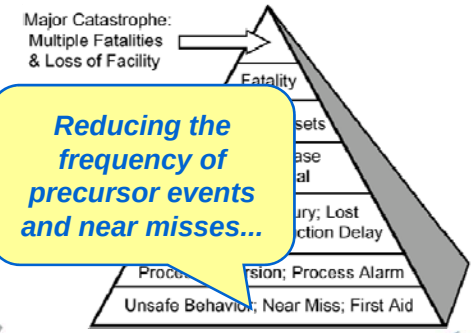
## Incident sequence without safeguards

## HOW do loss events occur?

- Anatomy of an Incident
- **Unsafe act & condition precursors**

## Unsafe act & condition precursors


## Pyramid principle of process safety




## Pyramid principle of process safety

## Key questions

- **Why** do loss events happen?
- **How** do loss events happen?
- **What** must be done to avoid loss events?

## Process Safety Overview

1. What is *process safety*?
2. Opposite of process safety: Major incidents
3. The basic anatomy of process safety incidents
4. **Overview of process safety strategies**
5. **Taking advantage of past experience**
6. **Defense in depth / layers of protection**
7. **Elements of process safety management**

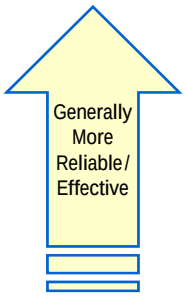
*What must be done*

## Process Safety Overview

1. What is *process safety*?
2. Opposite of process safety: Major incidents
3. The basic anatomy of process safety incidents
4. **Overview of process safety strategies**

## *Overview of process safety strategies*

- **Inherent** - Hazard reduction
- **Passive** - Process or equipment design features that reduce risk without active functioning of any device
- **Active** - Engineering controls
- **Procedural** - Administrative controls



## Process Safety Overview

1. What is *process safety*?
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3. The basic anatomy of process safety incidents
4. Overview of process safety strategies
5. **Taking advantage of past experience**

## Taking advantage of past experience

***"Those who cannot remember the past are condemned to repeat it."*** - George Santayana

- **Learnings from past** (usually bad) **experiences have been embodied in various forms:**
  - **Regulations**
  - **Codes**
  - **Industry standards**
  - **Company standards**
  - **"Best practices"**
  - **Handbooks**
  - **Guidelines**
  - **Procedures**
  - **Checklists**
  - **Supplier Recommendations**

## Taking advantage of past experience

- **One term commonly used for non-regulatory codes and standards is "RAGAGEPs"**
- **From U.S. OSHA's Process Safety Management Standard (Process Safety Information element):**

> 29 CFR 1910.119(d)(3)(ii) The employer shall document that equipment complies with **recognized and generally accepted good engineering practices**.

## Taking advantage of past experience

- **One term commonly used for non-regulatory codes and standards is "RAGAGEPs"**
- **From U.S. OSHA's Process Safety Management Standard (Process Safety Information element)**
- **Example:** International consensus standard **IEC 61511** [ANSI/ISA-84.00.01 (IEC 61511 Mod)], "Functional Safety: Safety Instrumented Systems for the Process Industry Sector"

## RAGAGEPs

***Recognized and Generally Accepted Good Engineering Practices***

- **Take advantage of wealth of experience**
- **Pass on accumulated knowledge**
- **Reduce recurrence of past incidents**
- **Enable uniformity of expectations**
- **Reduce liabilities when followed**

## Example: Anhydrous ammonia

- **Regulatory requirements:**
  E.g., U.S. OSHA Standard 29 CFR 1910.111, "Storage and Handling of Anhydrous Ammonia"
- **Industry standards**
  - CGA G-2, "Anhydrous Ammonia"
  - ANSI/CGA K61.1, "American National Standard Safety Requirements for the Storage and Handling of Anhydrous Ammonia"
- **Other standards apply to specific applications, e.g., EN 378 for ammonia refrigeration**

## RAGAGEPs Alphabet Soup

- **IEC**
- **NFPA**
- **ASME**
- **ISA**
- **UL**
- **FM**
- **CGA**
- **BS**
- **DIN**
- **ASHRAE**
- **IIAR**
- **ASTM**
- **API**
- **AIChE/CCPS**
- **IRI**
- **Chlorine Institute**
- **SOCMA**
- **etc.**

## DISCUSSION

**With what RAGAGEPs are you most familiar?**

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## Process Safety Overview

1. What is *process safety*?
2. Opposite of process safety: Major incidents
3. The basic anatomy of process safety incidents
4. Overview of process safety strategies
5. Taking advantage of past experience
6. **Defense in depth / layers of protection**

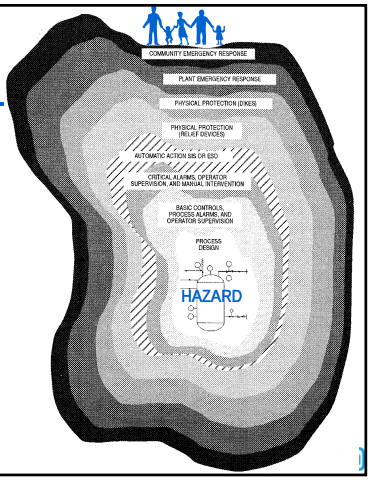
## *Defense in depth / Layers of protection*

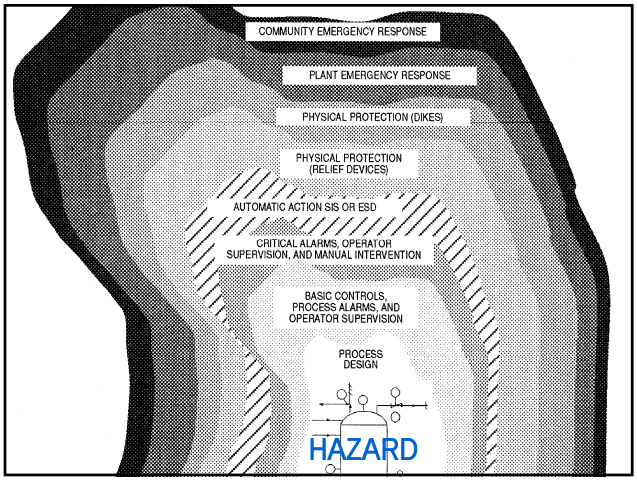
- **Also called "Safety layers"**
- **Multiple layers may be needed, since no protection is 100% reliable**
- **Each layer must be <u>designed</u> to be effective**
- **Each layer must be <u>maintained</u> to be effective**
- **Some layers of protection are *contain and control measures***
- **Other layers of protection are *safeguards***

**"Layers of protection"** between hazards and receptors

=

**"Defense in depth"**



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## Contain & control

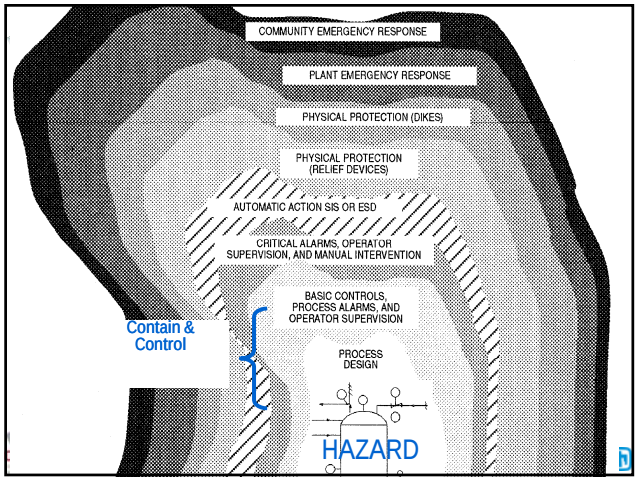
Contain & Control


Operational Mode: **Normal operation**

Objective: **Maintain normal operation; keep hazards contained and controlled**

Examples of ***Contain & control*** measures:

- Basic process control system
- Inspections, tests, maintenance
- Operator training
  - How to conduct a procedure or operate a process correctly and consistently
  - How to keep process within established limits
- Guards, barriers against external forces
- Management of change



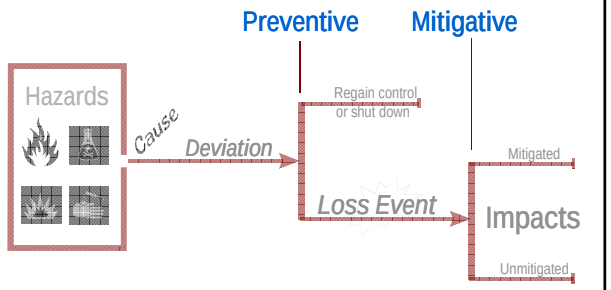

## Key definition

**Safeguard:**

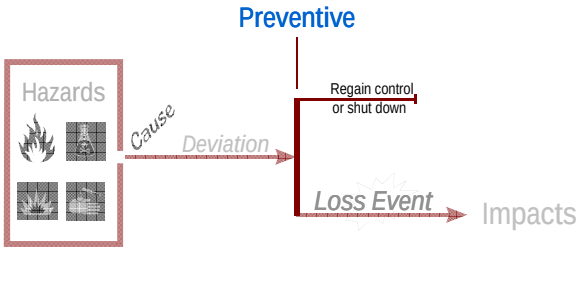
***Any device, system, or action that would likely interrupt the chain of events following an initiating cause or that would mitigate loss event impacts.***

**– CCPS 2008a Glossary**

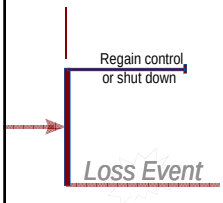
## Two types of safeguards




## Preventive safeguards




## Preventive safeguards

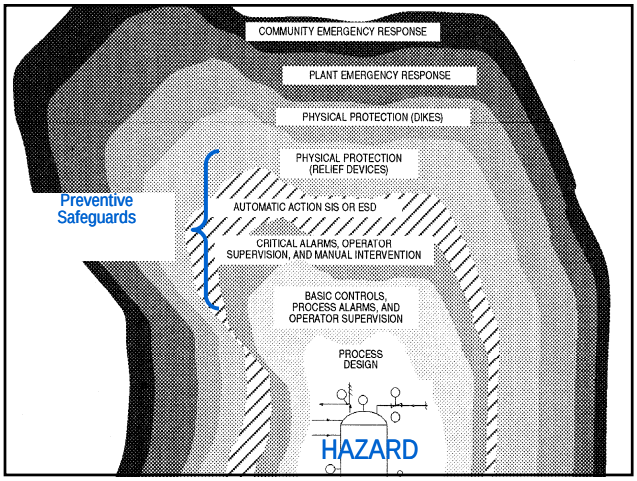



Operational Mode: **Abnormal operation**

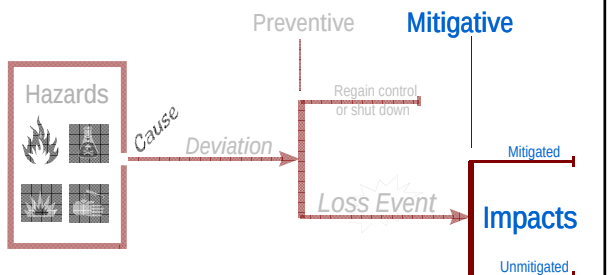
Objective: **Regain control or shut down; keep loss events from happening**

Examples of Preventive Safeguards:

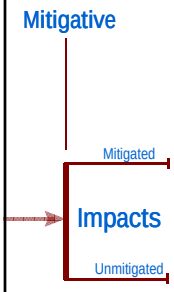
- Operator response to alarm
- Safety Instrumented System
- Hardwired interlock
- Last-resort dump, quench, blowdown
- Emergency relief system



## Mitigative safeguards




## Mitigative safeguards

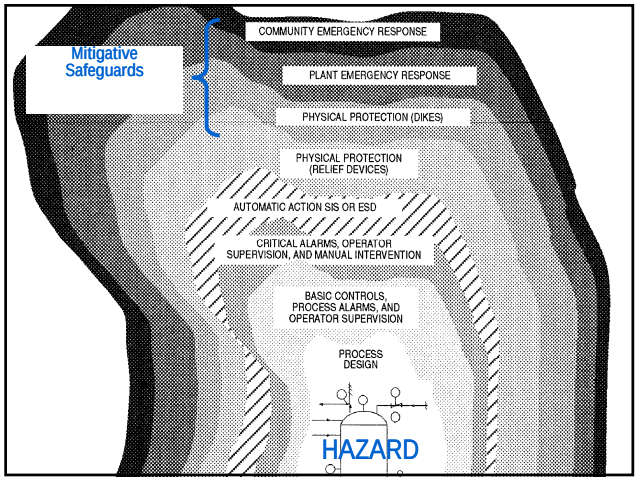



Operational Mode: **Emergency**

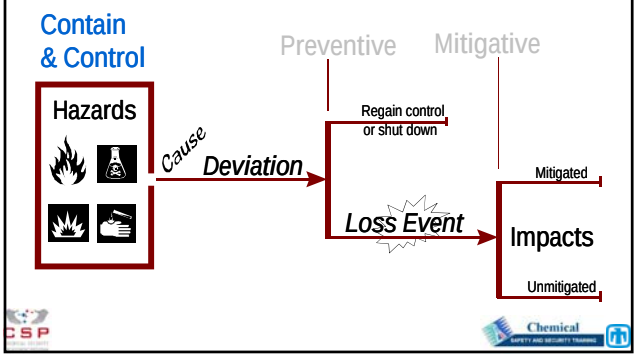
Objective: **Minimize impacts**

Examples of Mitigative Safeguards:

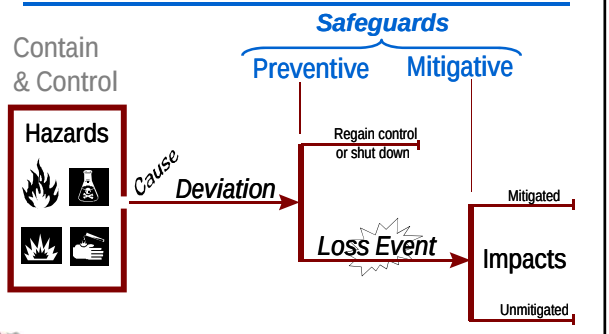
- Sprinklers, monitors, deluge
- Emergency warning systems
- Emergency response
- Secondary containment; diking/curbing
- Discharge scrubbing, flaring, treatment
- Shielding, building reinforcement, haven
- Escape respirator, PPE




## Contain & control: Before initiating cause



## Safeguards: After initiating cause




## Process Safety Overview

1. What is *process safety*?
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4. Overview of process safety strategies
5. Taking advantage of past experience
6. Defense in depth / layers of protection
7. **Elements of process safety management**

## *Elements of a comprehensive PSM program*

- Management systems
- Employee participation
- Process safety information
- Process hazard analysis
- Operating procedures
- Training
- Contractor safety
- Pre-startup safety reviews
- Mechanical integrity
- Safe work practices
- Management of change
- Emergency planning and response
- Incident investigation
- Compliance audits

## *PSM elements addressed in this course*

- Management systems
- Employee participation
- Process safety information
- **Process hazard analysis**
- Operating procedures
- Training
- Contractor safety
- **Pre-startup safety reviews**
- **Mechanical integrity**
- **Safe work practices**
- **Management of change**
- **Emergency planning and response**
- **Incident investigation**
- Compliance audits

## DISCUSSION

**What PSM elements do you find the most difficult to understand?**

**… the most challenging to implement?**

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