Process Safety Overview

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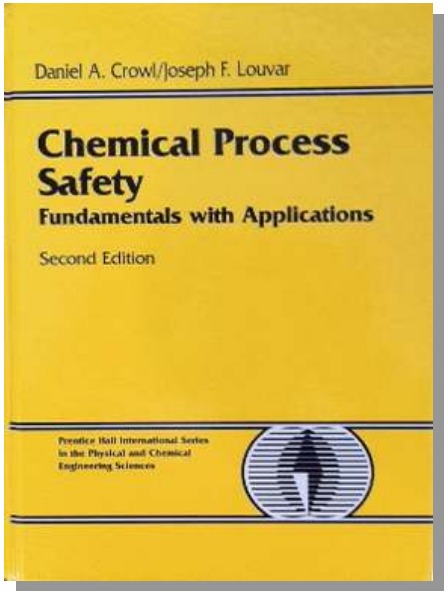
for the United States Department of Energy's National Nuclear Security Administration
under contract DE-AC04-94AL85000.

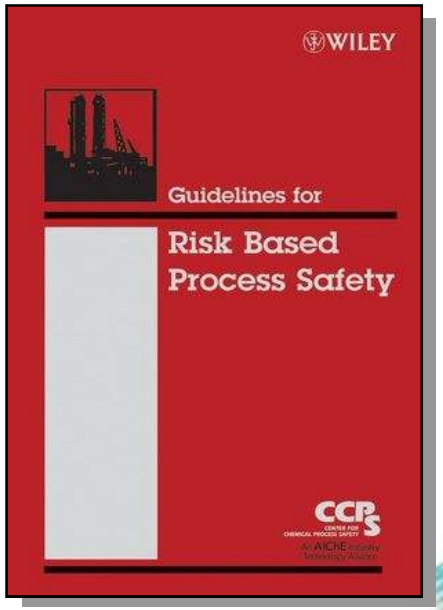
Sandia National Laboratories

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.

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





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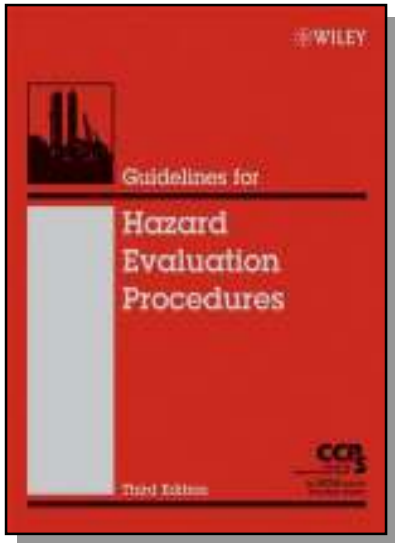
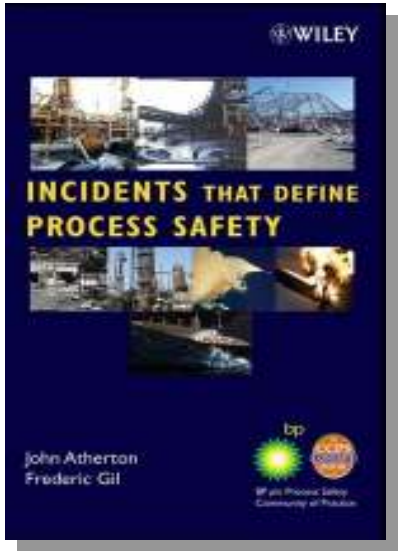
Process safety resources

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

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





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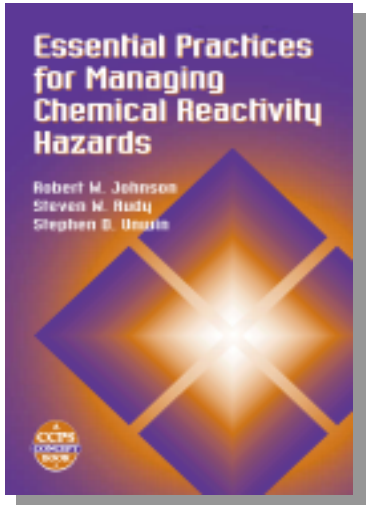
Johnson et al. 2003. ***Essential Practices for Managing Chemical Reactivity Hazards,*** **NY: American Institute of Chemical Engineers,** accessible free after registration on www.knovel.com

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



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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
7. Elements of process safety management

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Process Safety Overview

1. What is “Process Safety”?

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"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)

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Process Safety Overview

1. What is “Process Safety”?
2. **Opposite of process safety: Major incidents**

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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**

See CCPS 2008b for details of these incidents

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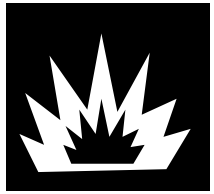
Some major process incidents

- **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



- 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

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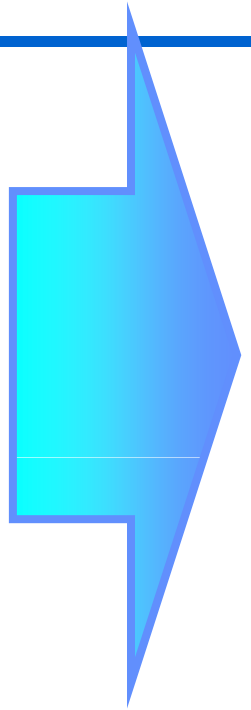
Loss Events



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

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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

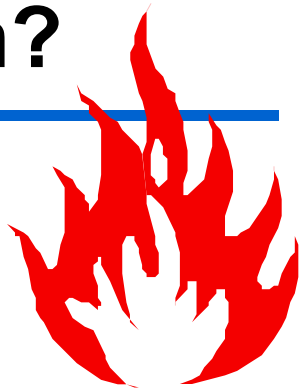
Examples:

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

Key Questions

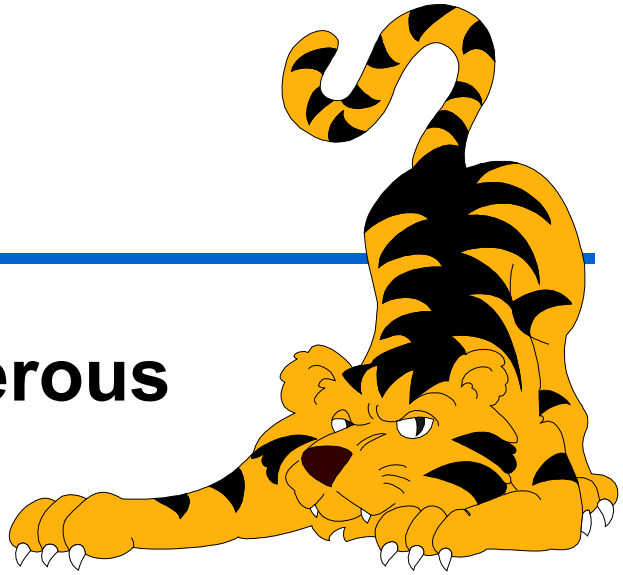
- **Why** do Loss Events happen?
- **How** do Loss Events happen?
- **What** must be done to avoid them?

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 <u>potential</u> 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.

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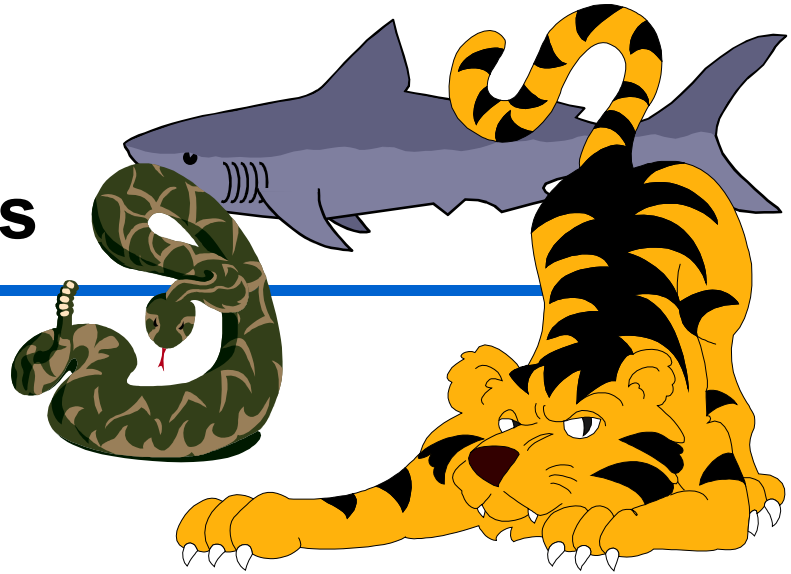
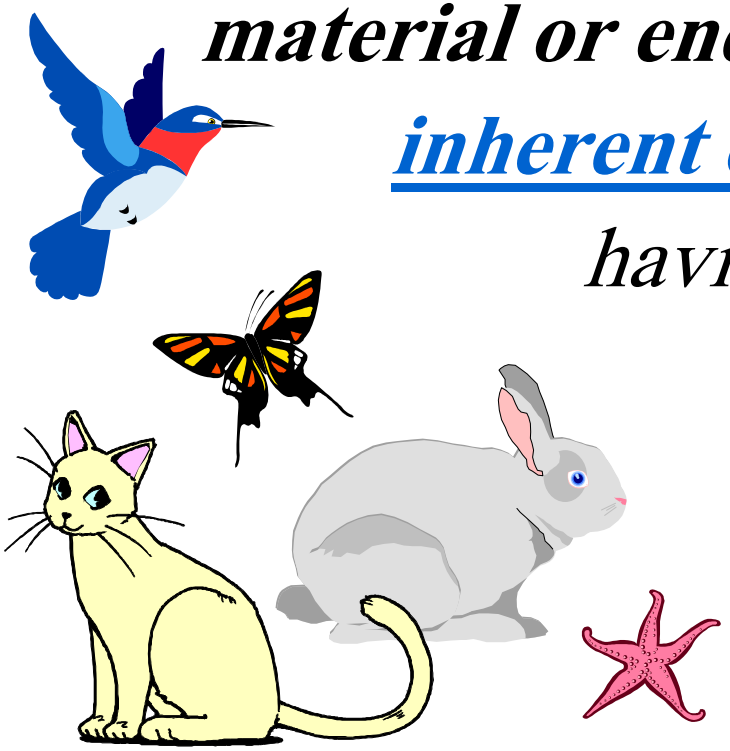
Inherent Characteristics



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



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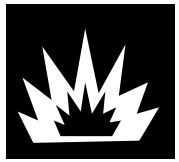
Three Types of Process Hazards

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

Material Hazards

Inherently hazardous characteristics:

Flammability



Instability

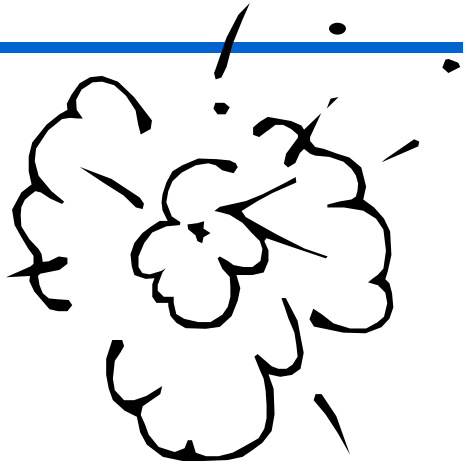
Toxicity

Corrosivity

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*

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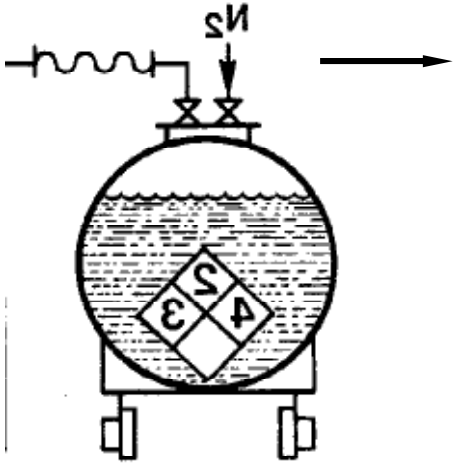

*having the **potential** for*

causing loss or harm.

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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)

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

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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

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Process Hazard

***Presence** of a*
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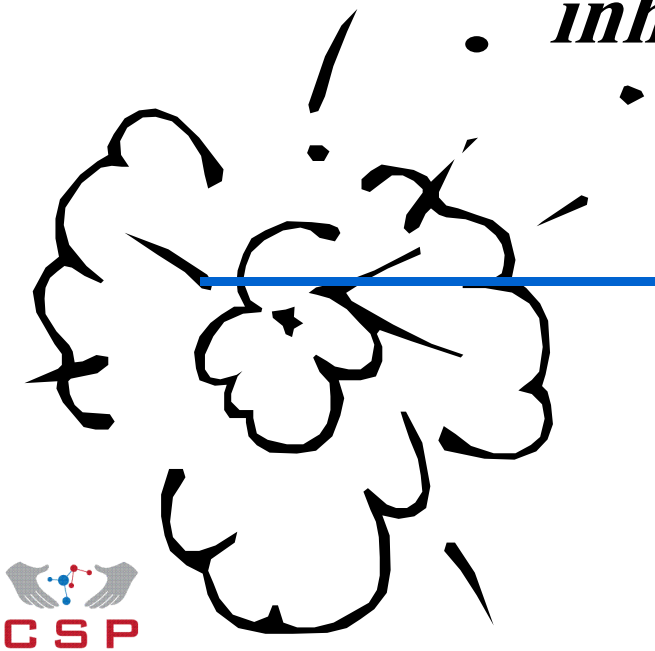

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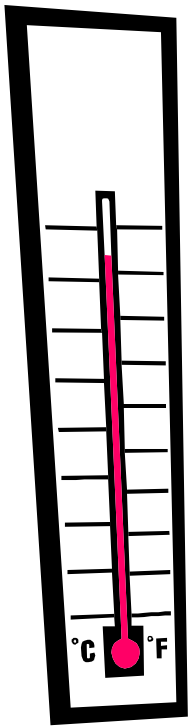
Degree of Hazard

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



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Key Questions

- **Why** do Loss Events happen?
- **How** do Loss Events happen?
- **What** must be done to avoid them?

Incident Sequence: *Initiating Cause*

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

Normal Operation

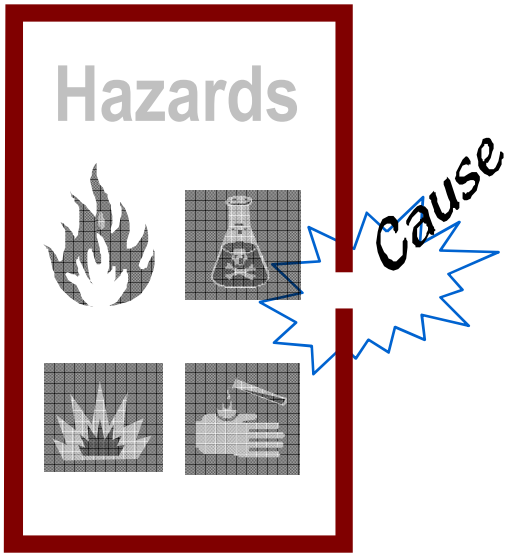
During normal operation, all hazards are contained and controlled, ***but they are still present***.

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

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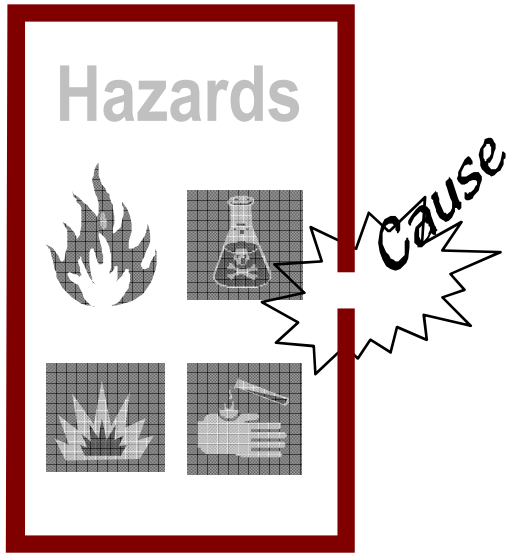
Initiating Cause

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

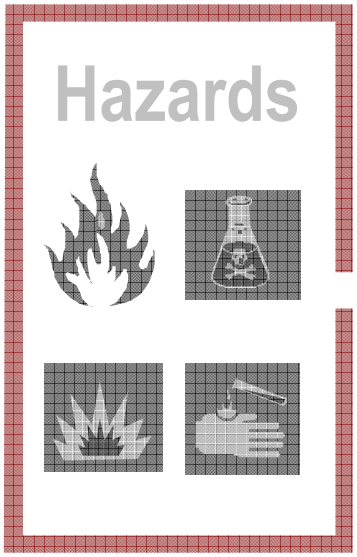


Incident Sequence: *Deviation*

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

Deviation

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



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:***

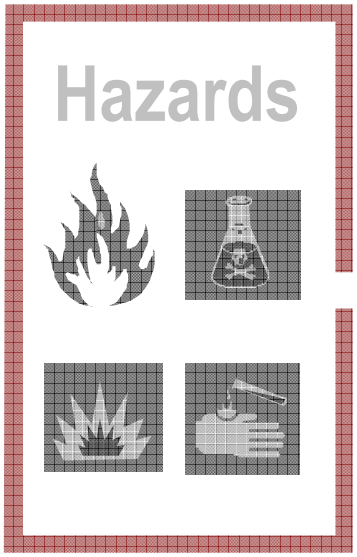
  "normal situation"

- 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.



Deviation

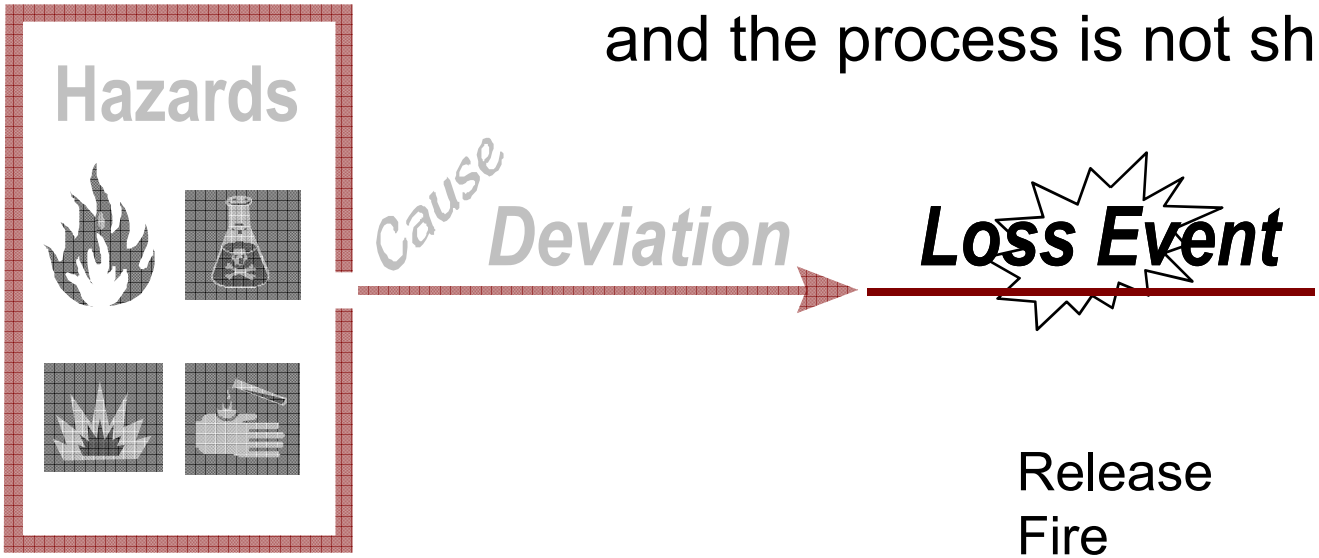
- No Flow
- Low Temperature
- **High Pressure** *(exceed upper limit of normal range)*
- Less Material Added
- Excess Impurities
- Transfer to Wrong Tank
- Loss of Containment
- etc.

Incident Sequence: *Loss Event*

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

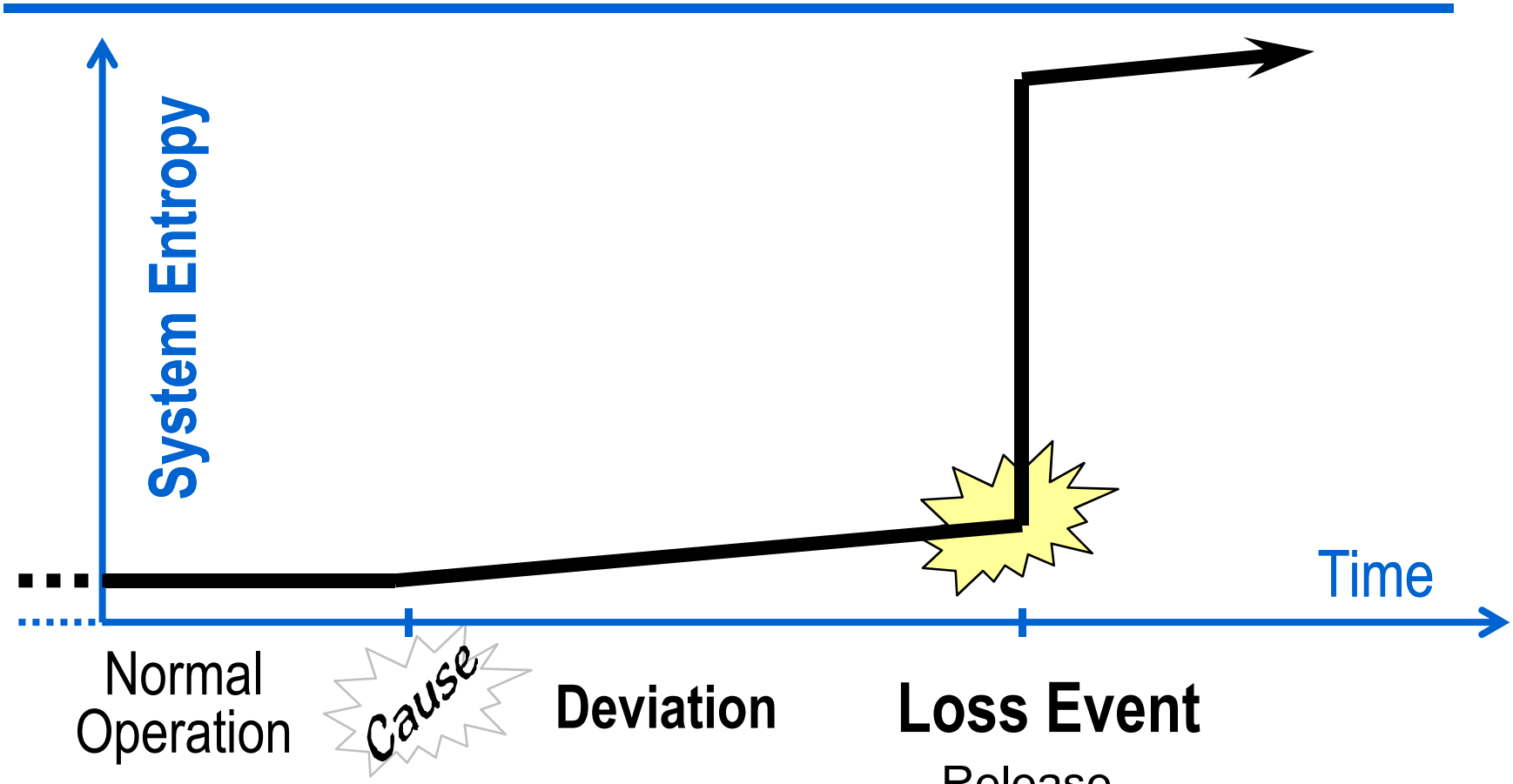
Loss Event

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



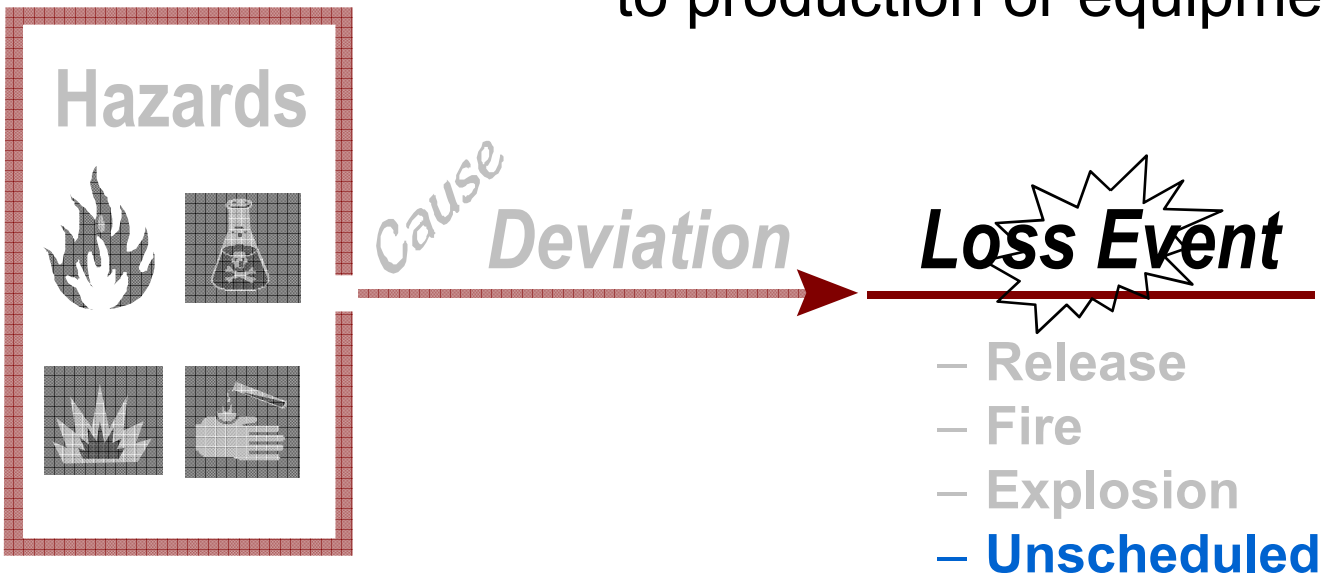
Release
Fire
Explosion

Loss Event: Step Change in System Entropy



Loss Event

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



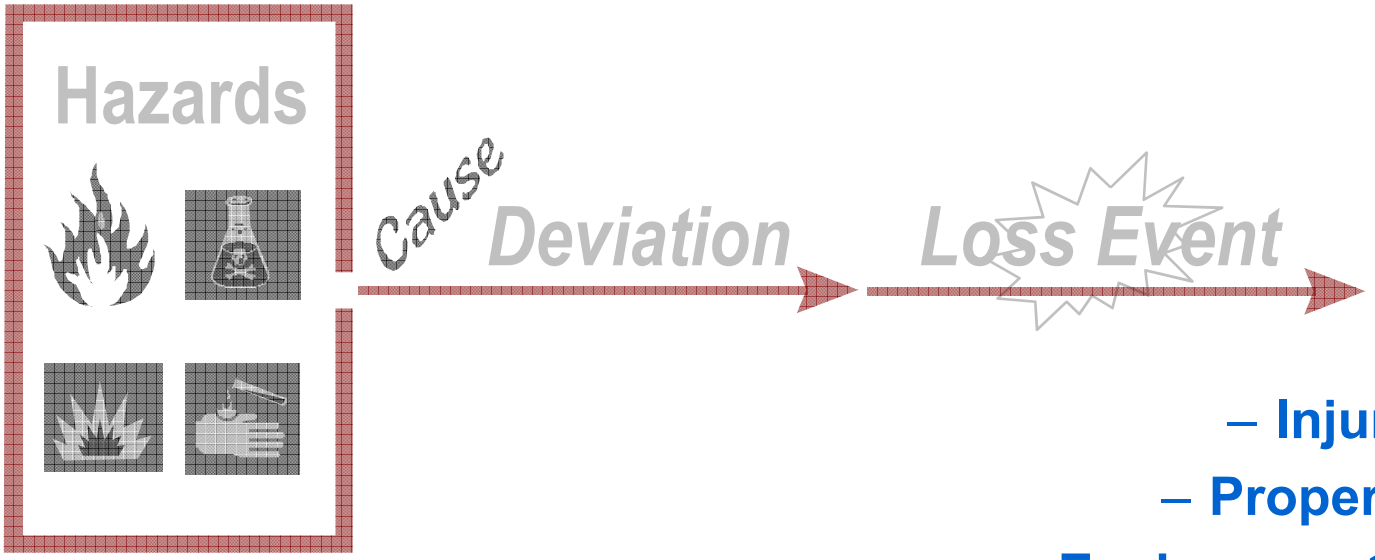
- Release
- Fire
- Explosion
- **Unscheduled shutdown**
- **Ruined batch**
- **Compressor failure**

Incident Sequence: *Impacts*

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

Impacts

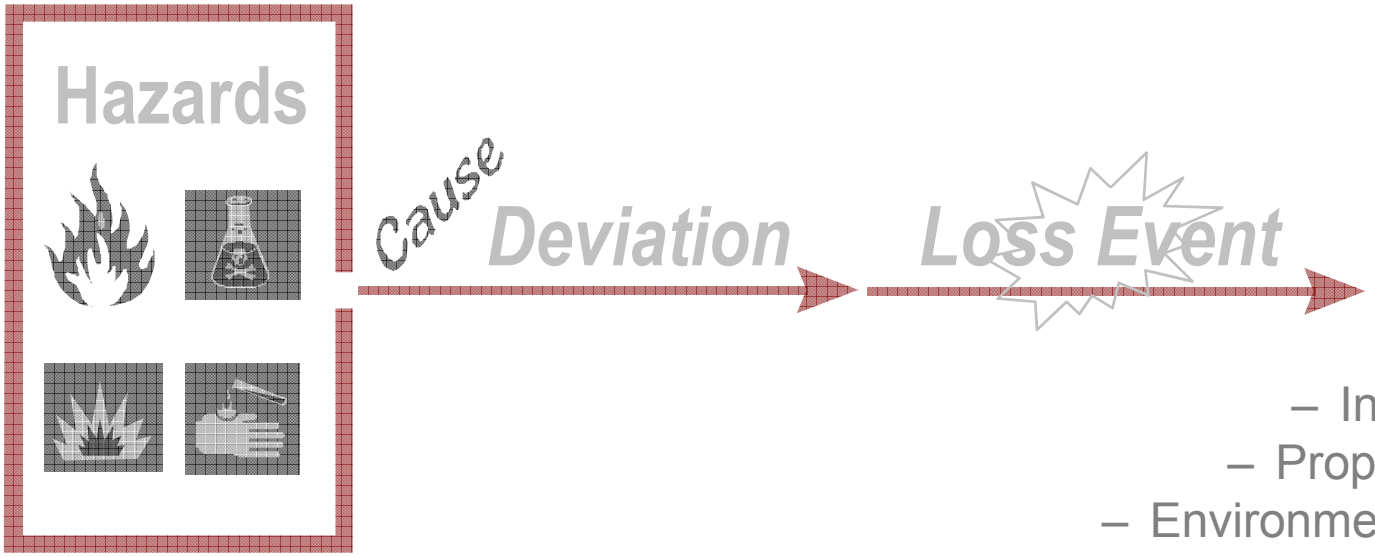
Impacts are the losses and injuries that can result from a loss event.



- Injury / Fatality
- Property Damage
- Environmental Damage

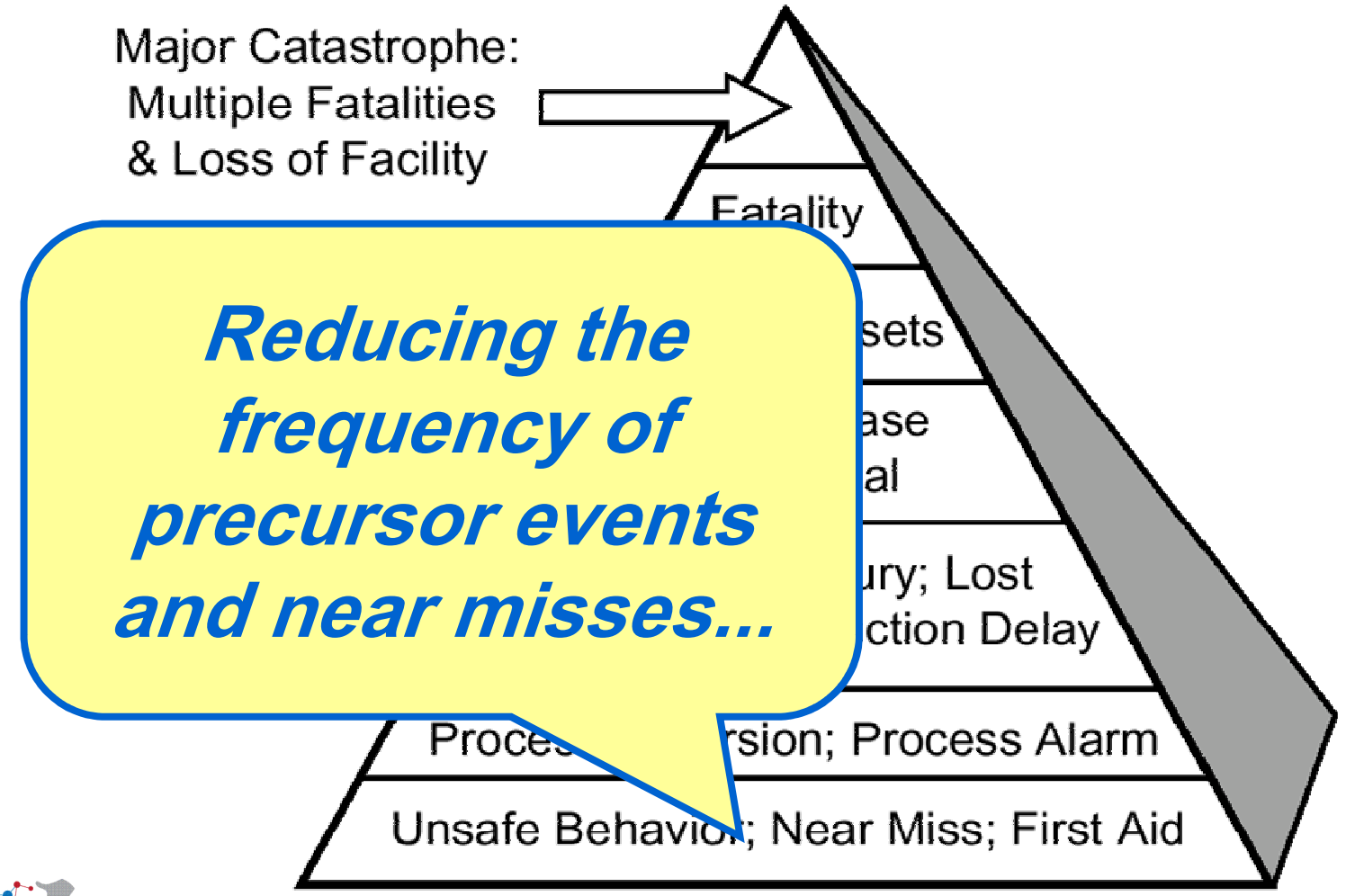
Impacts

There are often other, less tangible impacts as well.



Incident Sequence Without Safeguards

Pyramid Principle of Process Safety



Reducing the frequency of precursor events and near misses...

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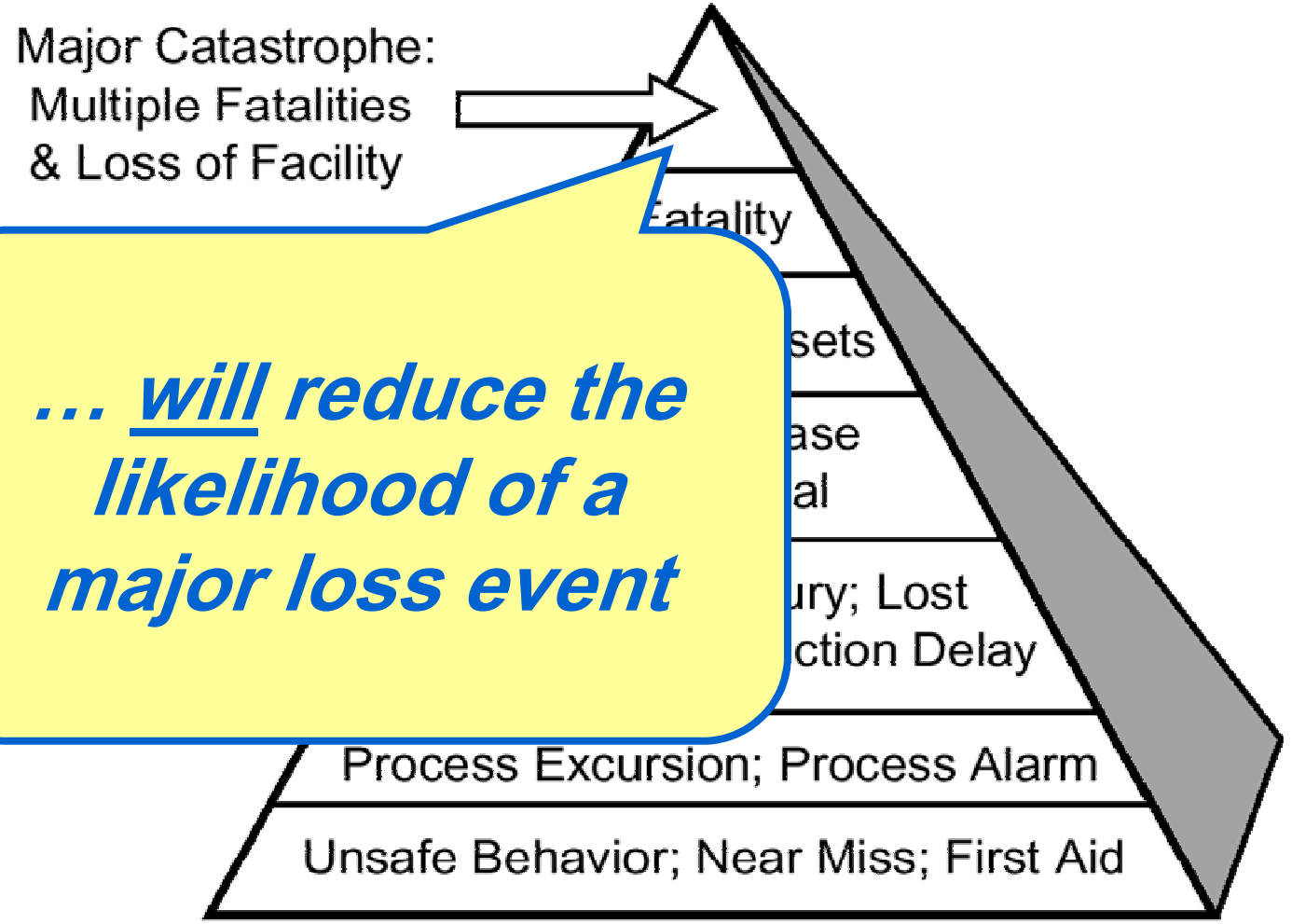
Pyramid Principle of Process Safety



… will reduce the likelihood of a major loss event

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Key Questions

- **Why** do Loss Events happen?
- **How** do Loss Events happen?
- **What** must be done to avoid Loss Events?

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6. **Defense in depth / layers of protection**
7. **Elements of process safety management**

What must be done

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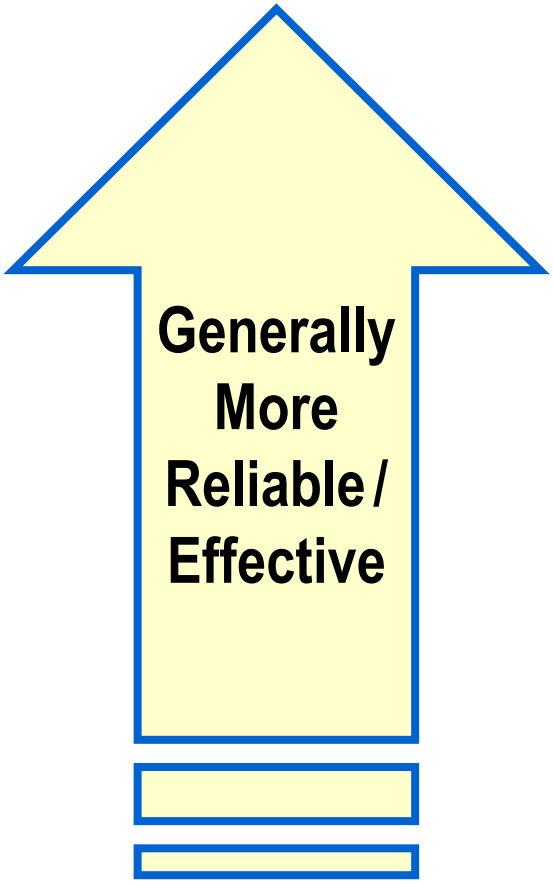
Overview of Process Safety Strategies

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



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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**

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Taking Advantage of Past Experience

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

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6. **Defense in depth / layers of protection**

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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***

Contain & Control

Contain & Control

Operational Mode: **Normal operation**

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

Examples of *Contain & Control*:

- 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

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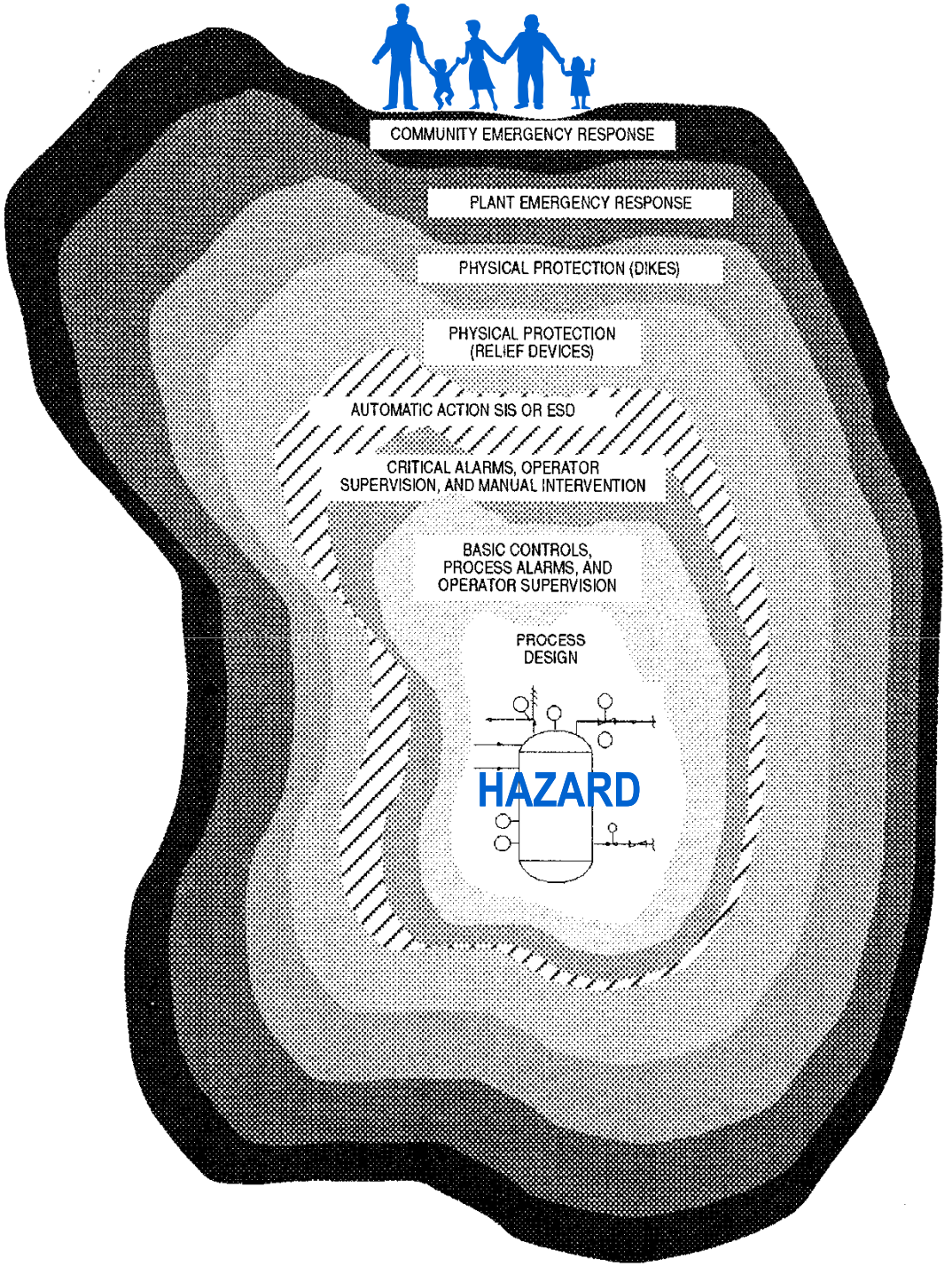
“Layers of Protection” between hazards and receptors

=

“Defense In Depth”



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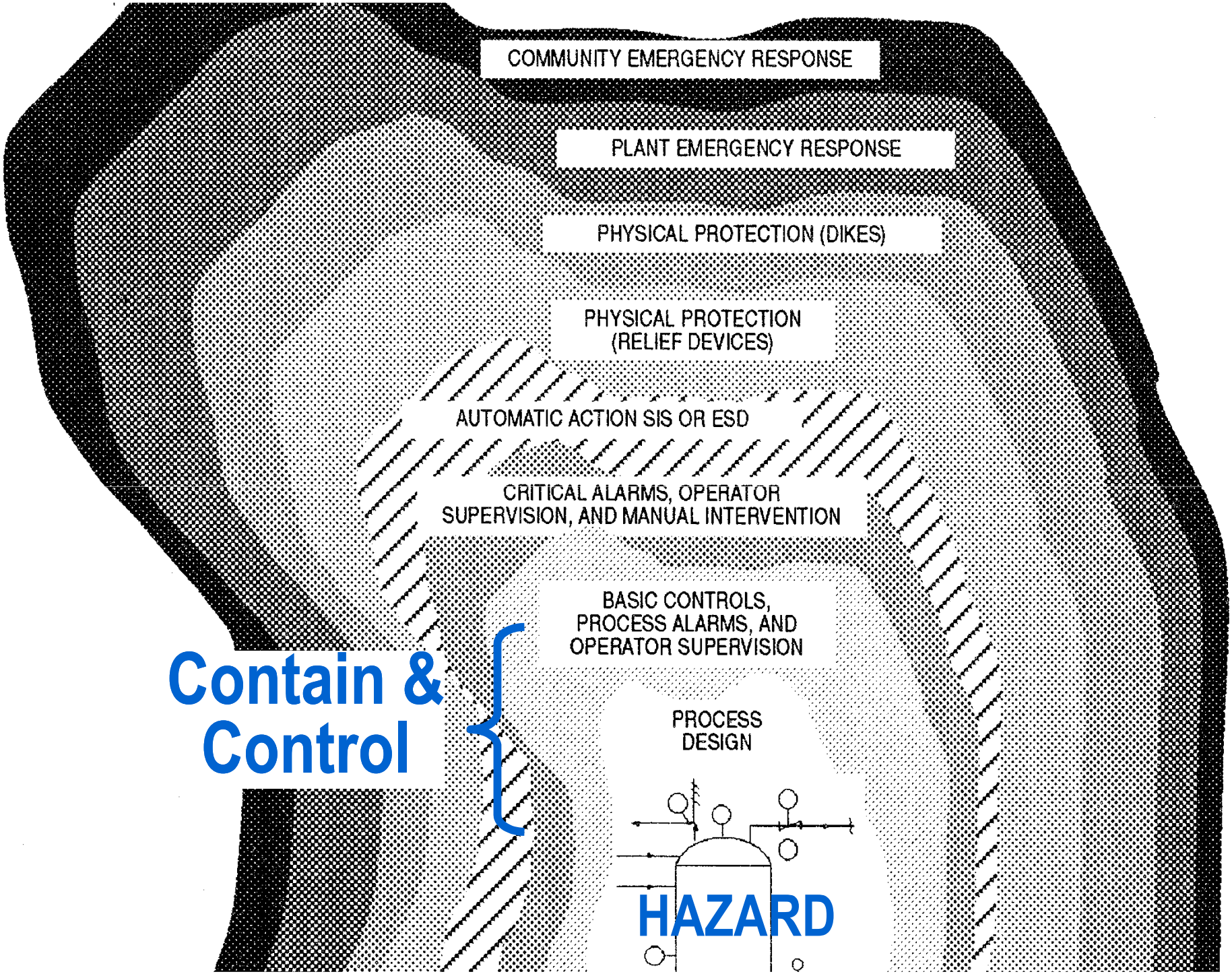
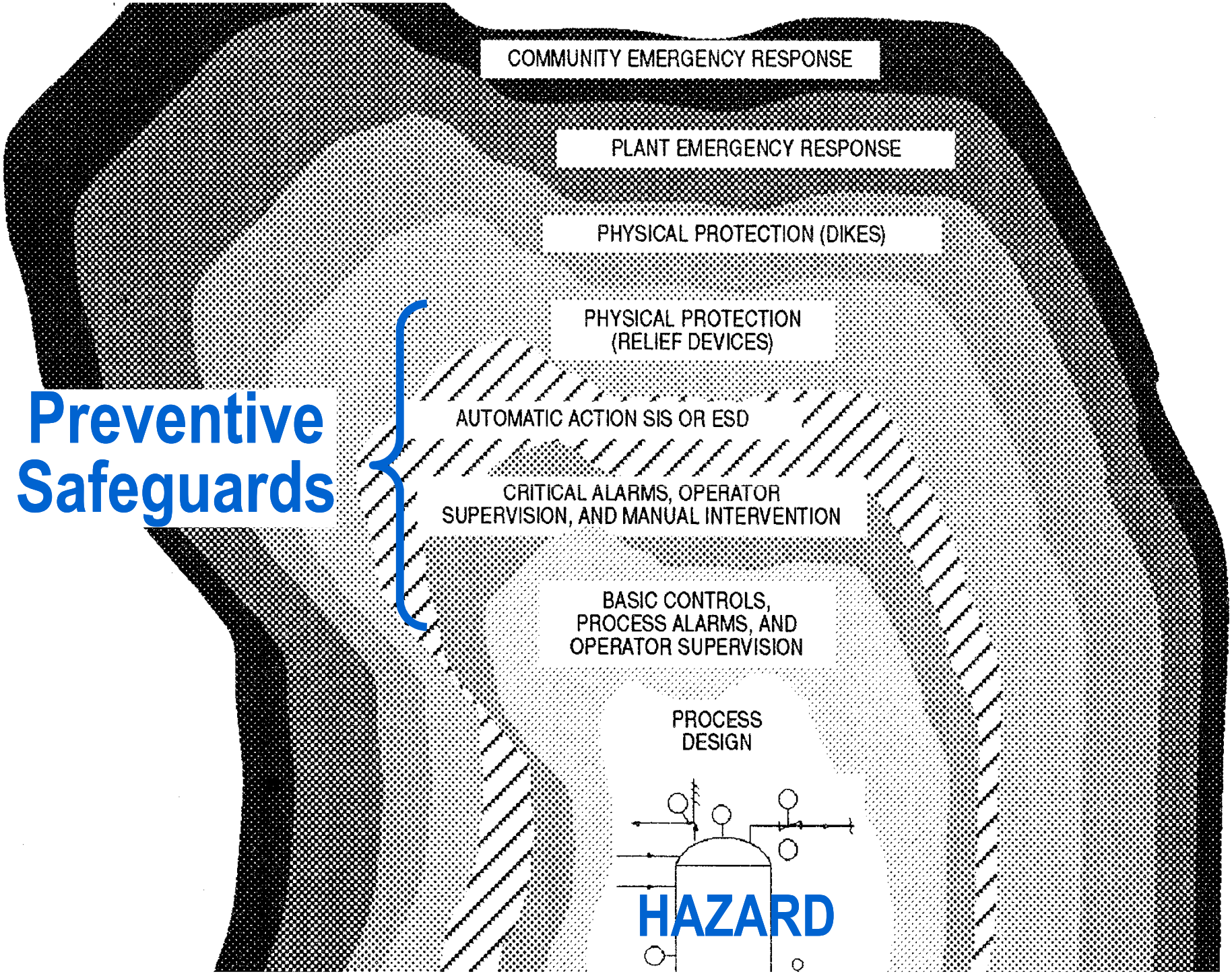

COMMUNITY EMERGENCY RESPONSE
PLANT EMERGENCY RESPONSE
PHYSICAL PROTECTION (DIKES)
PHYSICAL PROTECTION (RELIEF DEVICES)
AUTOMATIC ACTION SIS OR ESD
CRITICAL ALARMS, OPERATOR SUPERVISION, AND MANUAL INTERVENTION
BASIC CONTROLS, PROCESS ALARMS, AND OPERATOR SUPERVISION
PROCESS DESIGN
Contain & Control
HAZARD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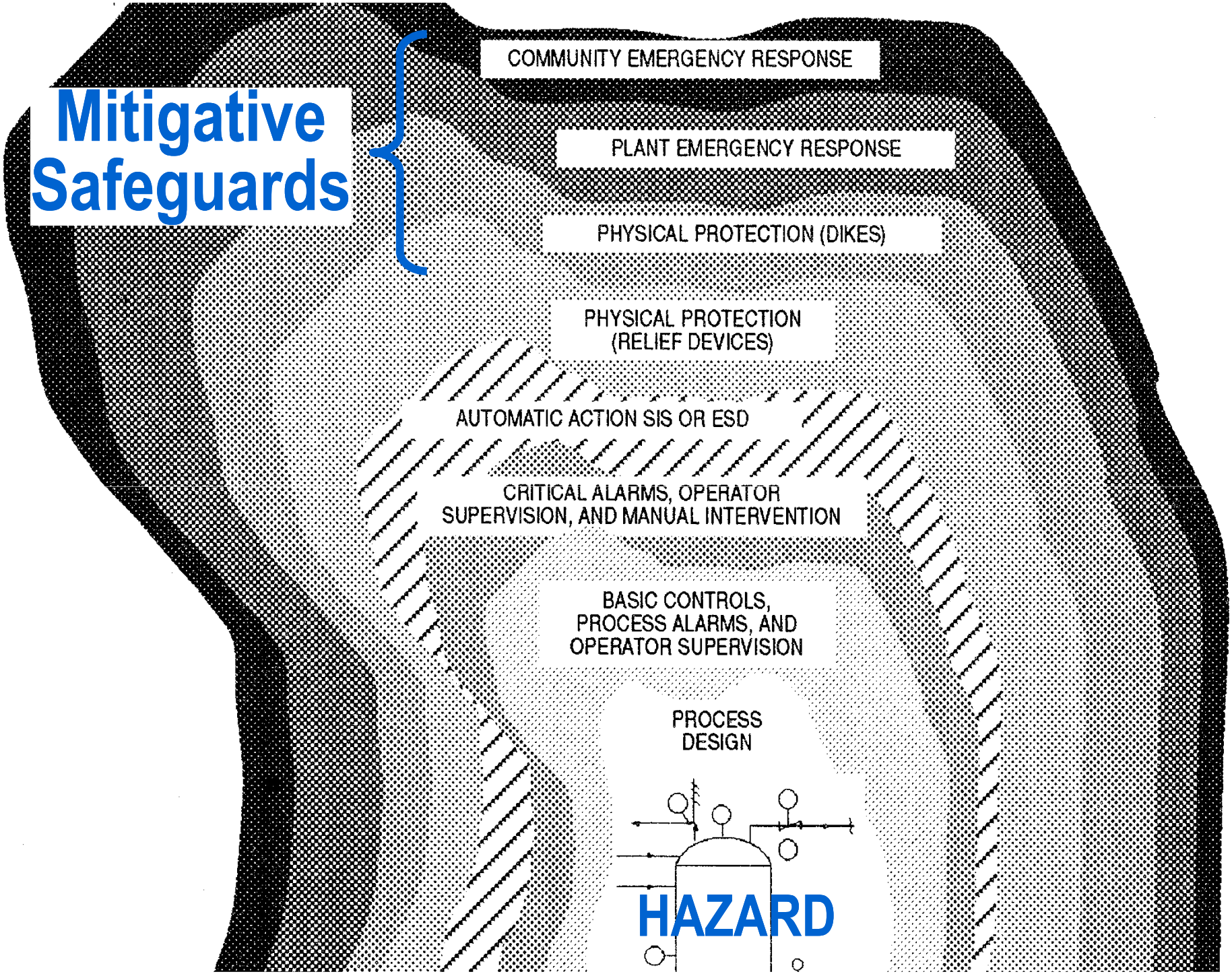
Preventive Safeguards


Mitigative Safeguards
COMMUNITY EMERGENCY RESPONSE
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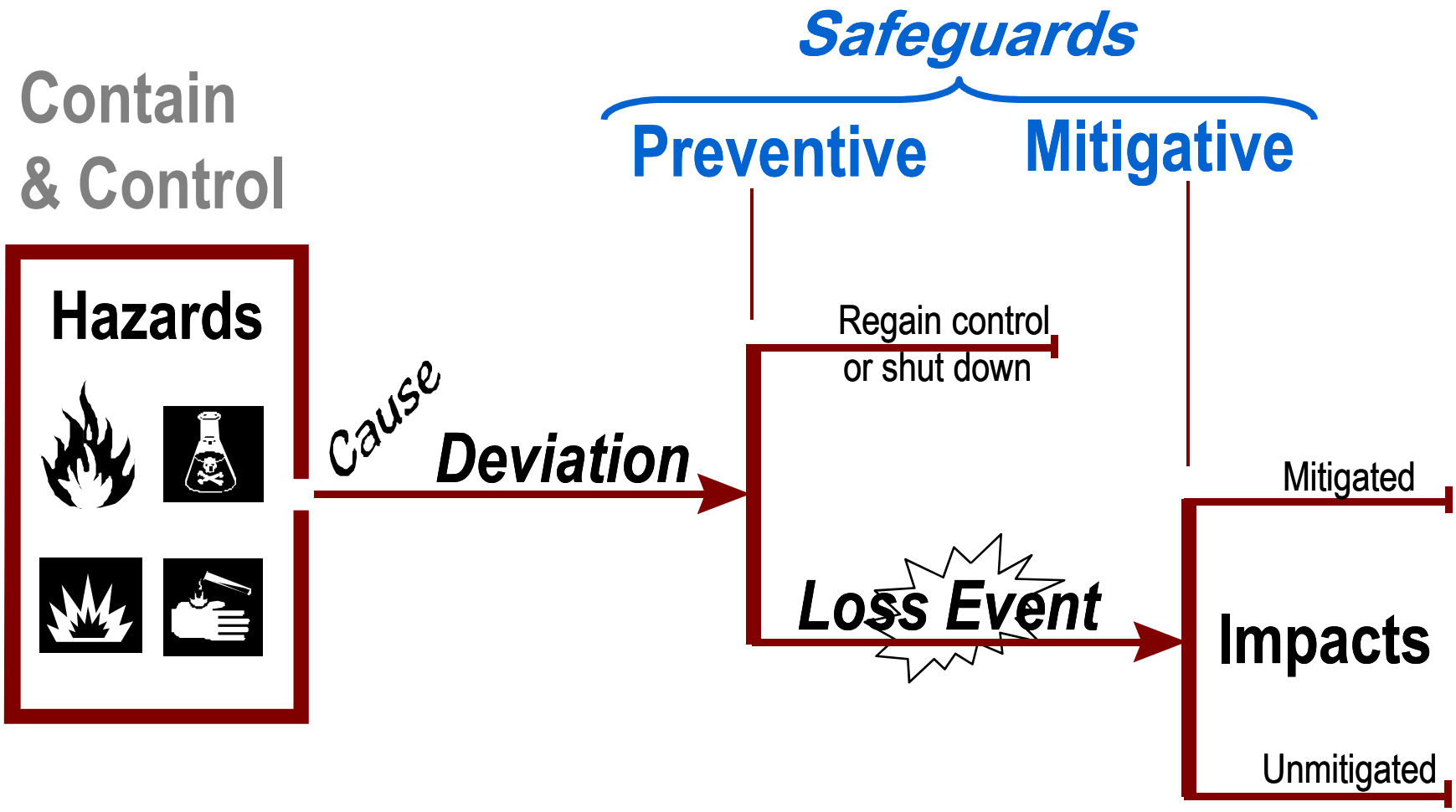
Safeguards: After Initiating Cause



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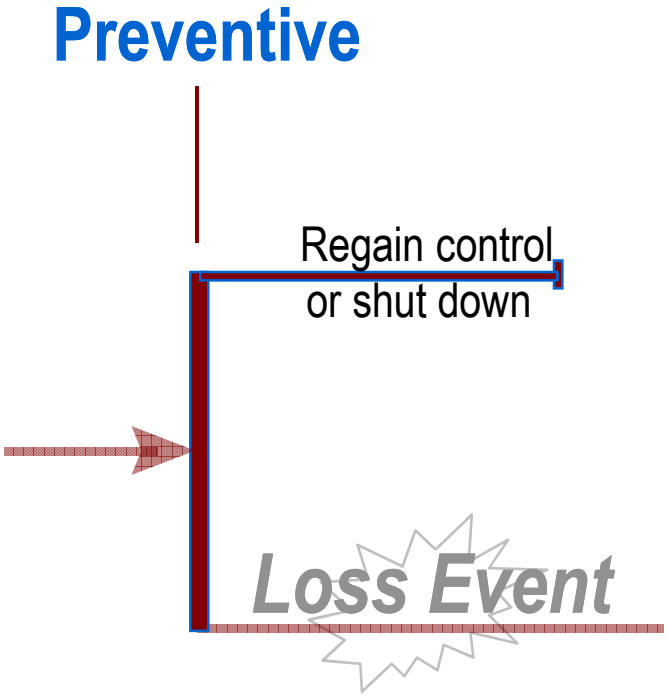
Preventive Safeguards



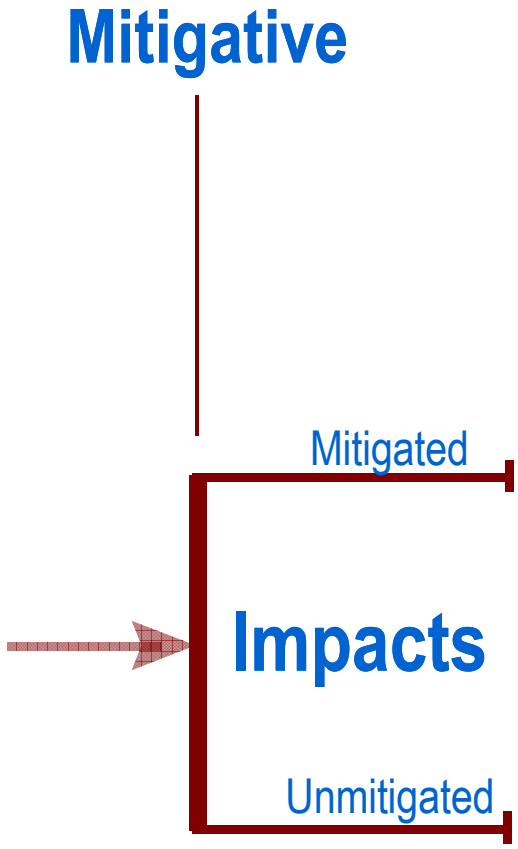
Operational Mode: **Abnormal operation**

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



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

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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
7. **Elements of process safety management**

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PSM Elements Addressed in Our Industry 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

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