



Chemical
SAFETY AND SECURITY TRAINING

Hazard and Risk Analysis



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Key acronyms

PHA = *process hazard analysis*

HAZOP = *hazard and operability [study]*

FMEA = *failure modes & effects analysis*

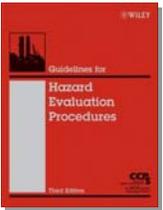


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Hazard and risk analysis resources

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



Chapter 4 • Non-Scenario-Based Hazard Evaluation Procedures

- 4.1 Preliminary Hazard Analysis
- 4.2 Safety Review
- 4.3 Relative Ranking
- 4.4 Checklist Analysis

Chapter 5 • Scenario-Based Hazard Evaluation Procedures

- 5.1 What-If Analysis
- 5.2 What-If/Checklist Analysis
- 5.3 Hazard and Operability Studies
- 5.4 Failure Modes and Effects Analysis
- 5.5 Fault Tree Analysis
- 5.6 Event Tree Analysis
- 5.7 Cause-Consequence Analysis and Bow-Tie Analysis
- 5.8 Other Techniques





Hazard and risk analysis resources

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



Chapter 10 • Hazards Identification
Chapter 11 • Risk Assessment



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Hazard and risk analysis resources

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



Chapter 9 • Hazard Identification and Risk Analysis

- 9.1 Element Overview
- 9.2 Key Principles and Essential Features
- 9.3 Possible Work Activities
- 9.4 Examples of Ways to Improve Effectiveness
- 9.5 Element Metrics
- 9.6 Management Review

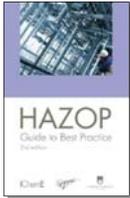



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Hazard and risk analysis resources

B. Tyler, F. Crawley and M. Preston 2008.
HAZOP: Guide to Best Practice, 2nd Edition,
Institution of Chemical Engineers, Rugby, UK.



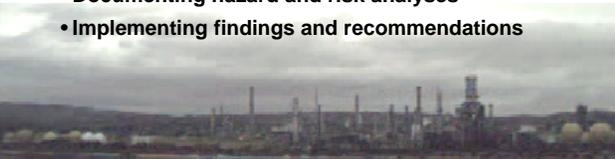


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Hazard and Risk Analysis

- Basic risk concepts
- Experience-based vs predictive approaches
- Qualitative methods (What-If, HAZOP, FMEA)
- Analysis of procedure-based operations
- Team meeting logistics
- Documenting hazard and risk analyses
- Implementing findings and recommendations




Hazard and Risk Analysis

- Basic risk concepts

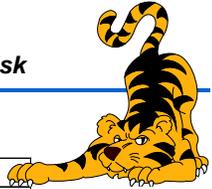


Hazard vs Risk

Fundamental definitions:

HAZARD
Presence of a material or condition that has the potential for causing loss or harm

RISK
A combination of the severity of consequences and the likelihood of occurrence of undesired outcomes



Source: R.W. Johnson, "Risk Management by Risk Magnitudes," *Chemical Health & Safety* 5(5), 1998

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RISK

Constituents of risk:

- Likelihood and
- Severity

of Loss Events

Risk = f (Likelihood, Severity)

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RISK

General form of risk equation:

Risk = Likelihood · Severityⁿ

Most common form:

Risk = Likelihood · Severity

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RISK

Example units of measure:

Risk = Likelihood · Severity

$$\frac{\text{injuries}}{\text{year}} = \frac{\text{loss events}}{\text{year}} \times \frac{\text{injuries}}{\text{loss event}}$$

$$\frac{\$ \text{ loss}}{\text{year}} = \frac{\text{loss events}}{\text{year}} \times \frac{\$ \text{ loss}}{\text{loss event}}$$

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Costs vs Risks

Another way of understanding risk is to compare risks with costs:

Costs	Risks
Near certain; expected	Uncertain; unexpected; probabilistic
Cost estimates are usually available	Risk estimates are usually not available
Higher-precision estimates	Lower-precision estimates, if available
Predictable benefits if cost incurred	Negative consequences if outcome realized
Incurred every year over life of project	Liability incurred only if outcome realized

Source: R.W. Johnson, "Risk Management by Risk Magnitudes," *Chemical Health & Safety* 5(5), 1998




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Costs + Risks

- **Costs** are certain, or expected, liabilities
 e.g., 30,000 km/year, 10 km/L, \$1.00/L = \$3,000/year
- **Risks** are uncertain liabilities
 e.g., \$10,000 collision, 1/20 year = \$500/year
- **Costs + Risks = Total Liabilities**
 \$3,000/year + \$500/year = \$3,500/year




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What Is a "Process Hazard Analysis"?

A **Process Hazard Analysis** **PHA** is a structured team review of an operation involving hazardous materials/energies, to

- identify previously unrecognized hazards,
- identify opportunities to make the operation inherently safer,
- identify loss event scenarios,
- evaluate the scenario risks to identify where existing safeguards may not be adequate, and
- document team findings and recommendations.




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} *Already addressed*




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} *Focus of this module*




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Hazard and Risk Analysis

- Basic risk concepts
- **Experience-based vs predictive approaches**





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Experience-based approaches

- Some PHA methods determine the adequacy of safeguards without assessing scenario risks
- This is done on the basis of collective past experience
- Compare process with recognized and generally accepted good engineering practices (RAGAGEPs)




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Experience-based approaches

- Effective way to take advantage of past experience
- Concentrates on protecting against events expected during lifetime of facility
- Low-probability, high-consequence events not analyzed
- Not good for complex or unique processes




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Experience-based approaches

Example experience-based approaches:

- Safety Review
- Checklist Analysis




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Experience-based approaches

Example experience-based approaches:

- Safety Review
- Checklist Analysis

Code/Standard/Reg.

1.1 The owner/operator shall ...

1.2 The owner/operator shall ...

1.3 The owner/operator shall ...

→

Checklist

Item 1

Item 2

Item 3

Item 4

...




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Experience-based approaches

Example experience-based approaches:

- Safety Review
- Checklist Analysis
 - Code/standard/regulatory requirements checklist
 - See Crowl and Louvar 2001, pages 433-436, for a checklist of process safety topics




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Predictive studies

- Supplement adherence to good practice
- Qualitative to quantitative
- Able to study adequacy of safeguards against low probability / high severity scenarios
- All predictive studies are **scenario-based approaches**




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Scenario - definition

Scenario:

An unplanned event or incident sequence that results in a loss event and its associated impacts, including the success or failure of safeguards involved in the incident sequence.

- CCPS 2008a



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Scenario necessary ingredients:

- Initiating cause
- AND
- Loss event or safe outcome



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Scenario necessary ingredients:

- Initiating cause
 - AND
 - Loss event or safe outcome
- } "Cause - consequence pair"



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Example of a simple scenario

While unloading a tankcar into a caustic storage tank, the tank high level alarm sounded due to the person unloading not paying close attention to the operation.

The operator noticed and responded to the alarm right away, stopping the unloading operation. Normal production was then resumed.

- What is the *initiating cause*?
- What is the *consequence*?



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Example of a more complex scenario

A reactor feed line ruptures and spills a flammable feed liquid into a diked area, where it ignites. A fire detection system initiates an automatic fire suppression system, putting the fire out.

The loss of flow to the reactor causes the temperature and pressure in the reactor to rise. The operator does not notice the temperature increase until the relief valve discharges to the relief header and stack. At that point, the emergency shutdown system is activated and the plant is brought to a safe state.





Predictive studies

Objective of scenario-based approaches:

- Identify and analyze all failure scenarios
 - Not generally possible just by inspection
 - Systematic approach needed
 - In reality, many scenarios eliminated by common sense and experience
 - Negligible likelihood (WARNING: Truly negligible?)
 - Unimportant consequence





Predictive studies

Some scenario-based approaches:

- What-If Analysis
- What-If/Checklist Analysis
- Hazard and Operability (HAZOP) Study
- Failure Modes and Effects Analysis (FMEA)
- Fault Tree Analysis (FTA)
- Event Tree Analysis (ETA)





Hazard and Risk Analysis

- Basic risk concepts
- Experience-based vs predictive approaches
- **Qualitative methods (What-If, HAZOP, FMEA)**





What-If Analysis

What If...?




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What-If Analysis

Concept: Conduct thorough, systematic examination by asking questions that begin with “What if...”

- Usually conducted by a relatively small team (3-5)
- Process divided up into “segments” (e.g., unit operations)
- Review from input to output of process
- Question formulation left up to the team members




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What-If Analysis

- Question usually suggests an **initiating cause**.
“What if the raw material is in the wrong concentration?”
- If so, postulated response develops a **scenario**.
“If the concentration of oxidant was doubled, the reaction could not be controlled and a rapid exotherm would result...”




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What-If Analysis

Answering each “What if ...” question:

- 1** Describe potential consequences and impacts
- 2** If a consequence of concern, assess cause likelihood
- 3** Identify and evaluate intervening safeguards
- 4** Determine adequacy of safeguards
- 5** Develop findings and recommendations (as required)
- 6** Raise new questions

Move to next segment when no more questions are raised.




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Adequacy of safeguards

- Determining the adequacy of safeguards is done on a scenario-by-scenario basis
- **Scenario risk** is a function of:
 - Initiating cause frequency
 - Loss event impact
 - Safeguards effectiveness
- If the **scenario risk** is found to be too high, safeguards are considered inadequate
 - Qualitative judgment
 - Risk matrix
 - Risk magnitude

See SVA Overview for matrix and magnitude approaches.




Safeguards

Evaluating the effectiveness of safeguards must take into account:

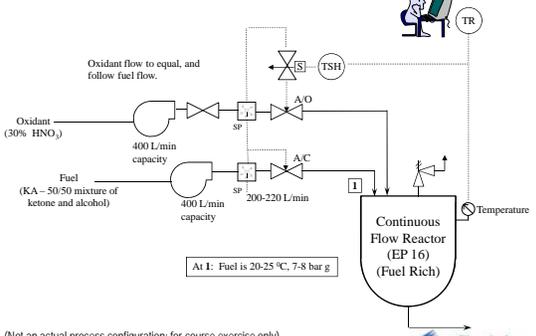
- **Fast enough?**
- **Effective for this scenario?**
- **Independent?**
- **Reliable enough?**



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Example: Continuous process

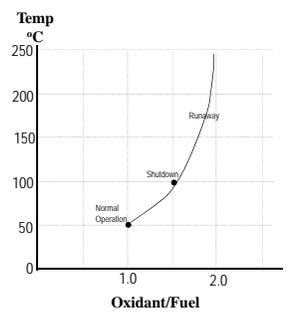


(Not an actual process configuration; for course exercise only)




Example: Continuous process (continued)

EP 16 produces adipic acid by an exothermic (heat-releasing) reaction of an oxidant (30% nitric acid) and a fuel (mixture of ketone and alcohol). An oxidant-to-fuel ratio greater than 2.0 in the reactor causes the reaction to run away (rapid temperature and pressure build-up). The high temperature shutdown system is intended to protect the reactor by stopping the oxidant flow if the reactor temperature reaches 100 °C. NOTE: RELIEF VALVE CANNOT CONTROL RUNAWAY REACTION.



Oxidant/Fuel Ratio	Temperature (°C)	State
1.0	~50	Normal Operation
1.0	100	Shutdown
2.0	~250	Runaway

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HAZOP sequence

- Establish review scope
- Identify study “nodes”
- Establish Node 1 design/operation intent
- Identify Deviation 1 from Node 1 intent
- Identify causes, loss events, safeguards
- Decide whether action is warranted
- Repeat for every node and deviation


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Study nodes

A **node** is a specific point in a process or procedure where deviations are studied.

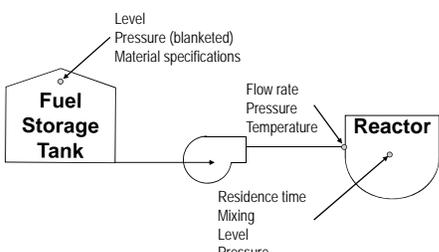
Typical study nodes:

- Process vessel
 - Strictly: Wherever a process parameter changes
 - At end of line (vessel interface)
 - Line may include pump, valves, filter, etc.
- Transfer line
- Procedural step


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Study nodes




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Design/operational INTENT

The **intent** describes the design/operational parameters defining normal operation.

- Functions
- Limits
- Compositions
- Procedural steps

It answers one of these questions:

“What is this part of the process designed to do?”

“What is supposed to be done at this point in time?”


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Design/operational intent

A complete design/operational intent includes:

- Equipment used
- All functions or operations intended to be achieved in this part of the process
- All intended locations/destinations
- Quantitative limits for all pertinent process parameters
- Intended stream composition limits





Design/operational intent

Example:

The intent of a reaction vessel might be to

Contain and control the complete reaction of 1000 kg of 30% A and 750 kg of 98% B in EP-7 by providing mixing and external cooling to maintain 470-500 °C for 2 hours, while venting off-gases to maintain < 1 bar g pressure.





Typical design intents

Storage tank

- Contain between 40 and 300 cubic meters of 50% caustic at atmospheric pressure and ambient temperature.

Transfer line

- Transfer 40 to 45 L/min of [pure] acetone from drum to mixer at room temperature.





Rotary kiln incinerator design intent

Contain and control the thermal incineration of incoming wastes to allow achievement of at least 99.9% destruction/removal of organics

- 4.76 Tons/hour
- 33.3 to 66.6 GJ/h heat load
- 1000-1400 C upstream of 2nd air injection point
- At least 2 seconds residence time for gases
- Oxygen at 9-13% at the downstream end of combustion zone
- Slight negative pressure (-100 Pa gage upstream 2nd air inject)
- Kiln rotation 0.05 - 0.5 rpm
- Loads up to 15% Cl₂, 3% S, 50% H₂O, 30% inerts




HAZOP Guide Words

Guide Words are applied to the design intent to systematically identify deviations from normal operation.

- NONE
- MORE OF
- LESS OF
- PART OF
- AS WELL AS
- REVERSE
- OTHER THAN

Guide Words

→

INTENT

HAZOP Guide Words

<u>Guide Word</u>	<u>Meaning</u>
NONE	Negation of intent
MORE OF	Exceed intended upper limit
LESS OF	Drop below intended lower limit
PART OF	Achieve part of intent
AS WELL AS	Something in addition to intent
REVERSE	Logical opposite of intent occurs
OTHER THAN	Something different from intent

Deviations from Intent

- Do not begin developing deviations until intent is fully described, documented and agreed upon
- List of deviations can be started as soon as intent is established

Guide Words

→

INTENT

↓

Deviation

Deviations

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

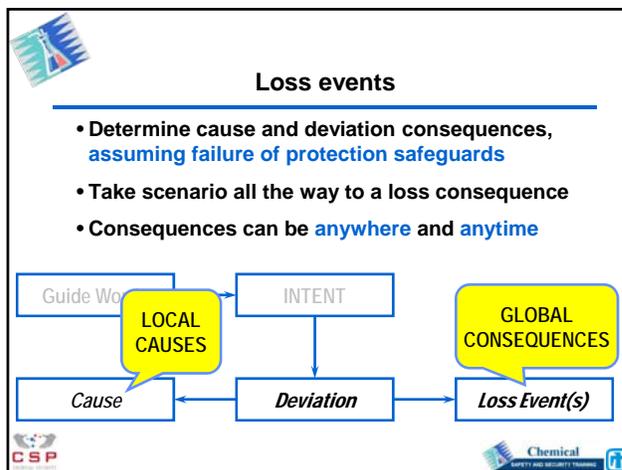
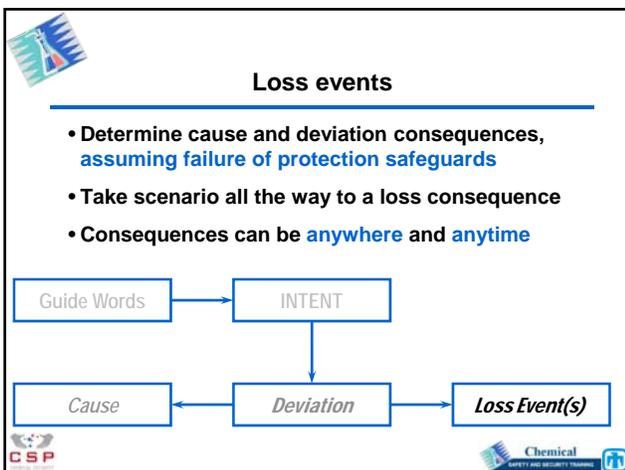
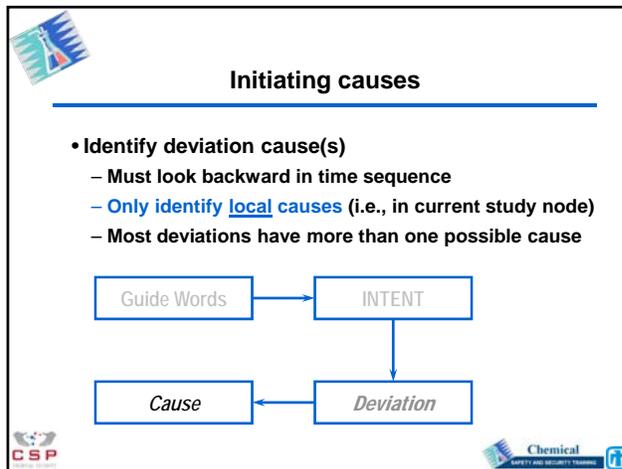
Hazards

Cause

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.

HAZOP Deviations Guide			
Design Intent	NO/NONE	MORE OF	LESS OF
<p><i>Apply each guide word to intent.</i></p> <p>A complete design intent for each line/vessel/node includes:</p> <ul style="list-style-type: none"> All functions and locations Controlled variables: SOCs Expected compositions Equipment used <p>E.g., the intent of a reaction step might be to "Contain and control the complete reaction of 1000 kg of 30% A and 750 kg of 98% B in EP-7 by providing mixing and external cooling to maintain 470-500 °C for 2 hours, while venting off-gases to maintain < 1 bar g"</p>	Containment lost Procedure step skipped No [function] No transfer No agitation No reaction	Procedure started too late Procedure done too long Too much [function] Too much transferred Too much agitation High [controlled variable] High reaction rate High flow rate High pressure High temperature	Procedure started too soon Procedure stopped too soon Not enough [function] Not enough transferred Not enough agitation Low [controlled variable] Low reaction rate Low flow rate Low pressure Low temperature
PART OF	AS WELL AS	REVERSE	OTHER THAN
Part of procedure step skipped Part of [function] achieved Part of [composition] Component missing Phase missing Catalyst deactivated	Extra step performed Extra [function] Transfer from more than one source Transfer to more than one destination Extra [composition] Extra phase present Impurities; dilution	Steps done in wrong order Reverse [function] Reverse flow Reverse mixing	Wrong procedure performed Wrong [function] achieved Transfer from wrong source Transfer to wrong destination Maintenance/test/sampling at wrong time/location





FMEA

- Originally developed for aerospace/military systems
- Good for systems with little human interaction
- Focus is primarily on independent equipment failures and their effects on the larger system




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FMEA level of resolution

Level of resolution determines detail in FMEA table:

- Subsystem level
- **Equipment (component) level**
- Component parts




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Equipment failure modes

EXAMPLE OF EQUIPMENT FAILURE MODES FOR FMEA

Equipment Description	Failure Modes
Pump, normally operating	a. Fails on (fails to stop when required) b. Transfers off c. Seal rupture/leak d. Pump casing rupture/leak
Heat exchanger, high pressure on tube side	a. Leak/rupture, tube side to shell side b. Leak/rupture, shell side to external environment c. Tube side, plugged d. Shell side, plugged




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DISCUSSION

What are some common failure modes for the following components?

- Safety relief valve
- Check valve
- Float switch
- Agitator

Which of the failure modes are *revealed* and which are *latent*?




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Hazard and Risk Analysis

- Basic risk concepts
- Experience-based vs predictive approaches
- Qualitative methods (What-If, HAZOP, FMEA)
- **Analysis of procedure-based operations**




Procedure-based operations

- Batch processes
- Continuous processes:
 - Start-up
 - Shutdown
 - Production changes
- Receipt and unloading of chemicals
- Loading of product
- Sampling
- Maintenance





Why analyze procedure-based operations?

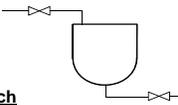
- Typical petrochemical facility time distribution:
< 10% of the time in “abnormal operations”
- IChemE analysis of 500 process safety incidents:
53% of the incidents occurred during “abnormal operations” (startup, shutdown, responding to avoid a shutdown)

References:
 S.W. Ostrowski and K.Keim, “A HAZOP Methodology for Transient Operations,” presented at Mary Kay O'Connor Process Safety Center International Symposium, October 2008
 I.M. Duguid, “Analysis of Past Incidents in the Oil, Chemical and Petrochemical Industries,” IChemE *Loss Prevention Bulletin* 144, 1999





Batch vs continuous processes



<u>Batch</u>	<u>Continuous</u>
• Transient process parameters	• Steady-state process parameters
• Many operations are time-dependent	• Operations do not generally have time-dependencies
• Manual operations / control common	• Process control is usually automatic
• Only part of system in use at any time	• Entire system almost always in use






PHA of continuous operations

- Address continuous flows from input to output
- Address startup, shutdown and transient steps as procedure-based operations




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PHA of procedure-based operations

Procedures usually follow these general steps:

1. Prepare vessel
2. Charge vessel
3. Reaction with monitor/control
4. Discharge
5. Purge

Which step is most like a continuous operation?




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PHA of procedure-based operations

Suggested approach:

- Select study nodes as for continuous process
- Group procedures by nodes
- Conduct procedure-based PHA
- When procedure completed, do equipment-based PHA as for a continuous process




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PHA of procedure-based operations

- PHA of procedure-based operation follows order of procedural steps
- All rules of continuous HAZOP Study apply
 - Local causes
 - Global consequences
 - All safeguards pertinent to cause-consequence pairs
- Consequence and safeguards considered at each succeeding step, until consequence occurs




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Three approaches

- **What-If Analysis** of each operating step
- **Two-Guide-Word Analysis**
 - OMIT (all or part of the step is not done)
 - INCORRECT (step is performed wrong)
 - Operator does too much or too little of stated task
 - Wrong valve is closed
 - Order of steps is reversed
 - Etc.
- **HAZOP Study** of each step or group of steps
 - All seven guide words used
 - Extra guide word of "MISSING" sometimes used




DISCUSSION

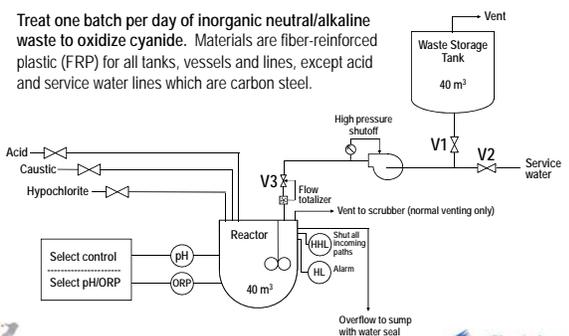
Give one or two examples of a deviation from a procedural step for each HAZOP guide word.

NONE	
MORE OF	
LESS OF	
PART OF	
AS WELL AS	
REVERSE	
OTHER THAN	




Example batch process

Treat one batch per day of inorganic neutral/alkaline waste to oxidize cyanide. Materials are fiber-reinforced plastic (FRP) for all tanks, vessels and lines, except acid and service water lines which are carbon steel.





Example batch process

Procedure:

1. Charge reactor with 5.3 m³ of cyanide waste.
2. Add 24.8 m³ service water to dilute waste to 0.3% (initially at 1.7%).
3. Add caustic (NaOH) on pH control to bring pH to 11.5.
4. Add sodium hypochlorite (NaOCl) on ORP control.
5. React with agitation for 6 hours; caustic and NaOCl to remain on auto-addition to maintain pH and ORP.
6. Send sample of reactor contents to lab to test for cyanide oxidation.
7. If lab approves, continue.
8. Add sulfuric acid (93%) on pH control to bring pH to 2.5.

Potential consequences:

- Concentration > 0.3% releases HCN during oxidation.
- Addition of acid before oxidation is complete releases all available CN⁻ as HCN.
- Excess NaOCl releases chlorine gas when acid is added.






Hazard and Risk Analysis

- Basic risk concepts
- Experience-based vs predictive approaches
- Qualitative methods (What-If, HAZOP, FMEA)
- Analysis of procedure-based operations
- **Team meeting logistics**






Team meeting logistics

The following are common to all PHA team reviews:

- **Team composition**
- **Preparation**
- **First team review meeting**
- **Final team review meeting**





PHA team composition

5 to 7 team members optimum

- **Team leader (facilitator)** – hazard analysis expertise
- **Scribe** – responsible for PHA documentation
- **Key members** – should have process/engineering expertise, operating and maintenance experience
- **Supporting members** – instruments, electrical, mechanical, explosion hazards, etc.





PHA preparation

At initial scheduling of review and designation as team leader:

- **Become familiar with the plant's PSM procedures**
- **Determine exact scope of PHA**
- **With PSM Coordinator, select one or more PHA methods that are appropriate to the complexity of the process**
(Different techniques can be used for different parts of the process)






PHA preparation

~ 6 weeks before start date of team review:

- t Compile process safety information for process to be studied
- t Obtain procedures for all modes of operation
- t Gather other pertinent information
- t Determine missing or out-of-date information
- t Make action plan for updating or developing missing information prior to the start of the team reviews




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PHA preparation

~ 4 weeks before expected start date:

- t Confirm final selection of review team members
- t Give copy of PHA Procedures to scribe; emphasize the necessity for thorough documentation
- t Estimate the number of review-hours needed to complete PHA team review, or check previous estimate
- t Establish an initial schedule of review sessions, coordinated with shift schedules of team members




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PHA timing

Plan PHA team review in half-day sessions of 3 to 3½ hours duration.

- *Optimum:* 1 session/day, 4 sessions/week
- *Maximum:* 8 sessions/week

- Schedule sessions on a long-term plan
- Schedule at set time on set days
- PHA team reviews usually take one or two days to get started, then ~ ½ day per typical P&ID, unit operation or short procedure




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PHA preparation

~ 2 to 3 weeks before start date:

- t Obtain copies of all incident reports on file related to the process or the highly hazardous materials in the process
- t Reserve meeting room
- t Arrange for computer hardware and software to be used, if any
- t Divide up process into study nodes or segments
- t Develop initial design intent for each study node, with the assistance of other review team members as needed




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PHA preparation

During the week before the start date:

- t **Select and notify one person to give process overview**
- t **Arrange for walk-around of facility, including any necessary training and PPE**
- t **Secure projector and spare bulb**
- t **Arrange for refreshments and lunches**




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PHA preparation

Immediately before each meeting:

- t **Check out meeting room and facilities, including heating/air conditioning**
- t **Set up computer and projection equipment**
- t **Lay out or tape up P&IDs and plant layout diagrams**




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First team review meeting

1 Attendance

- Go over emergency exits, alarms and evacuation procedures
- Introduce team members and their background / area of expertise
- Ensure all required team members are present
- Document attendance for each half-day session
- Emphasize need for punctuality and minimal interruptions




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First team review meeting

2 Scope and objectives

- Go over exact boundaries of system to be studied
- Explain purpose for conducting the PHA




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First team review meeting

3 Methodology

- Familiarize team members with methodology to be used
- Explain why selected methodology is appropriate for reviewing this particular process




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First team review meeting

4 Process safety information

- Review what chemical, process, equipment and procedural information is available to the team
- Ensure all required information is available before proceeding




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First team review meeting

5 Process overview

- Prearrange for someone to give brief process overview, covering such details as:
 - Process, controls
 - Equipment, buildings
 - Personnel, shift schedules
 - Hazardous materials, process chemistry
 - Safety systems, emergency equipment
 - Procedures
 - What is in general vicinity of process
- Have plant layout drawings available




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First team review meeting

6 Unit tour

- Prearrange for tour through entire facility to be included in team review
- Follow all safety procedures and PPE requirements
- Have team members look for items such as:
 - General plant condition
 - Possible previously unrecognized hazards
 - Human factors (valves, labeling, etc.)
 - Traffic and pedestrian patterns
 - Activities on operator rounds (gauges, etc.)
 - Emergency egress routes




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First team review meeting

7 Review previous incidents

- Review all incident and near-miss reports on file for the process being studied
- Also review sister-plant and industry-wide incidents for the type of process being studied
- Identify which incidents had potential for catastrophic on-site or off-site / environmental consequences
- Make sure detailed assessment (e.g., HAZOP Study) covers all previous significant incidents




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First team review meeting

8 Review facility siting

- Discuss issues related to whether buildings intended for occupancy are designed and arranged such that people are adequately protected against major incidents
- Various approaches are possible:
 - API Recommended Practices 752, 753
 - Topical review (e.g., CCPS 2008a page 291)
 - Checklist review (e.g., Appendix F of W.L. Frank and D.K. Whittle, *Revalidating Process Hazard Analyses*, NY: American Institute of Chemical Engineers, 2001)




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First team review meeting

9 Review human factors

- Discuss issues related to designing equipment, operations and work environments so they match human capabilities, limitations and needs
- Human factors are associated with:
 - Initiating causes (e.g., operational errors causing process upsets)
 - Preventive safeguards (e.g., operator response to deviations)
 - Mitigative safeguards (e.g., emergency response actions)




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First team review meeting

9 Review human factors (continued)

- Various approaches are possible:
 - Ergonomic studies
 - Topical review of positive and negative human factors (e.g., CCPS 2008a pages 277-279)
 - Checklist review (e.g., Appendix G of W.L. Frank and D.K. Whittle, *Revalidating Process Hazard Analyses*, NY: American Institute of Chemical Engineers, 2001)




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First team review meeting

10 Identify and document process hazards

- See earlier module on Hazards and Potential Consequences
- Also an opportunity to address inherent safety issues




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Final team review meeting

To do during the final team review meeting:

- Ensure entire scope of review has been covered
- Read through all findings and recommendations to
 - Ensure each finding and recommendation is understandable to those needing to review and implement them
 - Consolidate similar findings
- Ensure all previous significant incidents have been addressed in the PHA scenarios

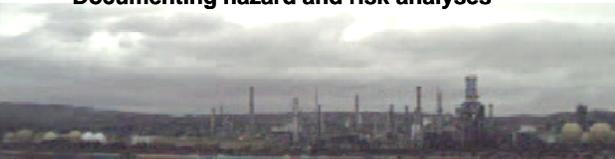



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Hazard and Risk Analysis

- Basic risk concepts
- Experience-based vs predictive approaches
- Qualitative methods (What-If, HAZOP, FMEA)
- Analysis of procedure-based operations
- Team meeting logistics
- **Documenting hazard and risk analyses**





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PHA report

Goal: Record the results such that study is understandable, can be easily updated, and supports the team's decisions.

- System studied
- What was done
- By whom
- When
- Findings and recommendations
- PHA worksheets
- Information upon which the PHA was based




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Report disposition

- Draft report
 - prepared by scribe
 - reviewed by all team members
 - presented to management, preferably in a face-to-face meeting
- Management input considered by review team
- Final report
 - prepared by scribe
 - reviewed by all team members
 - accepted by management
 - kept in permanent PHA file

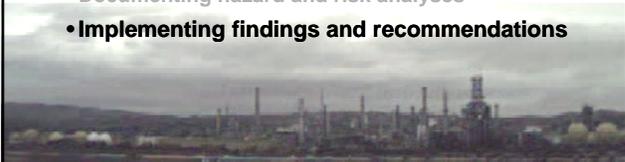



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Hazard and Risk Analysis

- Basic risk concepts
- Experience-based vs predictive approaches
- Qualitative methods (What-If, HAZOP, FMEA)
- Analysis of procedure-based operations
- Team meeting logistics
- Documenting hazard and risk analyses
- **Implementing findings and recommendations**






Implementing findings & recommendations

What is the most important product of a PHA?

1. The PHA report
2. A deeper understanding gained of the system
3. Findings and recommendations from the study




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Implementing findings & recommendations

What is the most important product of a PHA?

1. The PHA report
2. A deeper understanding gained of the system
3. Findings and recommendations from the study
4. **The actions taken in response to the findings and recommendations from the study**




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Implementing findings & recommendations

- Findings and recommendations are developed throughout team review
 - Analysis of hazards; inherent safety options
 - Facility siting review
 - Human factors review
 - HAZOP, What-If, etc.
- **Basis** for determining whether finding or recommendation is warranted:
 - CHECKLIST REVIEW: Code/standard is violated
 - PREDICTIVE ANALYSIS: Scenario risk is too high (also if code/standard is violated)




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Implementing findings & recommendations

Wording of findings and recommendations:

- Be as general as possible in wording of finding, to allow flexibility in how item is resolved

Install reverse flow protection in Line 112-9 to prevent backflow of raw material to storage	instead of	Install a Cagey Model 21R swing check valve in the inlet flange connection to the reactor
--	------------	---

- Describing the concern as part of the finding will help ensure the actual concern is addressed
- Use of words such as these warrants follow-up to ensure the team's concern was actually addressed:
 - CONSIDER... – INVESTIGATE...
 - STUDY... – _____...




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PHA risk-control actions

Example risk-control actions:

- Alter physical design or basic process control system
- Add new layer of protection or improve existing layers
- Change operating method
- Change process conditions
- Change process materials
- Modify inspection/test/maintenance frequency or method
- Reduce likely number of people and/or value of property exposed




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PHA action item implementation

The employer shall establish a system to promptly address the team's findings and recommendations; assure that the recommendations are resolved in a timely manner and that the resolution is documented; document what actions are to be taken; complete actions as soon as possible; develop a written schedule of when these actions are to be completed; communicate the actions to operating, maintenance and other employees whose work assignments are in the process and who may be affected by the recommendations or actions.

- OSHA PSM Standard, 29 CFR 1910.119(e)(5) and U.S. EPA RMP Rule, 40 CFR 68.67(e)




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1 - Document findings & recommendations

Example form:

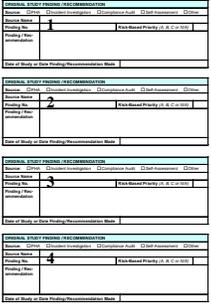
ORIGINAL STUDY FINDING / RECOMMENDATION	
Source: <input type="checkbox"/> PHA <input type="checkbox"/> Incident Investigation <input type="checkbox"/> Compliance Audit <input type="checkbox"/> Self-Assessment <input type="checkbox"/> Other	
Source Name	
Finding No.	Risk-Based Priority (A, B, C or N/A)
Finding / Recommendation	
Date of Study or Date Finding/Recommendation Made	

Note that this can also be used for incident investigation and compliance audit findings.

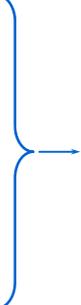



2 - Present findings & recommendations

PHA team



Line management

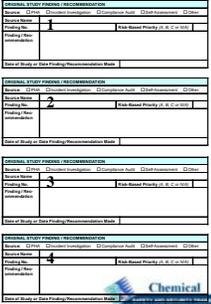





2 - Present findings & recommendations

PHA team

Line management






3 - Line management response

For each PHA team finding/recommendation:

ACTION COMMITTED TO BY MANAGEMENT	
Specific Action To Be Taken	
To Be Completed By	[date] <i>Time extension requires management approval</i>
Responsible Person	[person or position]

Suggestions:

- Use database or spreadsheet
- Flag imminent and overdue actions
- Periodically report overall status to top management




Example

ORIGINAL STUDY FINDING / RECOMMENDATION	
Source:	<input checked="" type="checkbox"/> PHA <input type="checkbox"/> Incident Investigation <input type="checkbox"/> Compliance Audit <input type="checkbox"/> Self-Assessment <input type="checkbox"/> Other
Source Name	Formaldehyde Unloading PHA
Finding No.	PHA-UF-11-01 Risk-Based Priority (A, B, C or N/A) B
Finding / Recommendation	<i>Safeguards against formaldehyde storage tank overfilling are considered to be inadequate due to the signals for the controlling level indication and the high level alarm both being taken off of the same level transmitter. Options for consideration: Take manual level reading before unloading into the tank to cross-check adequate capacity for unloading; add separate high level switch for the high level alarm.</i>
Date of Study or Date Finding/Recommendation Made	1 March 2011
ACTION COMMITTED TO BY MANAGEMENT	
Specific Action To Be Taken	The following steps are to be taken to adopt and implement finding PHA-UF-11-01: (1) Add a separate high level switch on the formaldehyde storage tank, using a different level measurement technology than the controlling level sensor. (2) Add the new level switch, in addition to the high level alarm, to the MI critical equipment list and schedule for regular functional testing. (3) Until the new level switch is installed, implement a temporary procedural change to take manual level readings before unloading into the tank to cross-check adequate capacity for unloading, ensuring proper PPE is specified and used for performing the manual level readings.
To Be Completed By	1 September 2011 <i>Time extension requires management approval</i>
Responsible Person	I. M. Engineer

4 - Document final resolution

Document how each action item was implemented.

FINAL RESOLUTION	
Resolution Details (attach drawings, procedures, etc.)	
Associated MOC(s)	
DATE COMPLETED	
Date Communicated	
How Communicated	<i>Attach documentation of the communication(s)</i>

Communication of actions

Communicate actions taken in response to PHA findings and recommendations.

TO WHOM?

- To operating, maintenance and other employees whose work assignments are in the process and who may be affected by the recommendations or actions

Communication of actions

HOW?

- **Train** through plant training program when needed
 - Use appropriate techniques
 - Verify understanding
- **Otherwise inform**, such as by
 - Safety meetings
 - Beginning-of-shift communications
 - E-mail
- **Document** communications



Communication of actions

WHAT?

- Physical changes
- Personnel or responsibility/accountability updates
- Operating/maintenance procedures
- Emergency procedures; Emergency Response Plan
- Safe work practice procedures
- Control limits or practices



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DISCUSSION

WHY?

What are two or more reasons why it is important to communicate PHA action items to affected employees?

-
-
-
-



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Final word

The task of the PHA team is to identify where action is needed, not to redesign the system.



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