An In-Depth Exploration of PHAs for Auditors and Industry

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Session Tu-A1

Objectives

- Understand why PHAs/Hazard Reviews are critical for facilities with hazardous chemicals
- Become familiar with the various PHA methodologies
- Discuss common issues found with PHAs and how to identify and resolve them

Definition

- Process Hazard Analysis (CalARP Program 3 and Program 4) – systematic and thorough approach used to identify, evaluate, and manage the risks associated with hazardous processes in industrial operations

- Hazard Review (CalARP Program 2) – approach used to identify, evaluate, and manage the risks associated with hazardous processes in industrial operations

Why are PHAs important?

- Safeguarding People, Assets, and the Environment

TPC Group Port Neches, TX

- Began Operation in 1944
- Produced high-purity butadiene & other petrochemical products
- 175 employees & 50 Contractors

Link to CSB Video

- The Danger of Popcorn Polymer: Incident at the TPC Group Chemical Plant (youtube.com)

Regulatory Framework

- Program 2 (19 CCR § 2755.2)
- Program 3 (19 CCR § 2760.2)
- Program 4 (19 CCR § 2762.2)

Program 2 - "Hazard Review"

- Identification of:
  - Process hazards
  - Potential release scenarios
  - Safeguards already implemented
  - Detection methods
  - External events
  - **Unmitigated risk**
- Tracking completion of identified actions must be performed
  - Resolution must occur within 2.5 years OR turnaround, in alignment with CUPA
- Must be reviewed and updated every 5 years
- Documentation for life of process

Program 2 (cont.)

- Hazard Review team must include those familiar with the process, including one with experience and knowledge of process
- Hazard Review must confirm process design, construction, and operation is in accordance with applicable standards
- Revalidation may take place once before a full Hazard Review must be performed
  - Initial HR → Revalidation of HR → Redone HR

Program 3 - "Hazard Analysis"

- Identification of:
  - Process hazards
  - Admin and engineering controls
  - Qualitative evaluation of the effects of a failure of process controls (review of safeguards)
  - Human factors
  - External events
  - Facility siting
  - Identification of previous incidents
- Tracking completion of identified actions must be performed
  - Resolution must occur within 2.5 years OR turnaround, in alignment with CUPA
  - Documentation for life of process

Program 3 (cont.)

- Hazard Review team must include those with expertise in engineering and operation of the process
  - Must also include individual trained in the selected PHA methodology
- PHAs must be retained for life of process

Program 4 - "Hazard Analysis"

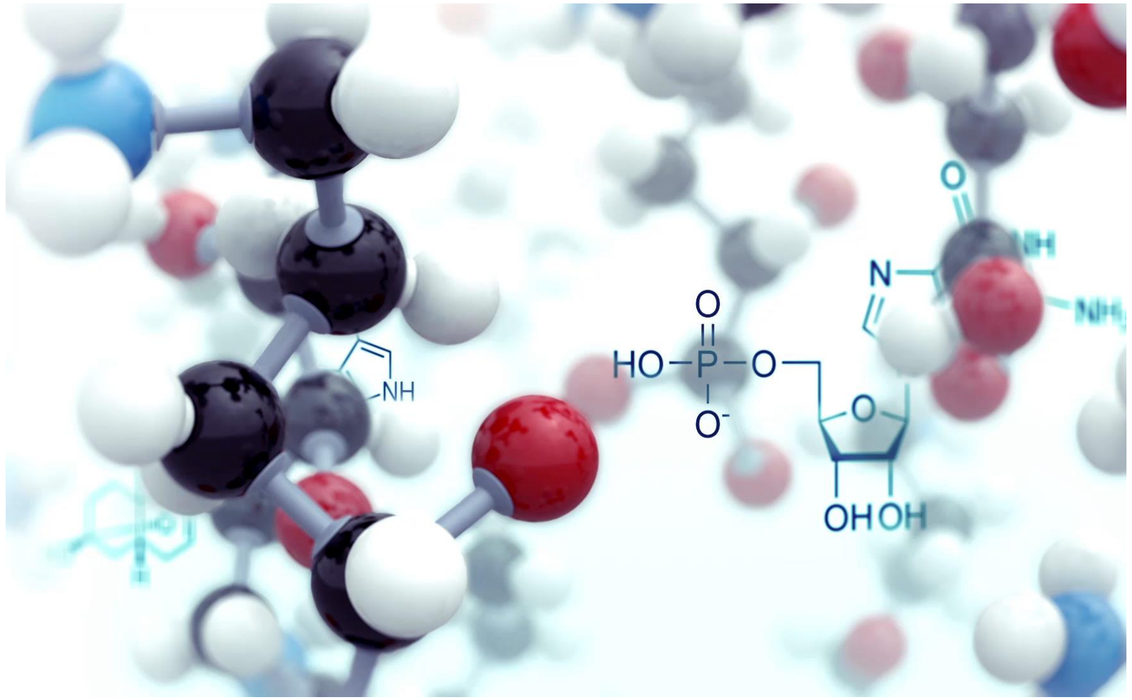
- Encompasses all requirements from Program 3, with key differences:
  - Specifies other PHA methodologies recognized by engineering organizations and governmental agencies (2762.2(a))
  - Clarifies language regarding consideration of publicly documented incidents within the petrochemical industry (2762.2(c)(2))
  - Requires review of damage mechanisms and hierarchy of hazard controls analysis (2762.2(c)(3)-(4))
- Tracking completion of identified actions must be performed
  - Resolution must occur within 2.5 years OR turnaround, in alignment with CUPA

Additional Regulation

- CalOSHA PSM
- EPA RMP
- Contra Costa County Industrial Safety Ordinance
  - Requires latent conditions to be identified as part of PHA
  - Human factors focus
  - Procedural PHAs
    - https://www.cchealth.org/health-and-safety-information/hazmat-programs/industrial-safety-ordinance/iso-guidance-document

Hazards

- Physical or chemical conditions that have potential for causing harm to people, property or the environment



Undesired event - human error or equipment failure that has the potential to lead to a consequence

E.g. Wrong valve turned, pigtail failure, compressor failure

Consequence – loss of control of hazard and resulting effects

Environment, Health and Safety, and Asset

Scenario – An undesired event or sequence of events associated with the realization of a hazard

Risk Assessment

- Risk formula:
  - Risk = Likelihood of Scenario + Severity of Consequence

Risk Ranking

Likelihood	Severity 1	2	3	4	5
5	C	D	E	E	F
4	B	D	D	E	E
3	A	B	D	D	E
2	A	A	B	D	D
1	A	A	A	B	C

*** accompanied by rubric**

Why PHA???

- Methodical approach to identifying the inherent risk in a process
- Tool used to identify gaps in process safeguards
- Improve process safety through recommendations

Why PHA???

Safeguards – controls that prevent a scenario from developing or mitigate the consequences of the scenario

Tolerable Risk – the amount of risk a facility is willing to accept

Recommendations – corrective actions developed by a hazard review team to reduce risk to a tolerable level

Documentation & Recommendations (P2)

- **Program 2**
  - **Results must be documented/maintained for life of process**
  - **Resolution of identified risk gaps**
    - **2.5 years or next planned turnaround**
    - **Document final resolution taken to address any recommendation and actual completion date**

Documentation & Recommendations (P3)

- **Program 3**
  - **Results must be documented/maintained for life of process**
    - **Includes documented resolution of recommendations**
  - **Establish system to:**
    - **Document recommendations**
    - **Develop written schedule to complete actions within 2.5 years or next scheduled turnaround**
    - **Document final resolution taken to address any recommendation and actual completion date**
    - **Communicate recommendations to operating/maintenance personnel who may be impacted by the changes**

Team Composition

- **Program 2**
  - **By a team familiar with process operations**
  - **At least one employee with experience specific to process**
- **Program 3**
  - **One employee with expertise and experience in each:**
    - **Engineering and process operations**
    - **the specific process**
    - **PHA methodology being used**

Management Commitment

- **Must be able and willing to assign adequate resources for the PHA**
  - **Experienced team**
  - **Sufficient time for analysis**
  - **Organized and accurate process safety information**
  - **Track record of taking results seriously**

PHA Methodologies

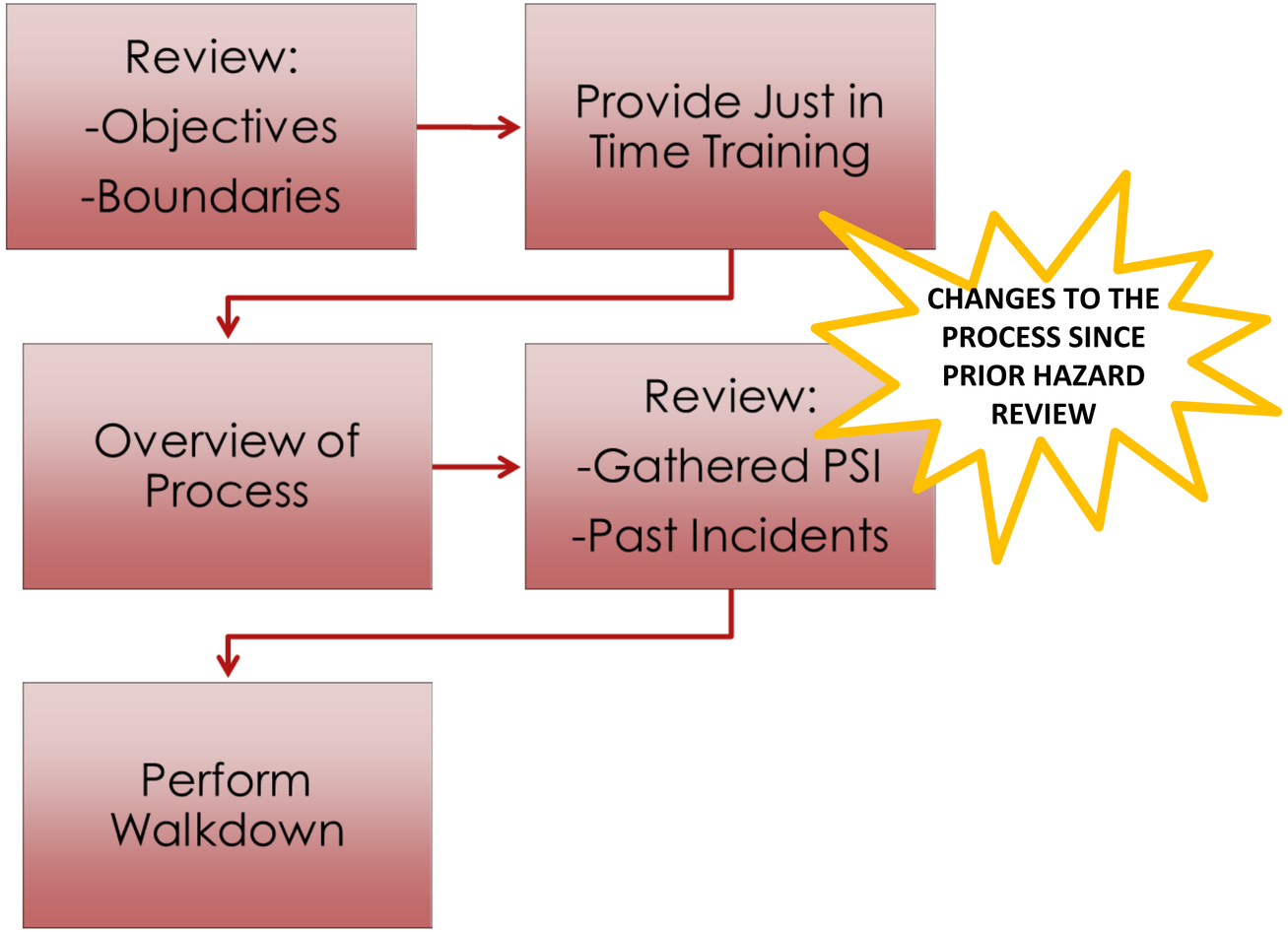
- **Program 2**
  1. **"What if?"**
  2. **Checklist**
  3. **"What if?"/Checklist**
  4. **Hazard and Operability Study (HAZOP)**
- **Program 3**
  1. **"What if?"**
  2. **Checklist**
  3. **"What-if?"/Checklist**
  4. **Hazard and Operability Study (HAZOP)**
  5. **Failure Mode and Effects Analysis (FMEA)**
  6. **Fault Tree Analysis**
  7. **An appropriate equivalent methodology**

Program 2 & 3 – Facility must consult with UPA to decide which methodology is most appropriate to the process

Preparation for Hazard Evaluation

- **Team composition**
  - **Experienced facilitator with the methodology selected**
  - **Varying levels and types of skills**
  - **On an as-needed basis include SMEs**
    - **Process Chemistry**
    - **Metallurgy and corrosion**
    - **Instrumentation**
- **Frontline personnel**
  - **Most accurate knowledge of day-to-day operation**
  - **Often highly motivated to identify and eliminate hazards**

Starting the Hazard Evaluation



“What if?” Analysis

- **Brainstorming approach**
- **Question-based**
- **What if the steam supply to the reactor is lost?**
- **Not inherently structured**
- **No ranking or quantitative calculation for the identified scenarios**

"What if?" Analysis

- **Resources**
  - **Small team**
  - **Chemical Data**
  - **P&IDs/PFDs**
  - **Procedures**
- **Conducting the Analysis**
  - **Generate questions**
  - **Identify:**
    - **Hazards**
    - **Consequences**
    - **Safeguards**
    - **Recommendations**

“What if?” Analysis

- **Advantages**
  - **Lack of structure allows for creative, out-of-the-box thinking**
  - **Low resource requirement**
- **Disadvantages**
  - **Very dependent of team experience**
  - **Hazards and scenarios can be easily overlooked**
  - **Analysis is limited to questions asked**

“What if?” Analysis

Area: Drawing Number			Meeting Date: February 5, 2024 Team Members:	
What If	**Hazard**	**Consequence**	**Safeguards**	**Recommendations**
What if the compressor fails?				
What if the pump seal leaks?				
What if utilities are lost?				

When to use a “What if?” Analysis

Facility Types

- **Chemical Storage**

Checklist Analysis

- **Resources**
  - Process Design
  - Operating Conditions
  - Instrumentation
  - Procedures
- **Conducting the Analysis**
  - Review of documentation
  - Personnel interviews
  - General observations
  - Summarize findings
    - Generate recommendations for non-tolerable risk level

Checklist Analysis

- **Advantages**
  - **Specific to the process**
  - **Low resource requirement**
- **Disadvantages**
  - **Effectiveness depends on author(s)**
  - **Structured approach can diminish creative thinking**
  - **Limited to known hazards**
  - **Not specific to the unique process conditions at a facility**

	Aqueous Ammonia	Yes	No	NA	Comments
	Are storage tank(s) painted white or other light reflecting colors and maintained in good order?				
	Is storage area free of readily ignitable materials?				
	Are storage tank(s) kept away from wells or other sources of potable water supply?				
	Are storage tank(s) located with ample working space all around?				
	Are storage tank(s) properly vented and away from areas where operators are likely to be?				
	Does receiving system include a vapor return?				
	Is storage capacity adequate to receive full volume of delivery vehicle?				
	Are storage tank(s) secured against overturn by wind, earthquake and/or flotation?				
	Are tank bottom(s) protected from external corrosion?				
).	Is aqua ammonia system protected from possible damage from moving vehicles?				
1.	Are storage tank(s) labeled as to content?				
2.	Are all appurtenances suitable for aqua ammonia service?				
3.	Are all storage tank(s) fitted with liquid level gauges?				
4.	Are liquid level gauge(s) adequately protected from				

When to use a Checklist Analysis

Facility Types

- **Chemical Storage**
- **Simple processes with well-defined industry standards and practices**
- **One process facilities**

“What if?”/Checklist Analysis

- **Hybrid of “What-if?” and Checklist methods**
  - **“What-if?” provides opportunity for creativity**
  - **Checklist provides structure**
  - **Checklist can cover gaps**

“What if?”/Checklist Analysis

- **Resources**
  - Process Design
  - P&IDs
  - Operating Conditions
  - Instrumentation
  - Procedures
- **Conducting the Analysis**
  - Review of Checklist
  - Identify
    - Hazards
    - Consequences
    - Safeguards
  - Summarize findings
    - Generate recommendations for non-tolerable risk level

“What if?”/Checklist Analysis

- **Advantages**
  - **Specific to the process**
  - **Low resource requirement**
- **Disadvantages**
  - **Effectiveness depends on author(s) & Team**

“What If?”/ Checklist Analysis

PART 3 PROCESSING VESSELS

What-If checklist

Feed

- What if vessel feed is increased?
- What if vessel feed is decreased?
- What if vessel feed is stopped?
- What if vessel feed temperature increases?
- What if vessel feed temperature decreases?
- What if vessel feed composition changes (e.g., more or less oil, gas, or water)?
- What if excessive solids are entrained in feed?

Vessel

- What if vessel pressure increases?
- What if vessel pressure decreases?
- What if vessel level increases?
- What if vessel level decreases?
- What if vessel LAH fails?
- What if vessel LAL fails?
- What if vessel PAH fails?
- What if vessel PAL fails?
- What if vessel TAH fails?
- What if vessel TAL fails?
- What if vessel solid/sand removal system fails?
- What if vessel interface transmitter fails?
- What if vessel high-interface alarm fails?
- What if vessel low-interface alarm fails?
- What if vessel internals plug?
- What if vessel internals collapse?
- What if vessel relief valve lifts or leaks by?
- What if vessel ruptures due to internal corrosion, defective materials, or poor workmanship?

Vessel piping

- What if vessel oil outlet block valve is closed?
- What if vessel water outlet block valve is closed?
- What if vessel gas outlet block valve is closed?
- What if vessel oil outlet control loop fails open or closed?

When to use a “What if?”/Checklist Analysis

Facility Types

- **Simple processes**
- **Storage facilities**
- **If considering doing either one of the two methods**

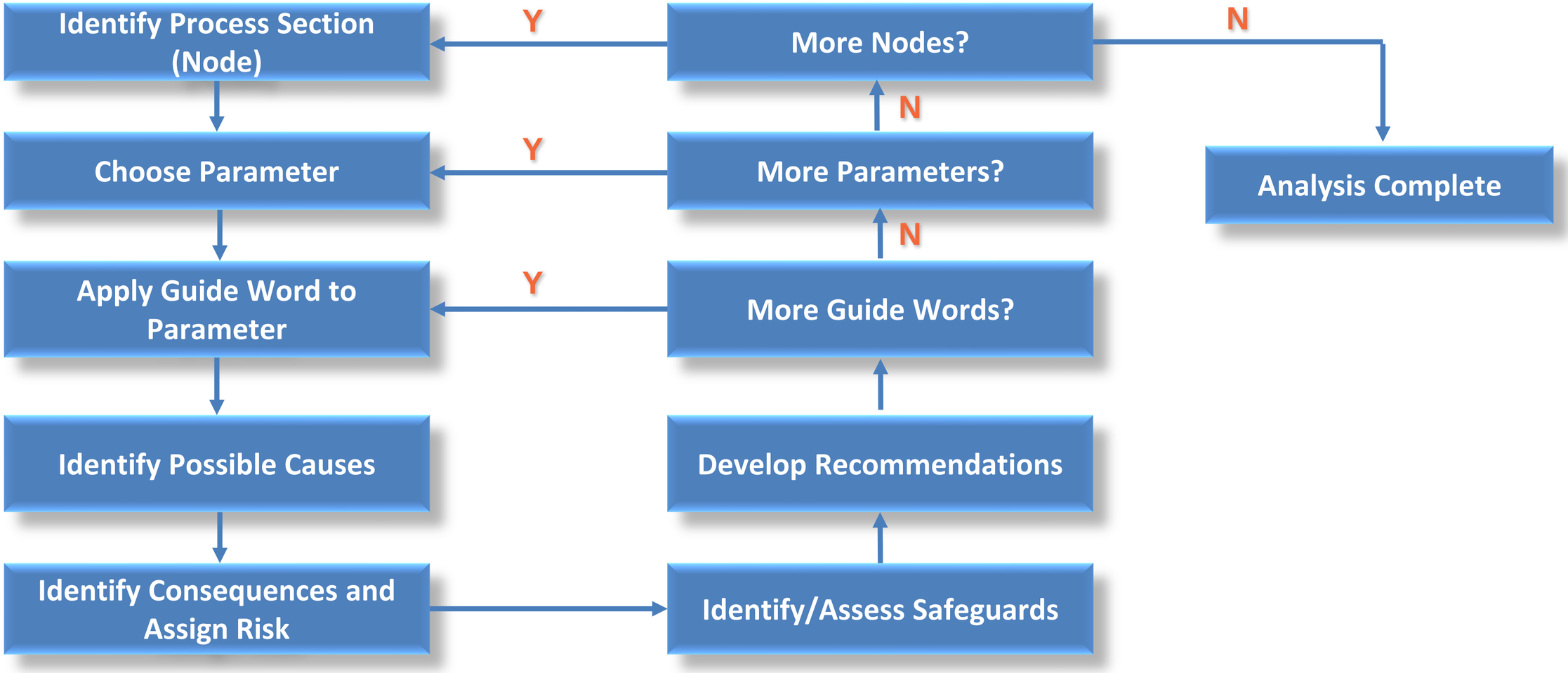
Hazard and Operability Study (HAZOP)

- **Systematic approach to identify and assess process risk, and recommend improvements as necessary**

HAZOP Nodes

- Specific areas within a process where HAZOP guidewords will be applied
- Selected based on design intent, process conditions, and/or major equipment

HAZOP Process



Guide Words & Parameters

- **Guide Words**
  - **More**
  - **Less**
  - **No**
  - **Reverse**
  - **High**
  - **Low**
  - **Loss of**

- **Parameters**
  - **Flow**
  - **Temperature**
  - **Pressure**
  - **Level**
  - **Concentration**
  - **pH**

Causes

- **Identify different ways that the process deviation identified may be realized**
  - **Instrument failure**
  - **Human Error**
  - **Equipment failure**
  - **Etc.**

Consequences

- Effects resulting from the loss of control of a hazard
  - Environment, Health & Safety, and Asset
- Team uses experience & knowledge to determine realistic consequence
- Causes can have multiple consequences
- Cause-consequence pairing

Risk Matrix

Likelihood	Severity 1	2	3	4	5
5	C	D	E	E	F
4	B	D	D	E	E
3	A	B	D	D	E
2	A	A	B	D	D
1	A	A	A	B	C

Safeguards

- Measures implemented to prevent, control, or mitigate hazardous events in chemical processes
- Types of Safeguards:
  - Engineering Controls: Physical devices (e.g., safety valves, alarms, containment structures, SIS, interlocks) to manage risks
  - Administrative Controls: Procedures or policies (e.g., training, maintenance protocols, emergency response plans) contributing to safety

Recommendations

- **Objective: Enhance safety and compliance**
- **Key Focus Areas:**
  - **Improving Safeguards: Upgrading or adding safety mechanisms**
  - **Operational Adjustments: Modifying procedures to increase safety**
- **Action Steps:**
  - **Assessment: Regularly review and assess existing safety measures**
  - **Implementation: Promptly apply approved safety recommendations**
  - **Training: Ensure ongoing staff education on safety protocols**
- **Follow-Up:**
  - **Monitoring: Continuously monitor the effectiveness of implemented actions**
  - **Documentation: Keep detailed records of actions and outcomes for compliance and review**
  - **Verification: confirmation that recommendations were implemented**

HAZOP Characteristics

- **Advantages**
  - **Exhaustive approach**
  - **Versatile**
  - **Organized results**
- **Disadvantages**
  - **Resource Intensive**
  - **Highly dependent on experience of Facilitator/Team**
  - **Information Overload**

When to use a HAZOP Analysis

Facility Types

- **Complicated processes**
- **Large facilities with multiple units (e.g. refineries, mining, pharmaceutical)**
- **Processes with severe consequences**

External Events (P3, P4)

- **Both natural and man-made events**
- **Events will vary among areas**
- **CA most common: earthquake, flood, fire**
- **Recent trends: evaluate cyber security and chemical security (Security Vulnerability Assessments)**

Facility Siting (P3, P4)

Process Hazard Analysis Facility Siting Checklist

Facility: _____ Date: _____

Team Members: _____

Note: For compliance, OSHA expects specific justification for each individual situation/condition.

Item	Question	Answer (Y, N, N/A)	Justification	Recommendations
GENERAL CONSIDERATIONS				
1.	If plant contains flammables above PSM/RMP/CalARP TQ, are they located outdoors to reduce risks?			
2.	Is plant exposed to hazards from neighboring plants?			
3.	Are there detection systems and/or alarms in place to assist in warning neighboring plants and the public if a release occurs?			
4.	Does site security prevent access by unauthorized persons while not hindering emergency services (e.g., fire fighters, paramedics)?			
5.	Are there below-ground-level locations (pits, ditches, sumps) where toxic or flammable materials can collect?			
6.	Are emergency shutdown switch locations protected against potential hazards, in easily accessible locations, and provided with knocking guards?			
7.	Can transportation of hazardous materials or impact of spillage be reduced by suitable site location?			
8.	Other general site concerns (specify)?			
BUILDING PROTECTION				
9.	Is ground or paving sloped so that flammables will not accumulate beneath vessels?			
10	Could drainage system cope with both storm water and fire			

Human Factors Checklist (P3, P4)

Facility: _____ Date: _____

Team Members: _____

Item	Question	Answer (Y, N, N/A)	Justification	Recommendations
HOUSEKEEPING AND GENERAL WORK ENVIRONMENT				
1.	Are working areas generally clean?			
1.	Is normal and emergency lighting sufficient for all area operations?			
1.	Is there adequate backup power for emergency lighting?			
1.	Are provisions in place to limit the time a worker spends in an extremely hot or cold area?			
1.	Are employees protected from excessive noise (e.g., the noise does not affect mental workload and cognitive ability as opposed to physical harm – "It is so loud I cannot concentrate")?			
1.	Are alarms audible above background noise both inside the control room and in the process area?			
1.	Are adequate signs posted near maintenance, cleanup, or staging areas to warn workers of special or unique hazards associated with the areas?			
ACCESSIBILITY / AVAILABILITY OF CONTROLS AND EQUIPMENT				
1.	Are all controls accessible?			
1.	Is communications equipment adequate, easily accessible, and functional?			
1.	Is emergency equipment accessible without presenting further hazards to personnel?			
1.	Are adequate supplies of protective gear readily available and in good working condition for routine and emergency use?			
1.	Would others quickly know if a worker is incapacitated in a process area?			

Latent Conditions Checklist (LCC)

- **Human factors applied to PHA**
- **"Latent conditions have two kinds of adverse effects: they can translate into error provoking conditions within the local workplace (for example, time pressure, understaffing, inadequate equipment, fatigue, and inexperience) and they can create longlasting holes or weaknesses in the defences (untrustworthy alarms and indicators, unworkable procedures, design and construction deficiencies, etc)."**

Reason J. Human error: models and management. BMJ. 2000 Mar 18;320(7237):768-70. doi: 10.1136/bmj.320.7237.768. PMID: 10720363; PMCID: PMC1117770.

Common Issues with PHAs

- **Inadequate identification of process hazards**
- **Delay in resolution of action items**
- **Team selection**
- **Consideration of external industry incidents (P4)**
- **Outdated PSI used in PHA**

Conclusion/Recap

- **“Safety is not a gadget but a state of mind.” – Eleanor Everet**

Resources

- **Chemical Safety Board**
  - **Incident Investigations, videos, other resources**

  www.csb.gov
- **Contra Costa County HazMat Website**
  - **CalARP Checklists, Guidance Documents, etc.**

  www.cchealth.org/hazmat

Thank You!

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https://cchealth.org/hazmat