Process Safety Management of Highly Hazardous & Explosive Chemicals

Process Hazard Analysis
29CFR1910.119(e)

Process Hazard Analysis (PHA)

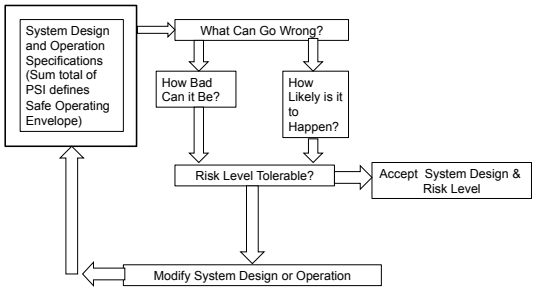
1910.119(e)

The employer shall perform an initial process hazard analysis (hazard evaluation) on processes covered by this standard. The process hazard analysis shall be appropriate to the complexity of the process and shall identify, evaluate, and control the hazards involved in the process. Employers shall determine and document the priority order for conducting process hazard analyses based on a rationale which includes such considerations as extent of the process hazards, number of potentially affected employees, age of the process, and operating history of the process.

Process Hazard Analysis (PHA)

- Process Hazard Analysis is a specific tool that:
- Assists in identifying possible deviations within a system
- Determines if those deviations could present undesired consequences
- If so, assesses degree and likelihood of consequence
- Provides mechanism for modifying the system if likelihood of consequence is not "tolerable"

Simplified PHA Flowchart



Process Hazard Analysis (PHA)

- Arguably the most difficult (and tedious) part of performing the Standard
- Performed by Your PSM Team
- Takes significant time & effort

Remember…

Process Safety Information (PSI) – Defines Safe Operation Envelope – Must be Known for a PHA

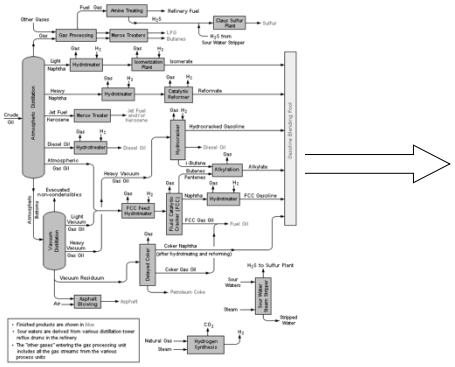
- **Safe operation envelope is determined/developed/ defined entirely by an assembly of:**
- **Properties of materials**
- **Process technology**
- **Equipment design**
- **System Operation**

F16 In a 9 G Turn

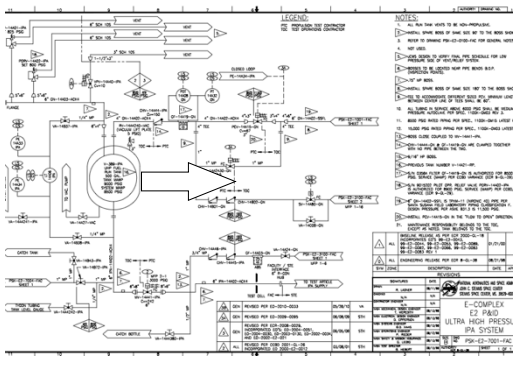
Remember

-
  - Before conducting PHA, compile and maintain
    - Chemical Hazards Information
    - Process Technology Information
    - Equipment Information
- Kept for the lifetime of the process
- Updated whenever changes other than "replacement in kind" are made or whenever necessary even when replacement in kind
- PSI applicable to various employees' jobs must be shared with those employees (operators, maintenance, contractors)

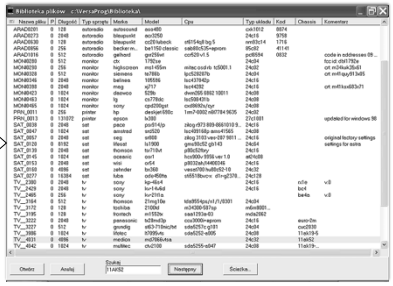
Block Diagram



P&ID



You Developed a List of Equipment Locations & Assets



The PHA Must Address:

- Equipment in the process
- Hazards of the process
- Identification of previous incidents
- Engineering and administrative controls
- Consequences of failure
- Facility siting
- Human factors
- Qualitative evaluation of Safety and Health effects
- Consequences of deviation
- Steps required to correct or avoid deviation

Facility Siting:

- Facility Siting -

——Texas City, TX 1947. *LEARNING: Confinement added to strength of explosion strength*

——Flixborough, UK 1974 Community fatalities and damage. *LEARNING: Plants are getting large enough to impact the neighbors*

——Norco, LA 1988 Control room in center of unit destroyed. *LEARNING: Control Buildings should be designed for VCEs*

——Pasadena, TX 1989 Muster location building destroyed. *LEARNING: Emergency Response should consider Facility Siting*

——BP, Texas City, TX 2005 *LEARNING: Portable buildings are weaker than previously thought, unnecessary people too close to unit, an Industry Standard for Portable Buildings was developed*

——Total, Buncefield, UK 2006 *LEARNING: Trees can act as congestion*

Reference: http://www.owlnet.rice.edu/~krcox/sache2010/pdf/m01_buchwald.pdf

Facility Siting

- Facility Siting – with respect to existing plants, "siting" does not refer to the site of the plant in relation to the surrounding community. It refers, rather, to the location of various components within the establishment. This includes, but is not limited to:
  - Permanent and temporary employee-occupied buildings, including trailers, that expose employees by virtue of their location, to potential hazards such as fires, explosions, overpressures, exposure to toxic or corrosive materials, or that risk being damaged by other process equipment, etc.
  - Cooling towers
  - Flares and other vents
  - Emergency access
  - Piperacks
  - Emergency response facilities
  - Fire pumps
  - Emergency isolation valves, etc.

PHA Methodologies

Must select a process hazard analysis (PHA) method

–What-If;

–Checklist;

–What-If/Checklist;

–Hazard and Operability Study (HAZOP);

–Failure Mode and Effects Analysis (FMEA);

–Fault Tree Analysis

– An appropriate equivalent methodology

Let's Choose HAZOP to Study

The Most Common Method used for PHAs

PHA - HAZOP Process

- The PHA process is based on the principle that a team approach to hazard analysis will identify more problems than when individuals working separately combine results.
- The HAZOP team is made up of individuals with varying backgrounds and expertise.
- The expertise is brought together during HAZOP sessions and through a collective brainstorming effort that stimulates creativity and new ideas, a thorough review of the process under consideration is made.

PHA - HAZOP Process

- The HAZOP team focuses on specific portions of the process called "nodes".
- Generally these are identified from the P&ID of the process before the study begins.
- A process parameter is identified, say flow, and an intention is created for the node under consideration.
- Then a series of guidewords is combined with the parameter "flow" to create a deviations.
- For example, the guideword "no" is combined with the parameter flow to give the deviation "no flow".

HAZOP Team Leader

- The PHA team leader works with the PHA coordinator in defining the scope of the analysis and selection of team members.
- Directs the team members in gathering of process safety information prior to the start of the study.

HAZOP Team Leader

- Plans the study with the PHA coordinator and schedules team meetings
- Leads the team in the analysis of the selected process
- Keeps team members focused on discovering hazards associated with the process
- Directs the team scribe in recording the results of the teams findings

HAZOP Resources

- The engineering experts assigned to the PHA may include some or all of the following:
  - project engineer
  - controls engineer
  - instrument engineer
  - electrical engineer
  - mechanical engineer
  - safety engineer
  - quality assurance engineer,
  - maintenance engineer or technician
  - corrosion/materials engineer

HAZOP

Guidewords & Parameters

- The HAZOP process creates deviations from the process design intent by combining guide words (No, more, less, etc.) with process parameters resulting in a possible deviation from design intent
- Application of parameters will depend on the type of process being considered, the equipment in the process and the process intent

- **Guidewords:**
  - No
  - More
  - Less
  - As Well As
  - Reverse
  - Other Than
- **Parameters:**
  - Flow
  - Temperature
  - Pressure
  - Composition
  - Phase
  - Level
  - Relief
  - Instrumentation

HAZOP
Deviations

- A deviation is considered realistic if there are sufficient causes to believe the deviation can occur
- Team judgment is used to decide whether to include events with a very low probability of occurring
- What could go wrong?

HAZOP
Three General Causes of Deviations

- Human Error - acts of omission or commission by an operator, designer, constructor or other person creating a hazard that could possibly result in a release of hazardous or flammable material

HAZOP
Deviation Causes

- Equipment failure in which a mechanical, structural or operating failure results in the release of hazardous or flammable material.

HAZOP
Deviation Causes

- External Events in which items outside the unit being reviewed affect the operation of the unit to the extent that the release of hazardous or flammable material is possible.

HAZOP
Consequences

- Identify scenarios which could result in undesired impacts
  - Loss of primary containment (LOPC)
  - Fires, explosions, toxic releases
  - Employee exposures
  - Injuries
  - Environmental issues
  - Operability issues
  - Quality concerns
- How bad could it be?

HAZOP
Consequences

- Help to determine a risk ranking in HAZOPs where multiple deviations are uncovered
- Help make the determination as to whether a particular deviation results in an operability problem or hazard.

HAZOP

Frequency

- Team must assess the likelihood of an undesired deviation/consequence
- Most commonly qualitative
  - Frequent
  - Often
  - Rare
  - Unlikely
  - Never
- How likely is it to occur?

HAZOP

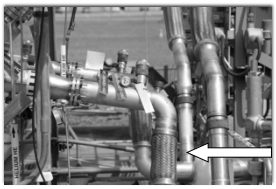
Safeguards

- Safeguards should be assessed whenever the team determines that a consequence is "of interest". (i.e. of sufficient impact and/ or credibility)

HAZOP

Safeguards - Three Classifications

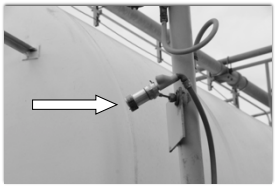
- Those systems, **<u>engineered designs and written procedures</u>** that are designed to prevent a catastrophic release of hazardous or flammable material.



HAZOP

Safeguards - Three Classifications

- Those systems that are designed to **detect and give early warning** following the initiating cause of a release of hazardous or flammable material.

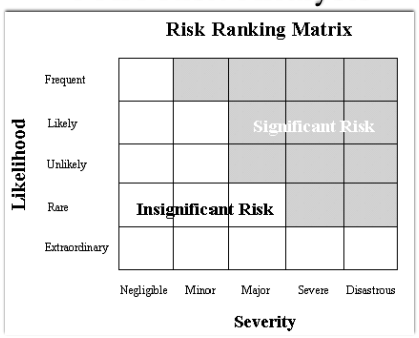


HAZOP

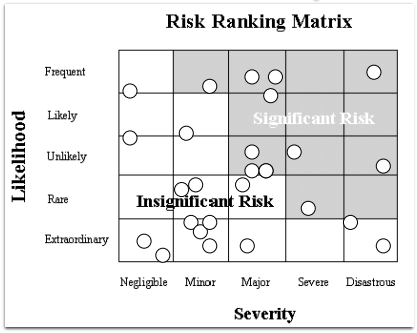
Safeguards - Three Classifications

- Those systems or written procedures that **mitigate the consequences** of a release of hazardous or flammable material.

PHA Risk Analysis



PHA Risk Analysis



HAZOP
Recommendations

- Recommendations are made when the safeguards for an identified scenario are judged insufficient to reduce risk to a tolerable level.

HAZOP
Recommendations

From OSHA Compliance Directive:

- Employer shall proceed with all due speed, considering the complexity of the recommendation and difficulty of implementation
- OSHA believes that employers will be able to complete these actions within a one to two year timeframe, but notes that in unusual circumstances longer completion periods may be necessary

HAZOP
Recommendations

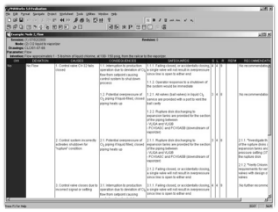
- Prioritize recommendations
- Establish a plan to track to completion
- Management review of progress

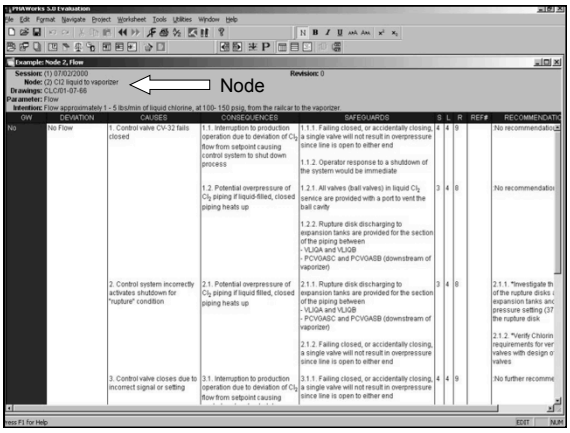
Using HAZOP

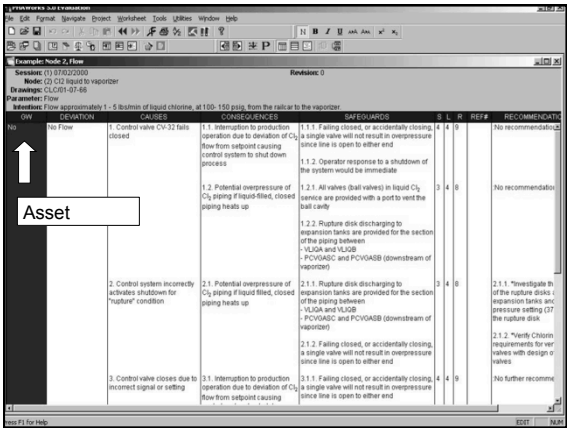
Let's Explore a PHA Process

Process Hazard Analysis

- A PHA must be performed on each asset of the covered process:
- A PHA from Block Diagram to P&ID to every equipment asset to determine what might happen if an element of the covered process fails




Node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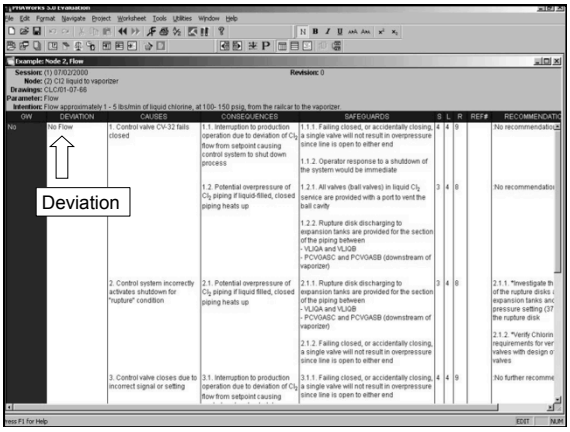
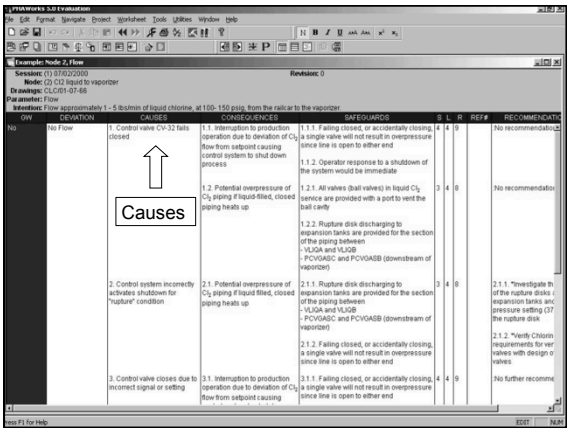
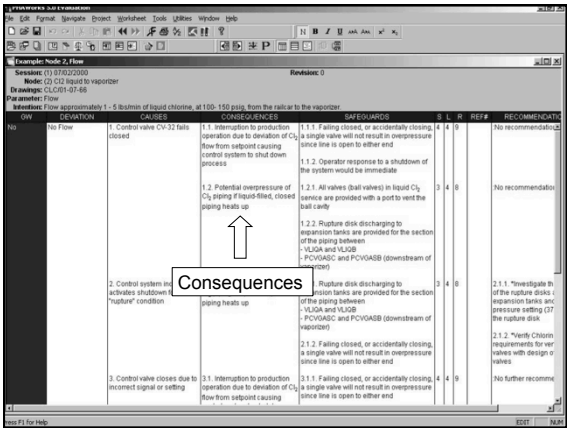
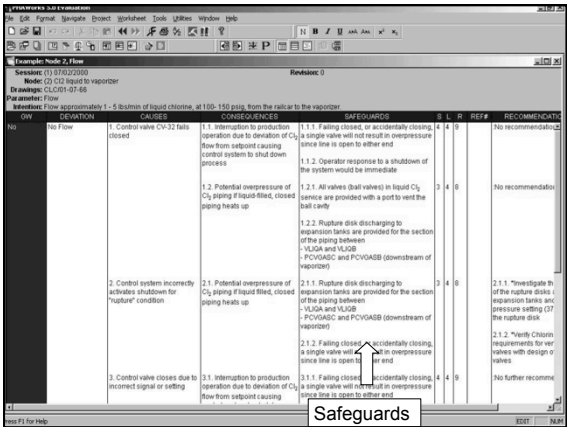
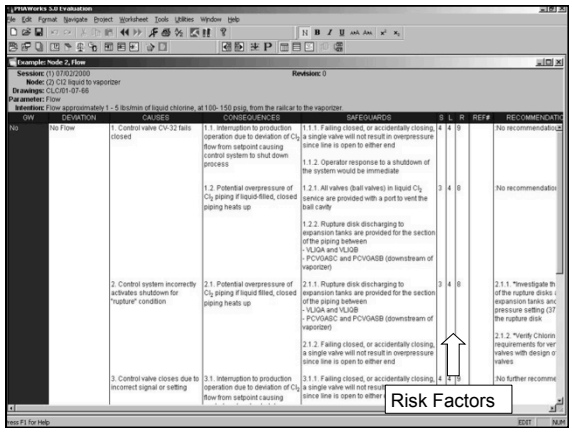
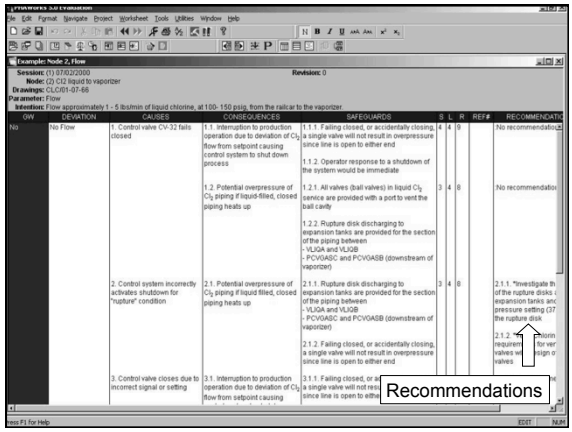

Deviation

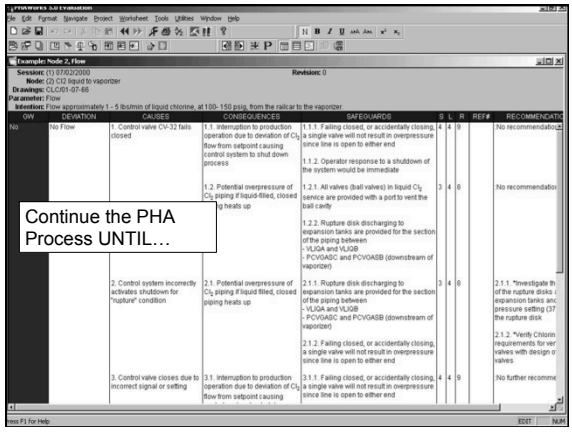

Causes

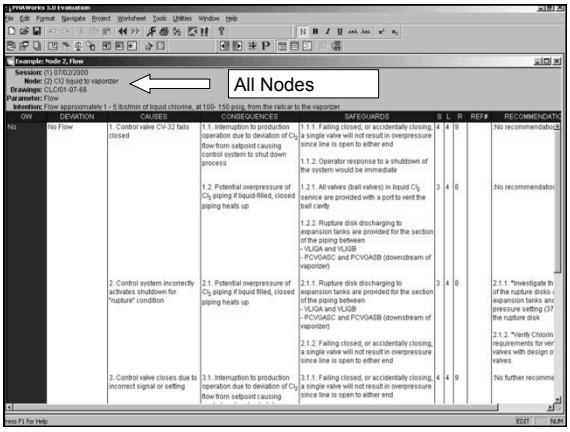

Consequences

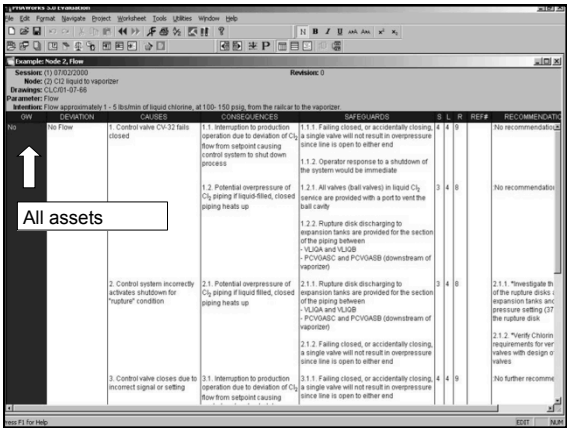

Safeguards

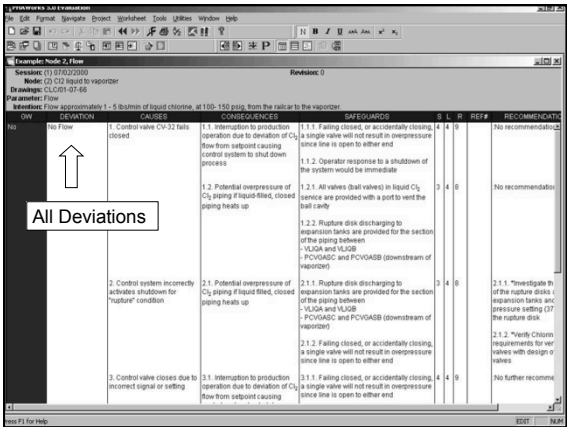

Risk Factors

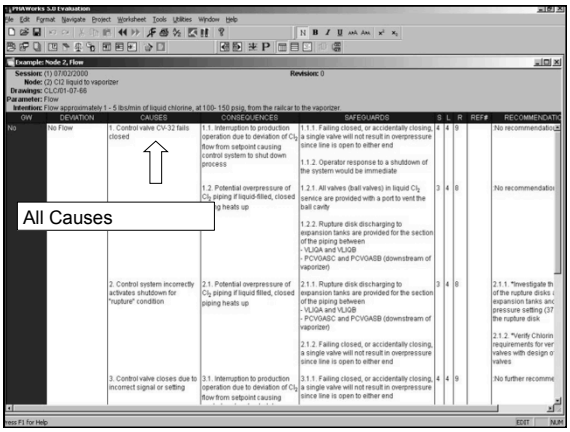

Recommendations

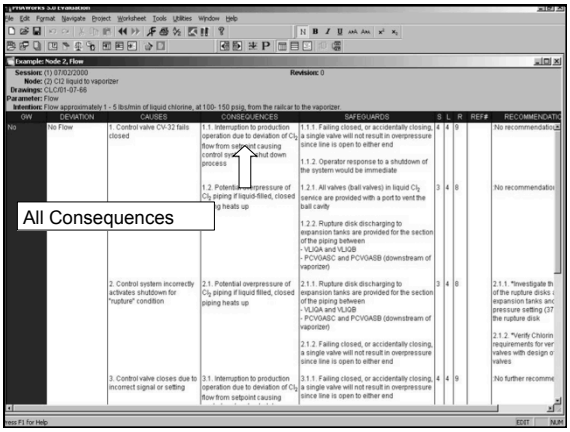

Continue the PHA Process UNTIL…

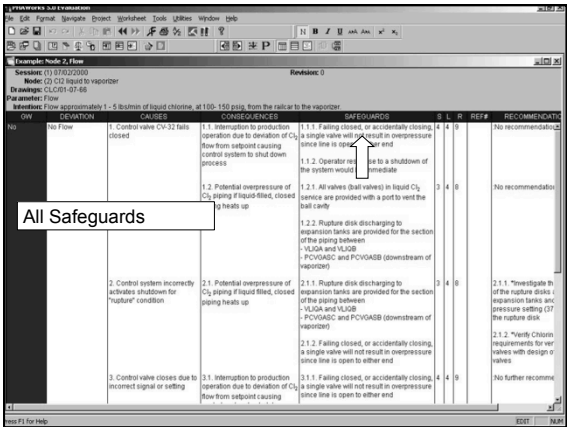

All Nodes

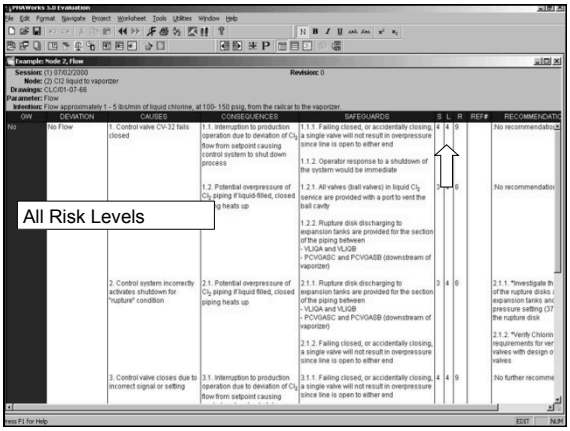

All assets

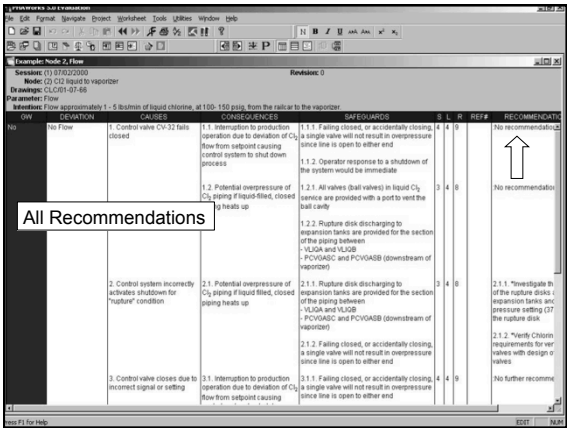

All Deviations

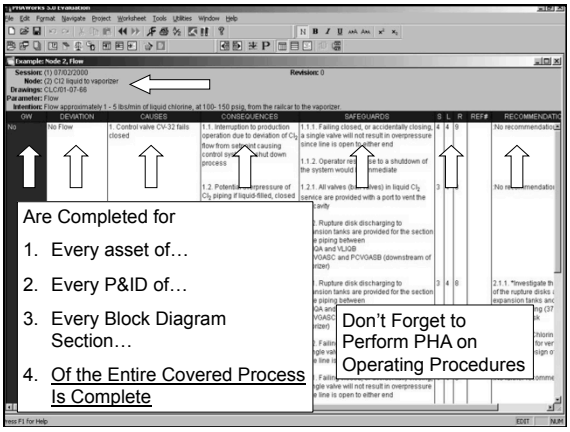

All Causes

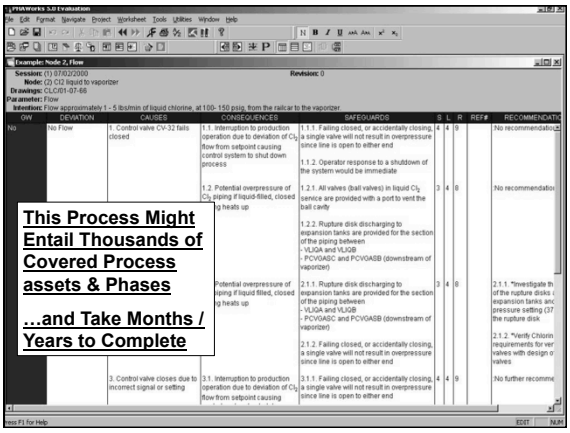

All Consequences


All Safeguards


All Risk Levels


All Recommendations


Are Completed for
1. Every asset of…
2. Every P&ID of…
3. Every Block Diagram Section…
4. Of the Entire Covered Process Is Complete
Don't Forget to Perform PHA on Operating Procedures



This Process Might Entail Thousands of Covered Process assets & Phases

…and Take Months / Years to Complete

Recommendations

Workflow to Closeout

Layer of Protection Analysis

Basics of Safety Instrumented Systems and LOPA

What if Recommendations aren't easily identified?

How do you know when you have enough recommendations?

Consider Layers of Protection Analysis (LOPA)

Layer of Protection Analysis (LOPA)

- Why is LOPA useful?
  - Turns out, PHA teams (and humans in general) are pretty terrible at qualitative likelihood assessment
  - Personal risk tolerance is unavoidable and is a function of too many variables (personal experiences, etc.)
  - Need a more quantitative approach for particularly high consequence or high qualitative risk scenarios
  - LOPA uses failure data to assess the likelihood of both the initiating event AND credited safeguards to determine if risk is tolerable.

Layers of Protection Analysis (LOPA)

Key Definitions:

- **Initiating Event** – The event that initiates the scenario leading to the undesired consequence. *(valve fails)*
- **Frequency** – the number of occurrences per unit of time *(normally per year, but all units must match)*
- **Independent Protection Layer (IPL)** – a device, system, or action that is capable of preventing the undesired consequence regardless of the initiating event or the action of any other protection layer associated with the scenario. **Independent** means the performance of the protection layer is not affected by failures of other protection layers. The **effective**ness and independence of an IPL should be **auditable**.
- **Probability of Failure on Demand (PFD)** – the probability that a system will fail to perform a specified function on demand.

Layers of Protection Analysis (LOPA)

- ***Generally***

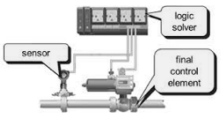
1. Company determines the consequence severity or risk level for screening scenarios
2. Identify frequency of initiating event (IEF)
3. Identify the Independent Protection Layers (IPLs) and estimate the probability of failure on demand (PFD) of each IPL
4. Calculate the scenario frequency with all IPLs in place (multiply probabilities because all must occur for consequence)

   $IEF \times PFD_1 \times PFD_2 \times \ldots\ldots$

5. Compare the estimated risk to company risk tolerance criteria. Make recommendations to lower risk if needed.

What is a Safety Instrumented System (SIS)?

- An SIS is designed to:
  - Respond to conditions in the plant which may be hazardous in themselves or,
  - If no action was taken, could eventually give rise to a hazard, and
  - To respond to these conditions by taking defined actions that either prevent the hazard or mitigate the hazard consequences.



Standards Bodies that Define Good Engineering Practice for Safety Instrumented Systems

- ISA, Instrumentation Systems and Automation Society
- IEC, International Electrotechnical Commission
  - **IEC 61508**
  - **IEC 61511**
- NFPA
- **ISA 84.01-2003**
- **API**
- **ASME**

Safety Instrumented System Standards

IEC 61508 - "Functional Safety: Safety Related Systems"
Current version released 1999
Under revision for next release 2005

IEC 61511 - "Functional Safety: Safety Instrumented Systems for the Process Industry Sector"
Published 2003

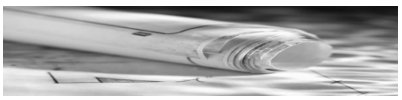
ISA 84.01-2003 - "
Instrumented Systems for the Process Industry Sector"
Identical to IEC 61511 with inclusion of grandfather clause
To be published October 2003

Safety Integrity Level (SIL)

SIL	PFDavg	Risk Reduction	Availability (%)
4	10^{-4} to 10^{-5}	10,000 to 100,000	99.99 to 99.999
3	10^{-3} to 10^{-4}	1,000 to 10,000	99.9 to 99.99
2	10^{-2} to 10^{-3}	100 to 1,000	99 to 99.9
1	10^{-1} to 10^{-2}	10 to 100	90 to 99

Design SIF

- Justify selection of devices
- Document the safety requirements specification
- Design SIFs to achieve Safety Integrity Level.



Prove it

- Verify
  - Safety Integrity Level
  - Fault tolerance
- Commissioning
  - Install SIFs per design documents
- Functional safety assessment
  - Make sure all documents are in place and all hazards analysis items are addressed.
- Validation
  - Test SIFs to ensure that they have desired functionality

Basically, You Have to Honor & Marry Your SIS

Layer of Protection Analysis (LOPA)

- **Why is LOPA useful?**
  - Turns out, PHA teams (and humans in general) are pretty terrible at qualitative likelihood assessment
  - Personal risk tolerance is unavoidable and is a function of too many variables (personal experiences, etc.)
  - Need a more quantitative approach for particularly high consequence or high qualitative risk scenarios
  - LOPA uses failure data to assess the likelihood of both the initiating event AND credited safeguards to determine if risk is tolerable.

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Layer of Protection Analysis (LOPA)

- LOPA is NOT a "stand alone" risk analysis tool
  - LOPA is a *compliment* or *"sharper pencil"* to hazard identification tools
  - LOPA depends on PHAs or other methods to identify the scenario (cause/consequence pair) and to identify safeguards

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Layers of Protection Analysis (LOPA)

- **Generally,**

1. Company determines the consequence severity or risk level for screening scenarios
2. Identify frequency of initiating event, taking into account enabling conditions and/or conditional modifiers (if desired)
3. Identify the Independent Protection Layers (IPLs) and estimate the probability of failure on demand (PFD) of each IPL
4. Calculate the scenario frequency with all IPLs in place (multiply probabilities because all must occur for consequence)
5. Compare the estimated risk to company risk tolerance criteria. Make recommendations to lower risk if needed.

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Layers of Protection Analysis (LOPA)

- **Key Definitions**

▪**Initiating Event** – The event that initiates the scenario leading to the undesired consequence. *(valve fails)*

▪**Frequency** – the number of occurrences per unit of time *(normally per year, but all units must match)*

▪**Independent Protection Layer (IPL)** – a device, system, or action that is capable of preventing the undesired consequence regardless of the initiating event or the action of any other protection layer associated with the scenario. Independent means the performance of the protection layer is not affected by failures of other protection layers. The effectiveness and independence of an IPL should be auditable.

▪**Probability of Failure on Demand (PFD)** – the probability that a system will fail to perform a specified function on demand.

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Layer of Protection Analysis (LOPA)

- Must establish/identify and consistently apply:
  - Initiating event frequencies
  - Conditional modifiers
  - Ignition likelihood
  - Component failure data
  - Rules for human failure frequency
  - Tolerable risk criteria

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Layer of Protection Analysis (LOPA)

- Example of Initiating Event Frequencies (per year)

Initiating Event	Company 1	Company 2	Company 3	CCPS	Comments
BPCS instrument loop failure - clean service	1 X 10-1	1 X 10-1	1 X 10-1	1 X 10-1	
Other - relief valve or rupture disc opens early	1 X 10-2		1 X 10-2	1 X 10-2	
Other - mechanical failures hoses: no moving parts - no vibration	1 X 10-2	1 X 10-2			Requires hose inspection, compatible construction, proper connections
Other - pressure regulator failures - clean service, periodic maintenance	1 X 10-2				
Other - pump failure, single pump	1 X 10-1	1 X 10-1			
Other - pressure vessel residual failure	1 X 10-6			1 X 10-6	This assumes a properly designed and inspected vessel without other process deviations in play. Other failure modes such as overpressurization, corrosion, glass lining damage, etc., must be considered separately.

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Layer of Protection Analysis (LOPA)

Typical Frequency Values, f^i, Assigned to Initiating Events

Initiating Event	Frequency Range from Literature (per year)	Example of a Value Chosen by a Company for Use in LOPA (per year)
Pressure vessel residual failure	10^{-5} to 10^{-7}	1×10^{-6}
Unloading/loading hose failure	1 to 10^{-2}	1×10^{-1}
BPCS instrument loop failure *Note:* IEC 61511 limit is more than 1×10^{-5}/hr or 8.76×10^{-2}/yr (IEC, 2001)	1 to 10^{-2}	1×10^{-1}
Regulator failure	1 to 10^{-1}	1×10^{-1}
Small external fire (aggregate causes)	10^{-1} to 10^{-2}	1×10^{-1}
Large external fire (aggregate causes)	10^{-2} to 10^{-3}	1×10^{-2}
LOTO (lock-out tag-out) procedure* failure *overall failure of a multiple-element process	10^{-3} to 10^{-4} per opportunity	1×10^{-3} per opportunity
Operator failure (to execute routine procedure, assuming well trained, unstressed, not fatigued)	10^{-1} to 10^{-3} per opportunity	1×10^{-2} per opportunity

Layer of Protection Analysis…, Wiley, CCPS, 2001

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Layer of Protection Analysis (LOPA)

Examples of Active IPLs

IPL	Comments *Assuming an adequate design basis and inspection/maintenance procedures*	PFD from Literature and Industry	PFD Used in This Book (For screening)
Relief valve	Prevents system exceeding specified overpressure. Effectiveness of this device is sensitive to service and experience.	1×10^{-1} – 1×10^{-3}	1×10^{-2}
Rupture disc	Prevents system exceeding specified overpressure. Effectiveness can be very sensitive to service and experience	1×10^{-1} – 1×10^{-3}	1×10^{-2}
Basic Process Control System	Can be credited as an IPL if not associated with the initiating event being considered (see also Chapter 11). (See IEC 61508 (IEC, 1998) and IEC 61511 (IEC, 2001) for additional discussion.)	1×10^{-1} – 1×10^{-2} (>1×10^{-1} allowed by IEC)	1×10^{-1}
Safety Instrumented Functions (Interlocks)	See IEC 61508 (IEC, 1998) and IEC 61511 (IEC, 2001) for life cycle requirements and additional discussion		

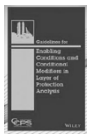
Layer of Protection Analysis…, Wiley, CCPS, 2001

Layer of Protection Analysis (LOPA) References

- *Layer of Protection Analysis, Simplified Process Risk Assessment*, 2001, Wiley, American Institute of Chemical Engineers, Center for Chemical Process Safety, ISBN 0-8169-0811-7

- *Guidelines for Initiating Events and Independent Protection Layers in Layer of Protection Analysis (soon to be released)*

- *Guidelines for Enabling Conditions and Conditional Modifiers in Layer of Protection Analysis*, 2013, Wiley, American Institute of Chemical Engineers, Center for Chemical Process Safety



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Layers of Protection Analysis (LOPA)

- **IPL Characteristics**
  - Is a device, system or action that is capable of preventing a scenario from proceeding to its undesired consequence independent of the initiating event or the action of any other layer of protection associated with the scenario.
  - In order to be considered an IPL and "credited", it must be
    - Effective
    - Independent
    - Auditable

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Layers of Protection Analysis (LOPA)

- **Limitations**
  - Reliability data is limited
  - Variability in consequence severity ratings
  - Be careful with enabling conditions and conditional modifiers
  - Be consistent

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Layer of Protection Analysis (LOPA)

Typical Frequency Values, *f*, Assigned to Initiating Events

Initiating Event	Frequency Range from Literature (per year)	Example of a Value Chosen by a Company for Use in LOPA (per year)
Pressure vessel residual failure	10^{-3} to 10^{-7}	1×10^{-6}
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Layer of Protection Analysis…, Wiley, CCPS, 2001

LOPA

Example values

INDEPENDENT PROTECTION LAYER	PFD
Control loop	1.0×10^{-1}
Relief valve	1.0×10^{-2}
Human performance (trained, no stress)	1.0×10^{-2}
Human performance (under stress)	0.5 to 1.0
Operator Response to Alarms	1.0×10^{-1}
Vessel pressure rating above maximum challenge from internal and external pressure sources	10^{-4} or better, if vessel integrity is maintained (i.e., corrosion understood, inspections and repairs in place)

Layer of Protection Analysis (LOPA)

Scenario number: 1	Equipment number:	Scenario title: Cooling water failure with runaway reaction and potential for reactor overpressure, leakage, rupture, injuries and fatalities. Agitation assumed		
Date: ##/##/####		Description	Probability	Frequency (per year)
Consequence description/category		Runaway reaction and potential for reactor overpressure, leakage, rupture, injuries, and fatalities **Category 5**		
Risk tolerance criteria (category or frequency)		Unacceptable (Greater than)		1×10^{-4}
		Tolerable (Less than or equal to)		1×10^{-5}
Initiating cause (typically a frequency)		Loss of cooling water		1×10^{-1}
Enabling event or condition		Probability that reactor in condition where runaway reaction can occur on loss of cooling (annual basis)	0.5 (per reactor)	
Conditional modifiers (if applicable)		Probability of ignition	N/A	
		Probability of personnel in affected area	N/A	
		Probability of fatal injury	N/A	
		Others	N/A	
Frequency of unmitigated consequence				5×10^{-1}
Independent protection layers				
BPCS alarm and human action		Shortstop addition on BPCS loop high reactor temperature alarm	1×10^{-1}	
Pressure relief valves		With required modifications to system (see Actions) (PFD may be conservative if modifications added)	1×10^{-2}	
SIF (Required PFD = 1×10^{-3}) (Part of SIS for all 3 reactors)		SIF to open vent valves (see Actions for design details) **Required PFD set by Scenario 5** TO BE ADDED — see Actions/Notes	1×10^{-3}	
Safeguards (non-IPLs)		**Operator action.** Other operator actions not independent of the same operator already credited. **Emergency cooling system** (steam turbine). Not credited as an IPL as too many common elements (piping, valves, jacket, etc.) that could have initiated initial cooling water failure.		
Total PFD for all IPLs			1×10^{-5}	
Frequency of mitigated consequence				5×10^{-6}
Risk tolerance criteria met? (Yes/No)		Yes **with added SIF**		
Actions required to meet risk tolerance criteria		Add SIS for all 3 reactors. Install SIF with minimum PFD = 1×10^{-3} for opening vent valves on high temperature. Separate nozzles and piping for each vent valve. Install separate nozzle and vent lines for each PSV to minimize blockage and common cause. Consider nitrogen purges under all vent valves / PSVs. **Responsible group / person / date:** Plant Technical / J. Doe / January ####		
Notes		Ensure operator response to high temperature meets requirements for IPL. Ensure RV design, installation, maintenance meet requirements for PFD 1×10^{-2} as a minimum. If determined to be better, consider PFD for Vent Valve SIF PFD.		

CCPS Guidelines for Hazard Evaluation Procedures, Wiley, 2008

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LOPA Example

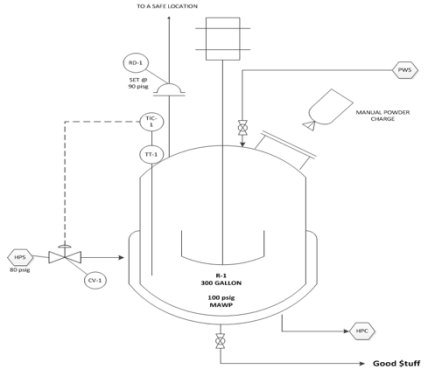
- **Simplified Example**
  - Batch system
  - 300 gallon reactor (100 psi MAWP) with rupture disk relief
  - Heated with steam jacket
  - Steam supply pressure 80 psi
  - Steam flow controlled by steam control valve and internal vessel temperature
  - Powder charge into water, then agitation
  - Powder not combustible
  - Runaway reaction initiation at 212 deg F, Pmax for runaway is 400 psi
  - This is scenario used for basis of design for rupture disk

LOPA Example

- PHA Excerpt:

Item	Deviation	Causes	Consequences	Consequence Rank	Safeguards	Likelihood	Risk Number
4.6	High Temperature	TT-1 fails low	High Pressure - runaway reaction resulting in vessel failure (Pmax > 3x MAWP). Vessel in normally occupied area, multiple fatalities possible.	5	RD-1 sized for this scenario and routed to a safe location based on modeling.	E	TD

LOPA Example



- Complete the LOPA Worksheet

Scenario Number	Equipment Number	Scenario Title:	
Date:	Description	Probability	Frequency (per year)
Consequence Description/Category			
Risk Tolerance Criteria (category or frequency)			
Initiating Event (typically a frequency)			
Enabling Event or Condition			
Conditional Modifiers (if applicable)			
	Probability of ignition		
	Probability of personnel in affected area		
	Probability of fatal injury		
	Others		
Frequency of Unmitigated Consequence			
Independent Protection Layers			
Safeguards(non-IPLs)			
Total PFD for all IPLs			
Frequency of Mitigated Consequence			
Risk Tolerance Criteria Met? (Yes/No):			
Actions Required to Meet Risk Tolerance Criteria:			
Notes:			
References (links to originating hazard review, PFD, P&ID, etc.):			
LOPA analyst (and team members, if applicable):			

Layer of Protection Analysis…, Wiley, CCPS, 2001

Process Hazard Analysis

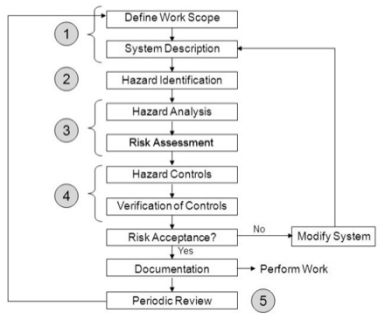
29CFR1910.119

Performing an Effective PHA Revalidation

Process Hazard Analysis (PHA)

- 1910.119(e)
- The employer shall perform an initial process hazard analysis (hazard evaluation) on processes covered by this standard. The process hazard analysis shall be appropriate to the complexity of the process and shall identify, evaluate, and control the hazards involved in the process. Employers shall determine and document the priority order for conducting process hazard analyses based on a rationale which includes such considerations as extent of the process hazards, number of potentially affected employees, age of the process, and operating history of the process. ***At least every 5 years after the completion of the initial process hazard analysis, the process hazard analysis must be updated and revalidated by a team meeting the standard's requirements to ensure that the hazard analysis is consistent with the current process.***

The Process



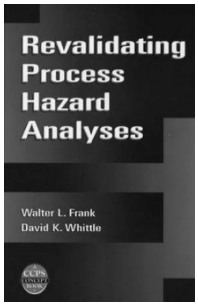
What is Intended to Accomplish

- A Hazard is Inherent Physical or Chemical Characteristic that has the potential to harm
- The Revalidation is a study effort to identify and analyze the significance of hazardous situations to associated with a process or activity
- It's is used to pinpoint weaknesses in the design and operation of facilities that could lead to accidental chemical releases, fires or explosions.
- It provides organizations with the information to help them improve the safety and manage the risk of their operations

Why?

Valero McKee Refinery Propane Fire

Why Use the CCPS Method?



Summary of The CCPS Steps

- Name The Team
- Notify Management
- Train the Team on the Basics and Why Revalidation Including Facility Tour
- Prepare for the Revalidation and Assemble PSI
- Evaluate the Prior PHA Study

Summary of The CCPS Steps

- Identify Changes that Have Occurred Since the Last PHA
- Identify the Appropriate Revalidation Methodology
- Conduct the Revalidation Study Sessions
- Document the Revalidation Study – Author the Report

Recommendation

Start Early Plan! Plan!

It Takes Months

Let's Review Each Step

Name & Train the Team

Key Elements to Success

- Train on What the PHA Revalidation Process is Meant to Accomplish
- Train and Review the PHA Process That Will be Used – What If, HAZOP, FMEA
- Review the PHA Team Makeup

PHA Preparation
Name the Team

Name Your PHA Team

- Consider 5 to 7 team members optimum
- Team leader (facilitator) – hazard analysis expertise
- Engage Your Consultant Early (if using one)
- 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
Process Overview & Tour

Process overview & Tour of Covered Process

- 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
- Tour the Covered Process with the Team

Notify Management – Revalidation, What Is It?

Key Elements to Success

- The Reason for Revalidation
- Revalidation Objective & Concept
- Revalidation Schedule & Budget
- The Role of Management and the Team in the Revalidation Procedure

Prepare for the Revalidation & Assemble PSI

Key Elements to Success

- Preplan the Revalidation
  - Establish Scope
  - Select Team, Schedule
- Identify and Collect PSI
  - Determine PSI Requirements
  - Review and Confirm Boundary
  - Assemble & Distribute PSI to Team for Pre-Review

Key Elements to Success

- Review and Analyze PSI
  - Prior PHA Report and Related Information
  - Resolution Completion Report for Prior PHA Recommendations
  - MOC & PSSR Documentation – Critical
  - PSM Audit Results
  - Incident and Near Miss Reports
  - Piping & Instrumentation Diagrams (P&ID's)
  - Operating Procedures & Safe Work Practices

Process Safety Information Required for a PHA

- Materials of Construction
- Process Chemistry
- Reactive Chemistry Information – Kinetic Data
- Design Energy & Mass Balances
- Correct P&ID's
- Mechanical Integrity
- Relief Calculations
- Electrical Classifications
- Operating Procedures: Walked Down & Correct
- Codes & Specifications
- Vendor Drawings
- MOC Packages
- Incident/Accident Reports
- Special/Unique Design Specifications
- Maintenance Procedures
- Testing & Inspection Reports
- Ventilation Systems
- Safety Systems (SIL's)
- Emergency Procedures

Process Safety Information Required for a PHA Revalidation

THE REALITY:

YOU MUST HAVE YOUR PSI ASSEMBLED, OR…

YOU CAN'T DO AN EFFECTIVE PHA

Evaluate The Prior PHA Study

Keys to Success

Evaluate the Prior PHA with Respect to Essential Criteria

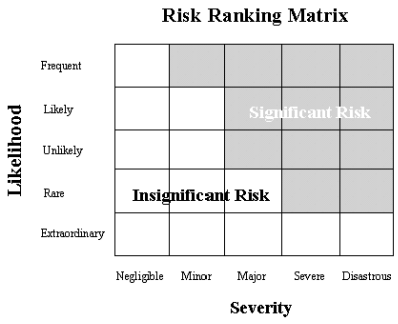
- PHA Rigor
- Methodology Used
- Team Make Up
- Documentation Used

Evaluate PHA Quality & Completeness

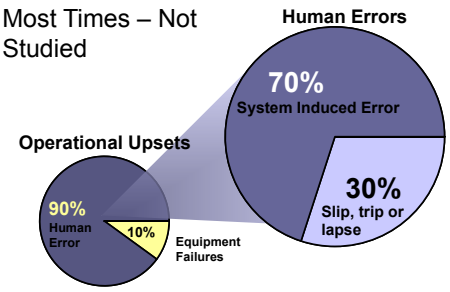
Realities We've Learned

- Many Initial and Prior PHA's Did Not:
  - Include Human Factors and Facility Siting
  - Include Evaluating Operation Procedures & Safe Work Practices
  - Identify the Appropriate Process Boundary
  - Use Complete or Correct PSI
  - Study the Hazards in Enough Detail

Many Times – Not Done



Most Times – Not Studied



Origin of Human Error

Todd Conklin Human Performance Training

Facility Siting-Not Properly Evaluated

Not Just This…

But This

Identify Changes that Have Occurred Since the Last PHA

What's Changed?

- Complete the Appropriate Section of the CCPS Revalidation Checklists on Changes: A Critical Step
  - PHA Quality & Completeness Checklist
  - Change Summary Worksheet
  - Facility & Process Modification Checklist
  - Facility Stationary Source Siting Checklist
  - Human Factors Checklist

Appendix C

PHA Quality and Completeness Checklist*

OBJECTIVE: To evaluate the prior PHA against quality and completeness criteria established by company and regulatory requirements. A "No" response to any item requires that the issue be adequately considered during the revalidation PHA study sessions.

Verification Questions	Yes, No, Maybe	Evidence of Compliance	Comments on Adequacy of Compliance
A. ACCESS TO AND USE OF PROCESS SAFETY INFORMATION			
1. Is there evidence that the PSI was complete and available for the PHA team to use (or were recommendations generated to complete the PSI)?			
2. Is there evidence that the PSI contained up-to-date P&IDs?			
3. Is there evidence that unit procedures were available?			
4. Is there evidence that the PSI contained design temperatures and pressures for major equipment (e.g., vessels, heat exchangers, pumps)?			
5. Is there evidence that the PSI contained relief device design and setpoint data?			
6. Is there evidence that the PSI contained ventilation system design data?			

* This checklist is provided for illustrative purposes only. Readers may wish to develop such a checklist specific to their own situation and needs.

Appendix D

Example Change Summary Worksheet

OBJECTIVE: To record both controlled and uncontrolled changes identified during documentation reviews and interviews. Changes will be reviewed during PHA revalidation sessions.

DRAWING NUMBER	IDENTIFIED CHANGE	SOURCE	REFERENCE/ COMMENTS	ACTION FOR REVALIDATION

Appendix E

Facility and Process Modification Checklist*

OBJECTIVE: To serve as an aid in identifying and recording changes that may have occurred in the process or facility. Changes will be reviewed during PHA revalidation sessions.

Facility Modifications	Response	Recommendations
1. Have buildings, trailers, etc., been constructed or relocated since the previous PHA such that they could be affected by a release?		
2. Have staffing levels changed since the previous PHA such that capabilities to quickly respond to emergency situations have diminished?		
3. Have traffic patterns (e.g., new rail spur, new chemical truck routing) changed since the previous PHA (e.g., could the process be affected by a new release source, can emergency responders reach the process easily, are external impacts more likely)?		
4. Has the operator training program remained substantially the same or been enhanced since the previous PHA?		
5. Have maintenance practices remained substantially the same or been enhanced since the previous PHA?		

* This checklist has been reproduced from Smith and Whittle (2000) and is provided for illustrative purposes only. Readers may wish to develop such a checklist specific to their own situation and needs.

Appendix **F**

Facility and Stationary Source Siting Checklist

Item No.	Question	Response	Recommendations
I. Spacing Between Process Components			
1	Are operating units and the equipment within units spaced to minimize potential damage from fires or explosions in adjacent areas?		
2	Are there safe exit routes from each unit?		
3	Has equipment been adequately spaced and located to safely permit anticipated maintenance (e.g., pulling heat exchanger bundles, dumping catalyst, lifting with cranes) and hot work?		
4	Are vessels containing highly hazardous chemicals located sufficiently far apart? If not, what hazards are introduced?		
5	Is there adequate access for emergency vehicles (e.g., fire trucks)?		
6	Can adjacent equipment or facilities withstand the overpressure generated by potential explosions?		
7	Can adjacent equipment and facilities (e.g., support structures) withstand flame impingement or radiant heat exposures?		
8	When provisions have been made for relieving explosions in process components, are the vents directed away from personnel and equipment locations?		

Appendix **G**

Human Factors Checklist*

Item No	Question	Response	Recommendations
I. Housekeeping and General Work Environment			
1	Are adequate signs posted near maintenance, cleanup, or staging areas to warn workers of special or unique hazards associated with the areas?		
2	Are adequate barriers erected to limit access to maintenance, cleanup, or staging areas?		
3	Are working areas generally clean?		
4	Are provisions in place to limit the time that a worker spends in an extremely hot or cold area?		
5	Is noise maintained at a tolerable level?		
6	Are alarms audible above background noise both inside the control room and in the process area?		
7	Is normal and emergency lighting sufficient for all area operations?		
8	Is there adequate backup power for emergency lighting?		
9	Is the general environment conducive to safe job performance?		
II. Accessibility/Availability of Controls and Equipment			
1	Are adequate supplies of protective gear readily available for routine and emergency use?		

* This checklist is provided for illustrative purposes only. Readers may wish to develop such a checklist specific to their own situation and needs.

What's Changed?

- Process changes have introduced new hazards or accentuated existing hazards
- Changes in on site or off site occupancy patterns that changed the at-risk populations
- New knowledge is now available to better understand the hazard potential, revealing potentially more severe consequences
- Actual incidents have revealed scenarios not previously identified in a PHA
- Safeguards previously credited in the PHA have been removed, compromised, or discredited.

Identify Revalidation Methodology

Keys to Success

- Revalidation Options
  - Update & Revalidate
  - Retrofit, Update & Revalidate
  - Redo
- Selecting the Revalidation Option

Conduct the Revalidation Study Sessions

Keys to Success

- Training – Covered Earlier
- Performing the Revalidation According to the Methodology Selected
- Special Considerations
  - Staying Productive
  - Facility Siting
  - Human Factors
  - Operating Procedures & Safe Work Practices
  - Wrap Up Discussions

Document the Revalidation Study

Keys to Success

- Documentation of Approach
- Documentation of Worksheets
- Author the Report
- Recommendation Documentation, Assignment and Follow up
- Records Retention and Distribution

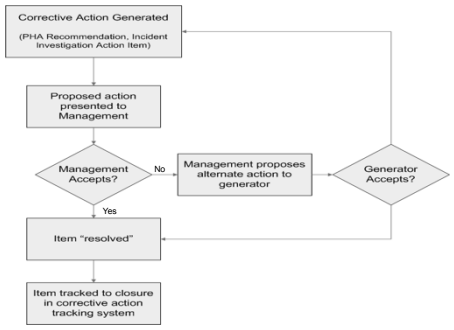
HAZOP

Recommendations

- I. High priority action items should be resolved within 4 months II.
- II.Medium priority action items should be resolved within 4-6 months
- III. Lower priority action items should be resolved following medium priority items.

Process Hazard Analysis (PHA)

- **Recommendations/Corrective Actions Resolution Process**



What's the Process?

PHA Revalidation Process
An Example Customized Process

- Why An Effective PHA is Necessary
- The PHA Re-Validation Process
- HAZOP Method Overview
- Overview of E Complex Process
- Overview of Last PHA Re-Evaluation
- Review Status of Audit Recommendations
- Review Status of Past PHA Recommendations
- Review Past E-Complex MOC's
- Review PHA Team Member's Change Checklist Results
- PHA Quality & Completeness Checklist Review
- Perform the PHA Revalidation Sessions
- Document the PHA Revalidation Study
  - Publish in Draft Form
  - Team and Management Review
  - Publish in Final Form
  - Assign Recommendation Responsibility and Track to Closure

PHA Revalidation Process

- PHA Re-Validation
- Final Review of Completed PHA's
- Review of PHA Recommendations Generated & Plan to Complete
- Next Steps – Preparing for the Report
- PHA Re-Validation Wrap Up

The Goal

An Effective PHA Revalidation
Maintaining System Integrity
Protecting the People

Let's Review An Example

Global Risk Management

Process Hazard Analysis Revalidation

GRM Chemical
Process Safety Management of Highly Hazardous and Explosive Chemicals

Version 1.0
Last Edited: 7/16/14

Steve Davis
Principle Consultant
GRM, Inc.

Table of Contents

Objectives

Objectives

The objective of this Process Hazard Analysis (PHA) Revalidation is to revalidate and combine the PHA's of the GRM Chemical Process and Storage Tank in June 2008, while adding qualitative analysis to the combined PHA's. The combining of these PHA's and the addition of the qualitative analysis is at the recommendation of the February 2014 Process Safety Management Corporate audit. In order to provide an effective PHA revalidation, the original 1993 and 1996 PHA's along with the 2007 and 2009 revalidations were included in the development of the new HAZOP worksheets for the combined PHA. This PHA revalidation is to ensure that all equipment, process modifications, operating instructions and safe work practices are properly studied.

The process system is located in the City of Smyrna, Georgia.

Process Boundary

The covered process of the PHA Revalidation is the GRM Chemical Process involving IPA and the IPA Storage Tank in the combined PHA. The physical process boundary of the equipment includes the following:

- IPA Chemical Process
  - IPA condenser
  - IPA Reactor
  - Cooling Tower
  - IPA Piping System Connected to Storage Tank
  - Associated equipment, piping, control valves and instrumentation
- IPA Storage Tank
  - IPA Storage Tank
  - IPA Storage Tank Fire Deluge System
  - IPA Storage Tank Dike System
  - IPA Process Sewer System
  - Associated equipment, piping, control valves and instrumentation

The PHA also included a revalidation of the PHA for operating instructions (or Standard Operating Procedures (SOP's) and Safe Work Practices related to the IPA Chemical and IPA Storage Tank and Unloading operations.

Summary of the PHA Revalidation Methodology

The following methodology was utilized for the PHA revalidation. The AIChe Center for Chemical Process Safety methodology for PHA revalidation was utilized to perform this revalidation. This process included the production and review of the entire PSM program documentation including the following:

- The team evaluated the documentation above to identify changes in the process equipment, design, operating procedures and safe work practices since the last PHA revalidation. (see documentation list in next section)
- The team completed the AIChe Center for Chemical Process Safety PHA revalidation checklists for the following areas to determine if any changes have occurred since last PHA revalidation or since original PHA's performed.
- The team reviewed any safety systems designs and management of change packages since last PHA.
- Completed a new PHA worksheet for both Chemical Process and IPA Storage Tank as recommended by the February 2014 PHA audit team and report. The new PHA worksheet included standard quantitative risk analysis for each node and deviation based on a standard five by five risk matrix (included in the addendum section. Quantitative analysis included likelihood, severity and detection. These values were multiplied to yield a Risk Priority Number (RPN).
- This new PHA worksheet was based on the original 1993 and 1996 PHA's and the PHA revalidations in 2007 and 2009.
- Based on the documentation reviewed and the new PHA worksheets completed, an action items list was developed and prioritized in accordance with the Risk Priority Number (RPN).
- The action items list was provided to Mead Westvaco management for follow up action and completion.

Based on the review of information detailed above, and the quality and completeness of the prior PHA's and PHA revalidations in addition to the February 2013 PHA audit recommendations, the GRM PHA revalidation team selected the **Retrofit, Update and Revalidate methodology** as defined by the CCPS.

The GRM PHA method of HAZOP was used in the completion of the new PHA worksheets.

The team also selected the digital management of this PHA revalidation and addendum documentation.

PHA Documentation Reviewed

The following documentation was reviewed in preparation for the PHA revalidation. This documentation is provided in electronic directories as addendums to this report.

Documents reviewed

1. Application (PHA boundary for Chemical Process and IPA Storage)
2. Employee Participation Plan in written program
3. Hazards of the Process – Chemical inventories and locations
   Toxicity – MSDS for IPA
4. Technology and Equipment in the Process ((current and red marked P&ID's reviewed and walked down in June and July 2014)
5. Mechanical Integrity documentation for vessels, relief systems, valves, etc.
6. PHA's – original 1993 and 1996 GRM and 2009 Revalidations
7. Facility Siting Documentation
8. Management of Change packages since the last PHA revalidation and corresponding P&ID red marked notations since last MOC
9. Operating Procedures – New GRM OI's.
10. Safe Work Practices for both Chemical Process and IPA Storage
11. PSM Training records
12. PHA Audit – GRM PHA 2nd Party Audit performed Corporate GRM PSM Audit Team
13. PHA Quality and Completeness Checklist
14. Facility & Process Modification Checklist
15. Facility Siting and Stationary Source Checklist
16. Human Factors Checklist

The documentation above was assembled in electronic form and studied by the team both before and during the PHA revalidation meetings. The hard copy documentation and most current P&ID's and current MOC packages were also assembled in the PHA revalidation meeting room for review by the team during the PHA revalidation and completion of the new PHA worksheets.

See the addendum sections in separate digital directories for documentation.

PHA Revalidation Team

The GRM PHA revalidation team consisted of the following team members:

PHA Revalidation Facilitator:	Steve Davis, GRM
GRM PSM Team Leader & Engineer:	John Smith
Engineering:	David Johnson
IPA Process:	William Johansen
IPA Process:	Mary Diedrik
IPA Process:	Helen Schumaker
Maintenance:	Ray Sanders
Chemical Storage:	Alex Morrison
Chemical Storage :	Dana Linden
Technician:	Jacob Smith
Safety:	Roy Rogers

The PHA revalidation team consisted of the necessary disciplines to perform an effective PHA revalidation.

PHA Validation Results

Previous PHA Results

The previous PHA results were reviewed and evaluated and found to be complete, but not include the necessary quantitative analysis elements required by applying recognized and generally accepted good engineering practices (RAGAGEP) in addition to the internal February 2014 GRM PSM Audit recommendations. Additionally, additional areas were also studied in the new PHA worksheets including the following:

- New PSM boundary adjustments that eliminated past PHA nodes and deviations
- New GRM operating instructions
- Additional review of IPA Storage Tank

These required revisions resulted in the decision to perform a the **Retrofit, Update and Revalidate methodology.**

Status of previous PHA action items lists

All previous PHA action items have been addressed. Additionally, complete MOC packages have detailed changes in the IPA Chemical Process & Storage Tank processes.

Past Incident Reports

Past Incident Reports were evaluated. Incidents required a review of the IPA storage tank hazards and design as noted above.

Management of Change Packages

Review of MOC packages indicated that changes in the process have been well documented with MOC packages completed on past and ongoing MOC's for the GRM processes.

Pre-Start Up Safety Review Documents

Review of the PSSR documentation indicated no changes since last PHA other than those documented in the MOC packages above.

Operating Instructions

New operating instructions have been recently developed for both GRM Chemical Process and IPA Storage operations. These operating instructions were studied as part of the new PHA revalidation. A recommendation was also developed to revise the current Chemical Process operating instruction.

Current Process Safety Information (PSI) and P&ID's

P&ID's were walked down, field verified, red marked and re-issued in July 2014 and found to be current and reflect the actual processes.

PHA Validation Results

Facility Siting

Prior facility siting documentation was reviewed with no changes found since the last PHA. This study was also confirmed by the completion of the facility siting checklist.

Human Factors Checklist

The prior human factors checklist completed indicated no action items.

List of New Safety Systems

Only one new safety system was noted installed since the last PHA. This new safety system not classified as a instrumented system, but a pressure gauge on the IPA storage tank due to a possible over pressurization condition suspected on the vessel. This 60 psi pressure gauge was installed to determine the pressure placed on the IPA storage tank due to an air pump pumping a certain load for tanker loading. The new safety system and the deviation created were studied as part of the PHA revalidation with recommendations developed.

New Action Items List

New action items were developed as part of this PHA revalidation and are listed in the following sections of this report document. The action item list was developed as a result of the completion of the PHA revalidation checklists in addition to the PHA worksheets.

Summary and Conclusions

The GRM PSM team has worked diligently to update PSI as a result of the recent PSM audit and also recent PSM training completed by members of the PSM team. The result is that process safety information is largely up to date.

The PHA revalidation method of **Retrofit, Update and Revalidate** was required due to the following:

- PSM Audit Recommendations February 2013
  - Qualitative Analysis
  - Combining of IPA Chemical Process and IPA Storage PHA revalidations
- New operating instructions for IPA Chemical Process and IPA Storage

Only one serious deviation was identified as part of the new PHA study involving the potential over pressurization deviation for the IPA storage tank. This deviation was already understood by the PSM team with management of change actions already underway. In that the deviation condition was still occurring, a recommendation was issued. The correction of this deviation was already underway and the conclusion of the validation.

The GRM PHA Revalidation team should be complimented for their dedication, time allocation and commitment to the completion of an effective PHA revalidation. The production of documentation, the completeness of the documentation and attention to detail during the HAZOP process resulted in an effective PHA revalidation.

Addendum I: Action Items List

The following action items were developed as part of this PHA revalidation. These recommendations were developed from both the completion of the checklists and the completion of the PHA study worksheets by the PHA team.

No.	Action Item	Priority (RPN)	Responsibility	Comments	Resolution
1.	Review design and safety instrumented systems for IPA Storage Tank to address potential over pressurization condition during tanker filling operations	40			
2.	Piping system labeling should be performed to identify those lines carrying HHC. Labeling should be properly maintained to withstand the environment.	1			
3.	Facility siting calculations should be performed to quantify the control building's and any occupied other building's capacity to withstand overpressure, and exposure to toxic or flammable vapors	10			
4.	Confirm IPA storage tank (bullet tank) pointing direction and the exposure to control rooms, other flammable or toxic chemical storage hazards. If hazard are present from pointing direction, quantify and address hazards	32			
5.	Address vehicular operational hazards to the IPA Process unit. Consider proper protection if required	10			
6.	Implement a card board or access card system for worker access / tracking in either the IPA Chemical & IPA Storage Tank covered process areas	1			
7.	Asset/ component tags in covered process areas of IPA Chemical Process & Storage Tank should match the callouts on the P&ID's. New labeling system should be implemented to accomplish following form.	10			
8.	The current PSM boundary signs do not adequately warn workers of the hazards of the process chemical. Signs for both the IPA Chemical Process & Storage Tank processes should properly warn employees of the hazards of IPA, i.e. Flammable and electrical classification and restrictions.	5			

Addendum II: PHA Quality & Completeness Checklist

Verification Question	Yes, No, Maybe	Evidence of Compliance	Comments on Adequacy of Compliance
Process Safety Information			
1. Is there evidence that the PSI was complete and available for the PHA team to use?	Yes		Provided in digital form and in hard copy for team review
2. Is there evidence that the PSI contained up to date P&ID's	Yes		Walked down, red marked and updated July 2013
3. Is there evidence that unit procedures were available	Yes		
4. Is there evidence that the PSI contained design temperatures and pressures for major equipment (e.g.vessels, heat exchangers, pump)?	Yes		On tank drawings and in SOP's
5. Is there evidence that the PSI contained relief design and set point data	Yes		Recent calculations were completed
6. Is there evidence that the PSI contained ventilation design data	Yes		
7. Is there evidence that PSI contained electrical classification drawings and information	Yes		
8. Is there evidence that the PSI contained list of materials of construction, flange ratings and temperature and pressure limits for piping (if this information was not on the P&ID's)	Partiall y		Update of MI currently underway
Hazard of the Process			
1. Are all the covered chemicals documented in the PHA report	Yes		
2. Are all pertinent hazards (fire, explosions, BLEVE's, toxicity, chemical burn, asphyxiation, etc.) associated with releases of all covered chemicals(HHC's) in the process addressed by the PHA?	Yes		
3. Is all equipment containing HHC's or that could contain HHC's addressed in the PHA?	Partiall y		PHA revision addresses changes in IPA storage tank Changes in boundary required revision to the PHA.
4. Is contamination of the process chemicals addressed in the PHA	N/A		
5. I loss of utilities addressed in the PHA	Maybe		Cooling tower / hill water documentation
6. Is the unit flare header addressed in the PHA?	N/A		
7. If the flare header is not covered in the PHA, will it be addressed in a separate PHA	N/A		
8. Were the MSDS reviewed by the PHA team?	Yes		
Previous Incidents with Potential for Catastrophic Release			
1. Is there evidence that the PHA team reviewed / discussed previous incidents associated with the unit?	Yes		
2. Is there evidence that near misses were included in the discussion of previous incidents	Yes		
Applicable Engineering & Administrative Controls			
1. Does the PHA report document the engineering and administrative controls applicable to the process hazards identified	Yes		

Addendum III: Human Factors Checklist

Housekeeping and General Work Environment			
1. Are adequate signs posted near maintenance, cleanup, or staging areas to warn workers of special or unique hazards associated with the areas?	Yes		
2. Are adequate barriers to limit access to maintenance, cleanup or staging areas?	Yes		
3. Are working areas generally clean?	Yes		Tour of both Chemical Process and IPA Storage confirmed
4. Are provisions in place to limit the time that a worker spends in extremely hot or cold area?	Yes		
5. Is noise maintained at a tolerable level?	Yes		
6. Are alarms audible above background noise inside the control room and in the process area?	Yes		
7. Is normal and emergency lighting sufficient for all area operations	Yes		
8. Is there adequate backup power for emergency lighting?	Yes		
9. Is the general environment conductive to safe job performance?	Yes		
Accessibility/Availability of Controls & Equipment			
1. Are adequate supplies of protective gear readily available for routine and emergency use?	Yes		
2. Are workers able to perform both routine and emergency tasks safely while wearing protective equipment?	Yes		
3. Is emergency equipment accessible without presenting further hazards to personnel?	Yes		
4. Is communications equipment and easily accessible?	Yes		New Motorola intrinsically safe radio system
5. Would others quickly know if a worker were incapacitated in the process area	Yes No		Yes in the Chemical Process area No in the Chemical Process Recommendation Action Item for Covered Process Access Card System
6. Are the right tools available and used when needed?	Yes		
7. Is the workplace arranged so that workers can maintain a good working posture while performing necessary movements to conduct routine tasks?	Yes		
8. Is access to all controls adequate?	Yes		
9. Can operators / maintenance workers safely perform all required routine / emergency actions, considering the physical arrangement of equipment?	Yes		
10. Are valves that require urgent manual adjustments easily identifiable and readily accessible?	No		Current asset tags are lockout tagout tags, not same callouts on P&ID's. Recommendation Action Item submitted

Labeling			
1. Is all-important equipment (vessels, pipes, valves, instruments, controls, etc.) legibly, accurately labeled?	No		See recommendation above for asset marking
2. Does the labeling program include components that are mentioned in the procedures even if they are not assigned as equipment number?	No		See recommendation above for asset marking
3. Has responsibility for maintaining and updating labels been assigned?	Yes		
4. Are emergency exit and response signs adequately visible and easily understood?	Yes		
5. Are signs that warn workers of hazardous materials or conditions adequately visible and easily understood?	No		PSM covered process signage notes the covered process, but not the hazards present in the process. Recommendation Action Item submitted to correct.
Feedback / Displays			
1. Is adequate information about normal and upset process conditions clearly displayed in the control room?	Yes		Consequences of upset are currently displayed on the control board
2. Are the controls and displays arranged logically to match operator's expectations	Yes		DCS system
3. Are the displays adequately visible from all relevant working positions?	Yes		DCS system
4. Do separate displays present similar information to a consistent manner?	Yes		
5. Are automatic safety features provided when a process upset requires rapid response?	Yes		
6. Are automatic safety features provided when a process upset may be difficult to diagnose due to complicated processing of various information?	Yes		DCS system and simplicity of system controls this issue
7. Are the alarms displayed by priority?	Yes		
8. Are critical safety alarms easily distinguishable from control alarms	Yes		
9. Is the alarm summary permanently on display?	Yes		
10. Are nuisance alarms correct and redundant alarms eliminated as soon as practical to help prevent complacency toward alarms?	Yes		
11. Have charts, tables or graphs been provided to reduce the need for operators to perform calculations as part of the operation?	N/A		DCS completes all operating calculations.
12. If operators are required to perform calculations, are critical calculations independently checked?	No		DCS completes all operating calculations
13. Does the computer check the values entered by operators are within a valid range?	N/A		
14. Do the displays provide an adequate view of the entire process as well as essential details of individual systems?	Yes		
15. Do the displays give ideate feedback for all operational actions?	N/A		
16. Are instruments, displays and controls promptly repaired after a malfunction?	Yes		
17. Do administrative features exist that govern when instruments, displays, or controls are deliberate disabled or bypassed and that govern their return to normal service at the appropriate time?	Yes		

Addendum IV: GRM PHA Revalidation Digital Documentation Addendum Directory

Addendum Sections Follow in Electronic Directories

2014 PHA HAZOP Worksheets – IPA Chemical & IPA Storage Tank
GRM IPA Chemical Process PSI
GRM IPA Chemical & IPA Storage Tank PSI
GRM PSM February 2014 Audit
GRM PSM Program Information
GRM PSM Program
GRM MOC Program GRM Mechanical Integrity Information
GRM PSM Training Documentation Block Flow Diagrams
P&ID's Chemical and IPA Storage
Historical PHA's
SOP's Chemical& IPA
2013 PHA Revalidation Worksheets & CCPS Documents

Plating Line 2
HCL Process

Original PHA Date; 6-27-2011
By: GRM

			2013 PHA HAZOP MEETING WORKSHEET						
LOCATION		GRM	Smyrna, GA						
PROCESS AREA		IPA CHEMICAL PROCESS AND IPA STORAGE TANK							
Node	Deviation	Cause	Consequence	Safeguards	Risk			RPN	Recommendations
					Probability	Severity	Detection		
1	3" Recovery IPA Storage Tank to Continuous Relief Ejector			Line carries Relief vapor to continuous Relief ejector					
1.1	High Pressure	Water valve left open after railcar loading	Rupture the recovery area storage tank	SOP; P/V Breaker if the valve is reopened after loading	1	5	3	15	Need a pressure gauge and pressure relief valve on the tank
1.2	Low Pressure	Ejector pulling too hard	Collapse the tank	P/V Breaker	1	5	3	15	
1.3	High Temp	Flame in Relief Line	Explode the tank	Flame Arrester	1	5	1	5	
2	3" IPA Line to Railcars			Line carries mill water to Conductivity probe to allow flushing of the					
2.1	High Pressure	Water valve opened to far						0	
2.2	Impurities	Water in line	Quality Issue					0	
2.3	High Temp	Static Charge		added ground indicator	4	4	1	16	is there continuity bond between line and rail car
3	2" Chemical IPA Pump to Recovery Storage			Line carries liquid IPA from the pump at the Chemical Storage Tank to the Storage Tank in Recovery					
3.1	High Temp	Pump / Motor Failure	Explosion / Fire Hazard	Over limit switch; Grounded	2	4	1	8	
3.2	No Flow	Hand Valve closed at Storage Tank	No IPA pumped out to the recovery storage area	Operator attention to high level alarm at Chemical storage tank	1	1	5	5	Confirm level alarms. Is there a high high alarm?
3.3	Start-Up / Shutdown	Static charge due to piping configuration (vertical drops too long causing liquid to develop charge)	Explosion / Fire Hazard	None	1	5	1	5	
4	3" IPA Storage to Conductivity Probe - Allow Flushing of Probe			Line carries mill water to Conductivity probe to allow flushing of the probe.					
4.1	Low Pressure	Ejector pulling too hard	Collapse the tank	P/V Breaker and Relief System to sewer	1	5	3	15	
4.2	Equip Testing	Conductivity Probe out of calibration	Dump IPA to sewer; Pulp Mill can't pump over if too high		4	1	8	32	low impact
4.3	Product Testing	Not unloading on time	IPA overflows to sewer	SOPs	1	1	1	1	How is this addressed by SOPs and what is the detection
5	Conductivity Flush to Drain			Line carries water / IPA from conductivity probe to sewer					
5.1	Low Pressure	Ejector pulling too hard	Collapse the tank	P/V Breaker and Relief System to sewer	1	5	3	15	
5.2	Equip Testing	Conductivity Probe out of calibration	Dump IPA to sewer; Pulp Mill can't pump over if too high		4	1	8	32	low impact
5.3	Product Testing	Not unloading on time	IPA overflows to sewer	SOPs	1	1	1	1	How is this addressed by SOPs and what is the detection
6	2" Batch IPA Pump to Chemical IPA Transfer Line			Batch Process					
6.1	Reverse Flow			Failure of check valve	3	2	9	54	
6.2	High Temperature			Operator Attention	1	5	1	5	
6.3	Low Flow							0	
7	3" Chemical Storage Tank to Chemical IPA Pump			Carries IPA from the top of the Chemical storage tank to the transfer					
7.1	High Temperature			Proper Procedures Hot Work Permit	1	4	1		
7.2	Equipment			leakage of 50 gallon to dike to sump	4	1	6		
7.3	Electrical			Continuity straps	1	4	2		

Plating Line 2
HCL Process

Original PHA Date; 6-27-2011
By: GRM

[illegible]

Plating Line 2
HCL Process

Original PHA Date; 6-27-2011
By: GRM

8	3" Chemical Storage Tank to Chemical IPA Pump			Carries IPA from the top of the Chemical storage tank to the transfer pump					
8.1	High Temperature	External Heat	Fire or Explosion	Proper Procedures Hot Work Permit	1	4	1	4	
8.2	Electrical	Static Charge	Fire or Explosion	Continuity straps	1	4	2	8	
9	2" Chemical Storage Tank Vent to Continuous Relief Ejector			Line carries vapor from Chemical Storage Tank to Continuous Relief Ejector				0	
9.1	High Pressure	Poor cooling in Condenser and / or gas cooler	PV Breaker / Rupture Disk relieves	PV Breaker first / Rupture Disk relieves	1 /1	1 / 1	1	1	
9.2	High Temp							0	
	Internal			Bonding Straps / Flame Arresters	1	3	2	6	
	External			Hot Work Permits	1	3	3	9	sprinkler system and deluge system into MI NOTE: THERE IS NO FIRE PROTECTION IN THE BATCH. THE TEAM RATED THIS LIKE THERE WAS A SPRINKLER AND DELUGE SYSTEM! THERE IS NEITHER.
10	2" IPA Reactor (27-77-013) Vent to Continuous Relief Ejector			Line carries vapor from Chemical Reactors to Continuous Relief Ejector				0	
10.1	High Pressure	Poor cooling in Condenser and / or gas cooler	PV Breaker / Rupture Disk relieves	PV Breaker first / Rupture Disk relieves	1 /1	1 / 1	1	1	
10.2	High Temp							0	
	Internal			Bonding Straps / Flame Arresters	1	3	2	6	
	External			Hot Work Permits	1	3	3	9	
11	3" Relief System - Chemical Storage Tank to Sewer			Line provides a seal loop for Chemical storage tank					
11.1	High Flow	Syphon effect	Air infiltration to Relief Header	??				0	original recommendation was to add water and for seal loop to prevent syphon - is there?
11.2	Equip Testing	No water in seal loop	Air infiltration to Relief Header	??				0	is there seal loop and vent
12	3" Chemical Storage Tank to Sewer			Carries IPA from Chemical storage tank to the sewer					
12.1	High Flow	Valve left open	Fire Hazard	Operator Training	1	4	5	20	is there a level indicator in the sump and if so put it in p&id; does this go to the sewer or dike?
13	1" IPA Reactor (27-77-013) Relief System to Continuous Relief Ejector			Carries vapors from Reactor seal loops to continuous Relief ejectors				0	
13.1	High Pressure	Poor cooling in Condenser and / or gas cooler	PV Breaker / Rupture Disk relieves	PV Breaker first / Rupture Disk relieves	1 /1	1 / 1	1	1	
13.2	High Temp							0	
	Internal			Bonding Straps / Flame Arresters	1	3	2	6	
	External			Hot Work Permits	1	3	3	9	
14	4" IPA Reactor (27-77-013) to IPA Transfer Loop (Relief System bypass)			Carries IPA overflow from Reactor to the IPA Transfer Loop bypassing the Relief System					
14.1	High Flow	No credible cause						0	
14.2	Impurities	Drain Valve Left open	IPA overflows to sewer		1	1	10	10	
15	4" IPA Reactor (27-77-006) to IPA Transfer Loop (Relief System bypass)			Carries IPA overflow from Reactor to the IPA Transfer Loop bypassing the Relief System					
15.1	High Flow	No credible cause						0	
15.2	Impurities	Drain Valve Left open	IPA overflows to sewer		1	1	10	10	
16	4" IPA Reactor (27-77-013) Relief System to IPA Transfer Loop			Carries IPA overflow from Reactor to the IPA Transfer Loop through the Relief System					
16.1	High Flow	No credible cause						0	
16.2	Impurities	Drain Valve Left open	IPA overflows to sewer		1	1	10	10	

There are 78 More Pages of Worksheets

PHA Revalidation Process

- Pre-PHA Revalidation Documentation Assembly
- Pre-PHA Revalidation Documentation Review
- Assembly of PHA Team
- Schedule PHA Revalidation
- Name a Scribe
- Complete CCPS PHA Revalidation Checklists
- Determine PHA Revalidation Method
- Perform PHA Revalidation / PHA Worksheet Completion
- PHA Review of PHA Recommendations Generated & Plan to Complete
- Prepare PHA Revalidation Report & Submit to Team for Review
- PHA Re-Validation Report Finalizing & Publishing
- Establish Action Plan for Recommendations

Process Safety Management of Highly Hazardous & Explosive Chemicals

Management of Change
29CFR1910.119(l)

What if Our PHAs (or a project, or just a random idea) Reveal the Need to Change Something?

We Must Use Management of Change (MOC)

Management of Change

1910.119(l)

The employer shall establish and implement written procedures to manage changes (except for "replacements in kind") to process chemicals, technology, equipment, and procedures; and, changes to facilities that affect a covered process.

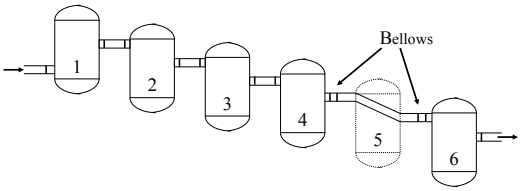
Management of Change - Why?

- Many of the catastrophic accidents over the past few decades can be traced, in large part, to a management of change system that was not in place or was not functional (e.g., Flixborough, Bhopal).

Case Study: Flixborough

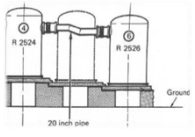
- Vapor cloud explosion - fueled by release of 30 tons of cyclohexane
- Largest single loss by fire or explosion in the United Kingdom
  - killed 28 people
  - injured 89 others
  - $63 million in property damage

MOC Cause: Temporary Modification



Why did the Bypass Piping Fail

- No safety review and inadequate supervision
- Job was beyond professional capabilities of the workers
- Only drawing was a full-size sketch in chalk on the workshop floor.
- No one understood the forces that would be imposed on the pressurized piping



What Was Learned?

- A proper MOC procedure could have prevented this accident.
- One of main recommendations from inquiry
  - Any modification should be designed, constructed, tested, and maintained to the same standards as the original plant.

Failures in MOC

- Vapor cloud explosion and major fire within a refinery
  - 7 deaths
  - 13 injuries
  - $35 million in losses (half in property damage, half in business interruption)
- Cause: Hidden Change to a valve

Failures in MOC

- Storage tank containing flashing, flammable fluid.
- Tank was connected to process unit via 10" line
- Corrosion attacked valve bonnet bolts and weakened them.
- Bonnet was blown off and an uncontrolled, catastrophic release occurred.

Can Changes Affect Everything in Our Program?

- Might Affect:
  - Process Information
  - Process Toxicity
  - Technology of the Process
  - Equipment in the Process
  - Mechanical Integrity
  - Inspection & Testing
  - Quality Assurance
- Might Affect:
  - PHAs
  - Operating Procedures
  - Safe Work Practices
  - Training for Both Employees & Contractors
  - Compliance Audits

Basically….Everything!

Management of Change (MOC)

Management of Change (MOC) is a process for **evaluating** and **controlling modifications** to facility design, operation, organization, or activities – *prior to implementation* – to make certain that **no new hazards are introduced** and that the **risk of existing hazards** to employees, the public, or the environment are **not unknowingly increased**.

CCPS Guidelines for Management of Change for Process Safety, Wiley, 2008

Management of Change (MOC)

- **MOC is one of the most important elements of process safety**
  - MOC has been called a minute-by-minute risk assessment control system in plants and companies.
  - It affords the opportunity to review changes which occur after the PHA has been completed. In fact, some changes are large or complex enough to require a PHA in and of themselves.
  - A change is any modification to process chemicals, technology, equipment, or procedures and changes to facilities that affect a covered process except for replacement in kind (satisfies the design speciation).

CCPS Guidelines for Management of Change for Process Safety, Wiley, 2008

Management of Change (MOC)

- Summary of Requirements
  - Written Program – "Written procedures to manage changes to process chemicals, technology, equipment, and procedures; and changes to facilities that affect a covered process"
  - Considerations must address:
    - Technical basis for change *(why the change is desired)*
    - Safety and health impacts
    - Modifications to procedures
    - Necessary time period for the change *(duration for temporary changes)*
    - Authorization requirements for the proposed change
  - All potentially affected employees and contractors must be informed of and trained in the change prior to the change
  - PSI, procedures, or practices must be updated accordingly
  - Exempts "replacements in kind"

MOC Application

- Management of Change should be Completed on BOTH:
- Temporary
- Permanent Changes

MOC

Replacement in Kind

- A replacement that satisfies the design specifications.
- Examples
  - raising reactor temp. within safe operating envelope
  - replacing equipment or piping meeting the same specifications as the original

Emergency MOC Procedures

- Program must manage Emergency Changes
- Should set limits for when allowable and how authorizations will be obtained
- "Paperwork" must follow very closely behind

Management of Change

- Important March 31, 2009 Letter From OSHA:

"Some organizational changes such as changes resulting from mergers, acquisitions, reorganizations, staffing changes or budget revisions, may affect PSM at the plant level and would therefore trigger a PSM MOC procedure"

Management of Change (MOC) Pre-Modification Issues

- Check codes, standards, internal engineering specifications
- Complete design review
- Perform reactivity testing for new substances
- Add materials to TSCA/SARA inventories
- Complete safety and health impact review
- Comply with safety and loss prevention requirements

Remember all the Codes We Have Already Discussed

Management of Change (MOC) Pre-Modification Issues

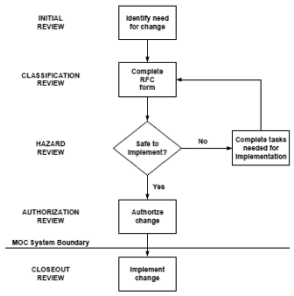
- Complete maintenance review/revise spare parts list
- Evaluate change against vent, relief, and flare capability
- Complete industrial hygiene review
- Review change against existing environmental permits
- Obtain required approvals
- Complete training on change for affected employees*
- SOPs marked-up
- P&IDs, PFDs, plot plans and other affected Process Safety Information (PSI) marked-up

Management of Change (MOC) Post-Modification Action Items

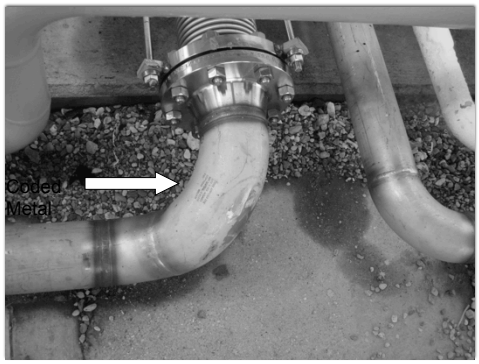
- Complete Pre-Start Up Safety Review (PSSR)
- Complete training on change for affected employees*
- SOPs issued effective
- P&IDs, PFDs, plot plans and other affected Process Safety Information (PSI) updated
- Training program modifications identified
- Preventive maintenance program modifications identified
- Mechanical Integrity information/files/records CMMS updated

Management of Change (MOC)

- **Generic MOC Process**



CCPS Guidelines for Management of Change for Process Safety, Wiley, 2008



What Type of Stainless? What type of Nozzle?

Management of Change (MOC)
To MOC or not to MOC? Class Exercise

1. You need to change the set point of a relief valve. MOC or no MOC?

Yes – this is a process control change outside of established limits

2. You are changing a solvent used to clean and flush piping in the covered process. MOC or no MOC?

Yes – there could be material of construction issues (corrosivity, material/process compatibility, etc.)

Management of Change (MOC)
To MOC or not to MOC? Class Exercise

- **To MOC or not to MOC? Class Exercise**

3. You are replacing an ASME code vessel with an API code vessel.

Yes – this is a code and application change although the design may be similar.

4. You are substituting an identical process chemical from another supplier.

It Depends

5. You are upgrading a section of pipe from carbon steel to stainless steel.

Yes – process material could be more corrosive to stainless than carbon steel. This is a change in equipment

How NASA Manages Initiation and Management of MOC

NASA MANAGEMENT OF CHANGE

Facility: E1 Process: HY MOC- E1HY - 0084

Title: Reset lifting pressure for RV-10A2337-LH

Type of Change: Equipment Change

MOC Required Change: Permanent Temporary

If Temporary, expiration date of MOC:

Completion Date: September 7, 2012 MOC Created Date: August 16, 2012

Summary of Change:
Reset the lifting pressure for RV-10A2337-LH from 155 psig to 150 psig.

Technical Reason for Change:
Protect the flex hoses (FH-10A4387-LH and FH-10A4388-LH) with a working pressure of 150 psig.

Safety Impact of Change:
System is protected in case of overpressurization.

Impact on Employees:
Minimal impact on employees. Employees will be safe when around the purge system.

Pre Modification Checklist (Completed prior to implementing change/modification)
Check any and all PSM items to be affected by the proposed change

Applicable	N/A	Process Safety Management Items Affected
X		Employee Participation
X		Process Safety Information
	X	Process Hazard Analysis
X		Mechanical Integrity of Process Equipment
	X	Pre Start-up Safety Review
X		Operating Procedures
		List Affected Procedures:
	X	Employee Training
	X	Hot Work Permit
	X	Emergency Planning and Response
	X	Trade Secrets
X		Contractors Notification: Lockheed Martin
		Other:

Originator: Date: 8/10/12
NASA Ops Manager/Test Director: Date: 8/10/12
Affected Contractor: Date: 8/10/12
Contractor SMMA: Date: 8/14/12
Affected PSM Lead: Date:
Other: Date: 8/14/12
Verification of Completed MOC
NASA SMA: Date:

Attach a copy of the completed MOC Form to the applicable EO/ECN.
Original MOC Form to be filed with implementation WAD.

Management of Change Summary

- We must establish and implement written procedures to manage changes except "replacements in kind" for a covered process.
- If a change in design or components is required, management of change must be employed, tracked, and analyzed.
- All P&IDs, procedures, equipment information, ETC. must be updated to reflect the change.
- Work-site employees and contract employers must be informed and trained on the changes prior to start-up.

PSM Documentation - Technology Use

- Consider the Use of Technology to:
  - Perform
  - Document
  - Track
  - Adjust
  - Maintain

The PSM Program

Process Safety Management of Highly Hazardous & Explosive Chemicals

Pre-Start Up Safety Review (PSSR)
29CFR1910.119(i)

PSSR- Why?

Pre-Start Up Review

- The employer shall perform a pre-startup safety review for new facilities and for modified facilities when the modification is significant enough to require a change in the process safety information.

Pre-Start Up Review

- The pre-startup safety review shall confirm that prior to the introduction of highly hazardous chemicals to a process
- Construction and equipment is in accordance with design specifications
- Safety, operating, maintenance, and emergency procedures are in place and are adequate

Pre-Start Up Review

- For new facilities, a process hazard analysis has been performed and recommendations have been resolved or implemented before startup; and modified facilities meet the requirements contained in management of change
- Training of each employee involved in operating a process has been completed.

Pre-Start Up Safety Review

- Must be specific for the covered process
- May require additional programs other than Lockout Tagout, Line Opening & Hot Work…such as Confined Space, Electrical Safe Work Practices, Combustible Dust

Process Safety Management of Highly Hazardous & Explosive Chemicals

Process Hazard Analysis
29CFR1910.119(e)

The Goal

An Effective PHA Revalidation
Maintaining System Integrity
Protecting the People