Process Safety Management of Highly Hazardous & Explosive Chemicals

Process Hazard Analysis
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’s)

- Arguably the Most Difficult Part of Performing the Standard
- Performed by Your PSM Team
- Takes Significant Time & Effort

Remember…
Process Equipment
Numbering

V-267-LH
MAWP 150 PSI G

HYDROGEN
FLAMMABLE GAS
-NO SMOKING-
NO OPEN FLAMES
You Developed a List of Equipment Elements
Choose a PHA Process Method

- 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
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 S and H effects
- Consequences of deviation
- Steps required to correct or avoid deviation
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- Human factors
- Qualitative evaluation of S and H effects
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- Steps required to correct or avoid deviation
PHA Risk Analysis

**Risk Ranking Matrix**

- **Likelihood**:
  - Frequent
  - Likely
  - Unlikely
  - Rare
  - Extraordinary

- **Severity**:
  - Negligible
  - Minor
  - Major
  - Severe
  - Disastrous

- **Significant Risk**
- **Insignificant Risk**
Choose a PHA Process Method

- 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
Let’s Choose HAZOP to Study
The Most Common Method used for PHA’s
The HAZOP 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.
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 Process

- Hazard - any operation that could possibly cause a catastrophic release of toxic, flammable or explosive chemicals or any action that could result in injury to personnel.

- Operability - any operation inside the design envelope that would cause a shutdown that could possibly lead to a violation of environmental, health or safety regulations or negatively impact profitability.
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 schedule team meetings. Leads the team in the analysis of the selected process keeping team members focused on discovering hazards associated with the process and directs the team scribe in recording the results of the teams findings.
HAZOP Engineers

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

Guidewords:
- No
- More
- Less
- As Well As
- Reverse
- Other Than
HAZOP

Selection of Parameters

Application of parameters will depend on the type of process being considered, the equipment in the process and the process intent.

- Specific Parameters
  - Flow
  - Temperature
  - Pressure
  - Composition
  - Phase
  - Level
  - Relief
  - Instrumentation

“There are more”
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.
**HAZOP**

Deviations - Three Basic Types

- **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

Deviations

- **Equipment failure** in which a mechanical, structural or operating failure results in the release of hazardous or flammable material.
**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.
The primary purpose of the HAZOP is identification of scenarios that would lead to the release of hazardous or flammable material into the atmosphere, thus exposing workers to injury.
HAZOP

Consequences

- it will help to determine a risk ranking in HAZOPs where multiple hazards are uncovered
- it will help make the determination as to whether a particular deviation results in an operability problem or hazard.
Safeguards should be included whenever the team determines that a combination of cause and consequence presents a credible process hazard.
Those systems, engineered designs and written procedures that are designed to prevent a catastrophic release of hazardous or flammable material.
Those systems that are designed to detect and give early warning following the initiating cause of a release of hazardous or flammable material.
Those systems or written procedures that mitigate the consequences of a release of hazardous or flammable material.
Recommendations are made when the safeguards for a given hazard scenario, as judged by an assessment of the risk of the scenario, are inadequate to protect against the hazard.
HAZOP

Recommendations

I. High priority action items should be resolved within 4 months.

II. Medium priority action items should be resolved within 4-6 months.

III. Lower priority action items should be resolved following medium priority items.
Using HAZOP

Let’s Explore a PHA Process
A PHA Process Must be Performed on Each Component of the Covered Process:

- A PHA From Block Diagram to P&ID to Every Equipment Component to Determine What Might Happen if an Element of the Covered Process Fails

Those in the one day course will remember this…
### Table: Containment Analysis

<table>
<thead>
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### Components

- Control valve CV-32
- Control system

Session: 07/02/2000
Node: Node 2, Flow
Drawing: CLC/01-07-66
Parameter: Flow

Intention: Flow approximately 1 - 5 lbs/min of liquid chlorine, at 100-150 psig, from the railcar to the vaporizer.
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**Revision:** 0
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<td>1.2. Rupture disk discharging to expansion tanks are provided for the section of the piping between VLJQA and VLJQB - PCVGASC and PCVGASB (downstream of vaporizer)</td>
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<td>3.1.1. Falling closed, or accidentally closing, a single valve will not result in overpressure since line is open to either end</td>
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**Press F1 for Help**
### PHAWorks 5.0 Evaluation

**Session:** 07/02/2000  
**Node:** (2) Cl2 liquid to vaporizer  
**Drawings:** CLC/01-07-66  
**Parameter:** Flow  
**Intention:** Flow approximately 1 - 5 lbs/min of liquid chlorine, at 100-150 psig, from the railcar to the vaporizer.

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<td>2.1.2.2. *Investigate the design requirements for rupture disk valves with design of vaporizer</td>
<td>2.1.2.3. *Verify Chlorine *2 requirements for rupture disk valves with design of vaporizer</td>
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**Recommandation:** No recommendation
### Risk Factors

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**Intention:** Flow approximately 1 - 5 lbs/min of liquid chlorine, at 100-150 psig, from the railcar to the vaporizer.
### Recommendations

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- **2.1.1.** Rupture disk discharging to expansion tanks are provided for the section of the piping between:
  - VIQA and VIQB
  - PCVGASC and PCVGASB (downstream of vaporizer)

- **2.1.2.** Failing closed, or accidentally closing, a single valve will not result in overpressure since line is open to either end

**No recommendation for: 1.2.2.**

**No recommendation for: 2.1.1.**

**2.1.2.** *Investigate the requirement for chlorine feed valves and design overpressure setting (37 psig) to the rupture disk.*
Continue the PHA Process UNTIL...
### PHAWorks 5.0 Evaluation

**Session:** 07/02/2000  
**Node:** Cl2 liquid to vaporizer  
**Drawings:** CLC/01-07-66  
**Parameter:** Flow  
**Intention:** Flow approximately 1 - 5 lbs/min of liquid chlorine, at 100-150 psig, from the railcar to the vaporizer.

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1.2.2. Rupture disk discharging to expansion tanks are provided for the section of the piping between 
- VIQA and VIQB  
- PCVGASC and PCVGASB (downstream of vaporizer)  
1.3. Failing closed, or accidentally closing, a single valve will not result in overpressure since line is open to either end  
1.4. Rupture disk discharging to expansion tanks are provided for the section of the piping between  
- VIQA and VIQB  
- PCVGASC and PCVGASB (downstream of vaporizer) | 4 | 4 | 9 | No recommendation |
| 2  |     | 1. Control system incorrectly activates shutdown for “rupture” condition | 2.1. Potential overpressure of Cl2 piping if liquid-filled, closed piping heats up | 2.1.2. Rupture disk discharging to expansion tanks are provided for the section of the piping between  
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- PCVGASC and PCVGASB (downstream of vaporizer)  
1.3. Failing closed, or accidentally closing, a single valve will not result in overpressure since line is open to either end | 3 | 4 | 8 | No recommendation |
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- PCVGASC and PCVGASB (downstream of vaporizer)  
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**All Components**
**Example: Node 2, Flow**

**Session**: 07/02/2000  
**Node**: Cl2 liquid to vaporizer  
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1.1.2. Operator response to a shutdown of the system would be immediate  
1.2.1. All valves (ball valves) in liquid Cl2 service are provided with a port to vent the ball cavity  
1.2.2. Rupture disk discharging to expansion tanks are provided for the section of the piping between - VLQJ and VLQB  
- PCVGA and PCVGB (downstream of vaporizer)  
2.1.1. Rupture disk discharging to expansion tanks are provided for the section of the piping between - VLQJ and VLQB  
- PCVGA and PCVGB (downstream of vaporizer)  
2.1.2. Failing closed, or accidentally closing, a single valve will not result in overpressure since line is open to either end | 449  
348  
449  
No recommendation | 449  
No recommendation | 2.1.1. *Investigate the design of the rupture disks for these tanks and verify the pressure setting (37 psig) of the rupture disk  
2.1.2. *Verify Chlorin requirements for verification valves with design or working valves |

**All Nodes**
### PHA Works 5.0 Evaluation

**Session:** 07/02/2000  
**Node:** C12 liquid to vaporizer  
**Drawings:** CLC/01-07-66  
**Parameter:** Flow  
**Intention:** Flow approximately 1 - 5 lbs/min of liquid chlorine, at 100-150 psig, from the railcar to the vaporizer.

<table>
<thead>
<tr>
<th>G/Y</th>
<th>DEVIAION</th>
<th>CAUSES</th>
<th>CONSEQUENCES</th>
<th>SAFEGUARDS</th>
<th>S</th>
<th>L</th>
<th>R</th>
<th>REF#</th>
<th>RECOMMENDATION</th>
</tr>
</thead>
</table>
| No  | No Flow  | 1. Control valve CV-32 fails closed  
2. Control system incorrectly activates shutdown for "rupture" condition  
3. Control valve closes due to incorrect signal or setting  | 1.1. Interruption to production operation due to deviation of Cl₂ flow from setpoint causing control system to shut down process  
1.2. Potential overpressure of Cl₂ piping if liquid-filled, closed piping heats up  
3.1. Interruption to production operation due to deviation of Cl₂ flow from setpoint causing control system to shut down process  | 1.1.1. Failing closed, or accidentally closing, a single valve will not result in overpressure since line is open to either end  
1.1.2. Operator response to a shutdown of the system would be immediate  
1.2.1. All valves (ball valves) in liquid Cl₂ service are provided with a port to vent the ball cavity  
1.2.2. Rupture disk discharging to expansion tanks are provided for the section of the piping between - VUQA and VUQB  
- PCVGA/C and PCVGA/B (downstream of vaporizer)  
2.1.1. Rupture disk discharging to expansion tanks are provided for the section of the piping between - VUQA and VUQB  
- PCVGA/C and PCVGA/B (downstream of vaporizer)  
2.1.2. Failing closed, or accidentally closing, a single valve will not result in overpressure since line is open to either end  | 4 4 7 | No recommendation |

*All Causes*

**Press F1 for Help**
## All Consequences

### Causes:

1. Control valve CV-32 fails closed
2. Control system incorrectly activates shutdown for "rupture" condition
3. Control valve closes due to incorrect signal or setting

### Consequences:

1.1. Interruption to production operation due to deviation of Cl₂ flow from setpoint causing control system to shut down process
1.2. Potential overpressure of Cl₂ piping if liquid-filled, closed piping heats up

### Safeguards:

- Investigate the reduction of the rupture disk sizes of expansion tanks and safety relief valve pressure setting (37 psi) on the rupture disk
- Verify Chlorine services with design of valves with design of valves

### Recommendations:

- No recommendation

**Revision:** 0
<table>
<thead>
<tr>
<th>GYV</th>
<th>DEVIATION</th>
<th>CAUSES</th>
<th>CONSEQUENCES</th>
<th>SAFEGUARDS</th>
<th>R</th>
<th>RECOMMENDATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>No</td>
<td>No Flow</td>
<td>1. Control valve CV-32 fails closed</td>
<td>1.1. Interruption to production operation due to deviation of Cl₂ flow from setpoint causing control system to shut down process</td>
<td>1.1.1. Falling closed, or accidentally closing, a single valve will not result in overpressure since line is open to other end</td>
<td>4</td>
<td>No recommendation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2. Control system incorrectly activates shutdown for “rupture” condition</td>
<td>1.2. Potential overpressure of Cl₂ piping if liquid-filled, closed piping heats up</td>
<td>1.2. Rupture disk discharging to expansion tanks are provided for the section of the piping between - VLQA and VLQB - PCVGASC and PCVGASB (downstream of vaporizer)</td>
<td>3</td>
<td>No recommendation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3. Control valve closes due to incorrect signal or setting</td>
<td>2.1. Potential overpressure of Cl₂ piping if liquid-filled, closed piping heats up</td>
<td>2.1. Rupture disk discharging to expansion tanks are provided for the section of the piping between - VLQA and VLQB - PCVGASC and PCVGASB (downstream of vaporizer)</td>
<td>3</td>
<td>No recommendation</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3.1. Interruption to production operation due to deviation of Cl₂ flow from setpoint causing control system to shut down process</td>
<td>3.1.1. Falling closed, or accidentally closing, a single valve will not result in overpressure since line is open to other end</td>
<td>4</td>
<td>No further recommendations</td>
</tr>
</tbody>
</table>

All Safeguards
# All Risk Levels

## PHA Evaluation

**Session:** 07/02/2000  
**Node:** Cl2 liquid to vaporizer  
**Parameter:** Flow  
**Intention:** Flow approximately 1 - 5 lbs/min of liquid chlorine, at 100 - 150 psig, from the railcar to the vaporizer.

<table>
<thead>
<tr>
<th>G/V</th>
<th>DEVIATION</th>
<th>CAUSES</th>
<th>CONSEQUENCES</th>
<th>SAFEGUARDS</th>
<th>RECOMMENDATION</th>
</tr>
</thead>
</table>
| No  | No Flow   | 1. Control valve CV-32 fails closed  
2. Control system incorrectly activates shutdown for “rupture” condition  
3. Control valve closes due to incorrect signal or setting  
1.1 Interruption to production operation due to deviation of Cl2 flow from setpoint causing control system to shut down process  
1.2 Potential overpressure of Cl2 piping if liquid filled, closed piping heats up  
3.1 Interruption to production operation due to deviation of Cl2 flow from setpoint causing control system to shut down process  
1.1.1 Failing closed, or accidentally closing, a single valve will not result in overpressure since line is open to either end  
1.1.2 Operator response to a shutdown of the system would be immediate  
1.2.1 All valves (ball valves) in liquid Cl2 service are provided with a port to vent the ball cavity  
1.2.2 Rupture disk discharging to expansion tanks are provided for the section of the piping between  
- VUQA and VUQB  
- PCVGASC and PCVGASB (downstream of vaporizer)  
2.1.1 Rupture disk discharging to expansion tanks are provided for the section of the piping between  
- VUQA and VUQB  
- PCVGASC and PCVGASB (downstream of vaporizer)  
2.1.2 Failing closed, or accidentally closing, a single valve will not result in overpressure since line is open to either end  
2.1.3 Investigate the calculation and use of the rupture disks to ensure that the rupture disks and pressure setting (37 psi) will work as designed  
2.1.4 Verify Chlorin requirements for very small valves with design orifice size valves | 4 | 4 | 9 | No recommendation |
| No  | No Flow   | 1. Control valve CV-32 fails closed  
2. Control system incorrectly activates shutdown for “rupture” condition  
3. Control valve closes due to incorrect signal or setting  
1.1 Interruption to production operation due to deviation of Cl2 flow from setpoint causing control system to shut down process  
1.2 Potential overpressure of Cl2 piping if liquid filled, closed piping heats up  
3.1 Interruption to production operation due to deviation of Cl2 flow from setpoint causing control system to shut down process  
1.1.1 Failing closed, or accidentally closing, a single valve will not result in overpressure since line is open to either end  
1.1.2 Operator response to a shutdown of the system would be immediate  
1.2.1 All valves (ball valves) in liquid Cl2 service are provided with a port to vent the ball cavity  
1.2.2 Rupture disk discharging to expansion tanks are provided for the section of the piping between  
- VUQA and VUQB  
- PCVGASC and PCVGASB (downstream of vaporizer)  
2.1.1 Rupture disk discharging to expansion tanks are provided for the section of the piping between  
- VUQA and VUQB  
- PCVGASC and PCVGASB (downstream of vaporizer)  
2.1.2 Failing closed, or accidentally closing, a single valve will not result in overpressure since line is open to either end  
2.1.3 Investigate the calculation and use of the rupture disks to ensure that the rupture disks and pressure setting (37 psi) will work as designed  
2.1.4 Verify Chlorin requirements for very small valves with design orifice size valves | 4 | 4 | 9 | No further recommendation |
## PHAWorks 5.0 Evaluation

### Example: Node 2, Flow

**Session:** 07/02/2000  
**Node:** C2 liquid to vaporizer  
**Drawings:** CLC/01-07-66  
**Parameter:** Flow  
**Intention:** Flow approximately 1 - 5 lbs/min of liquid chlorine, at 100-150 psig, from the railcar to the vaporizer.

### All Recommendations

<table>
<thead>
<tr>
<th>No.</th>
<th>DEVIATION</th>
<th>CAUSES</th>
<th>CONSEQUENCES</th>
<th>SAFEGUARDS</th>
<th>REF#</th>
<th>RECOMMENDATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>No Flow</td>
<td>1. Control valve CV-32 fails closed</td>
<td>1.1. Interruption to production operation due to deviation of Cl₂ flow from</td>
<td>1.1.1. Falling closed, or accidentally closing, a single valve will not result</td>
<td>4</td>
<td>No recommendation</td>
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<td></td>
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<td>setpoint causing control system to shut down process</td>
<td>in overpressure since line is open to either end</td>
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<td></td>
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<td>1.2. Potential overpressure of Cl₂ piping if liquid-filled, closed piping</td>
<td>1.1.2. Operator response to a shutdown of the system would be immediate</td>
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<td>heats up</td>
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<td></td>
<td>2. Control system incorrectly activates shutdown for “rupture” condition</td>
<td>2.1. Potential overpressure of Cl₂ piping if liquid-filled, closed piping</td>
<td>2.1. All valves (ball valves) in liquid Cl₂ service are provided with a port</td>
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<td></td>
<td>heats up</td>
<td>to vent the ball cavity</td>
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<td>2.1.2. Rupture disk discharging to expansion tanks are provided for the section of</td>
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<td>- VUQA and VUQB</td>
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<td></td>
<td>- PCVGASC and PCVGASB (downstream of vaporizer)</td>
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<td>setpoint causing control system to shut down process</td>
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</tbody>
</table>

*Investigate the pressure relief requirements for the rupture disks. Verify Chlorine valves with design of vaporizer valves.*

![Image of a PHAWorks 5.0 Evaluation tool with highlighted text: All Recommendations.](image)
Are Completed for

1. Every Component of...
2. Every P&ID of...
3. Every Block Diagram Section...
4. Of the Entire Covered Process
5. Is Complete
This Process Might Entail Thousands of Covered Process Components & Phases

...and Take Years to Complete
Establish a Project Tracking Method for all PHA Activities
What Do We Do With the PHA’s Developed?

- Using the Risk Column, Begin:
  - Reviewing Defense Designs
  - Warning/Alarms to Warn of Deviations
  - Relief Systems
  - Ventilations Systems

Let’s Discuss Defense Designs…
Defense Designs
Examples of Defense Designs

- Relief Valves
- Piping Designs
- Detection Sensors
- Monitoring Cameras
- Containment Systems
Defense Designs

IR Camera
What Do We Do With the PHA’s Developed?

With Those Analysis Complete:

- Begin Implementation of Engineering Controls to Minimize Potential of Releases
NASA High Pressure Gas Plant

Process Hazard Analysis
Case Study
Team Exercise
Nitrogen & Helium Plant
Team Exercise

- With the Information to Follow in The NASA Case Study Video, Presentation & Notebook,

- With Your Team Members, Perform the Following Exercises & Answer the Following Questions:
Case Study Exploration

This PHA Case Study will Focus on the V267-LH Tank in the Hydrogen Plant

1. What is the Definition of a “Hazard” in HAZOP?
2. What types of Engineers & Team Members Would be required in a PHA Team to Complete a PHA’s on the V267-LH Tank?
3. Find the PHA for the Hydrogen Plant for HPGF-LH43
4. What is the Consequence of Unloading System Contamination for HPGF-LH43?
5. What is the Hazard Description & Effect of System?
6. What is the Hazard Likelihood/Impact?
7. What are the Hazard Control Elements?
8. What are the Recommendations on the PHA for this hazard?
9. What Other Recommendations Would Your Team Suggest to Control this Hazard?
What’s Next

- What if we need to change something in the process... We’ll discuss:

  Management of Change (MOC)