SAFETY BULLETIN 49/25

Hazard Identification and Risk Assessment

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PSM Element #06, Hazard Identification and Risk Assessment

1. Introduction

Process Safety Hazard Analysis (PHA) is a systematic and structured method used to identify potential hazards and evaluate risks associated with industrial processes, particularly those involving the production, handling, storage, and distribution of industrial gases. PHA aims to proactively prevent incidents by understanding what could go wrong and implementing appropriate safeguards. It's about building layers of protection to minimise the likelihood and severity of potential consequences.

The industrial gases sector deals with substances that can be flammable, oxidizing, cryogenic & high temperature, or toxic. Therefore, a robust approach to hazard identification and risk management is paramount.

PHA helps us to:

- **Identify Specific Hazards:** Pinpoint dangers unique to industrial gases, such as leaks, fires, explosions, asphyxiation, and cryogenic & hot burns.
- **Assess Risks Quantitatively or Qualitatively:** Evaluate the likelihood and potential impact of these hazards, allowing for prioritized risk reduction efforts, consistent with the risk-based philosophies of AIGA
- **Determine Adequate Safeguards:** Ensure that appropriate engineering controls (e.g., relief systems, detection systems, interlocks), administrative controls (e.g., operating procedures, emergency response plans, trainings), and personal protective equipment (PPE) are in place.
- **Learn from Experience:** Provide a framework for incorporating lessons learned from past incidents and industry best practices, often shared through AIGA webinars and guidelines.
- **Maintain Operational Integrity:** Contribute to the overall safety and reliability of gas production and handling facilities.

2. PHA Methodology

The selection of the appropriate methodology should consider the complexity of the process and the level of detail required for effective risk management, in line with the principles of risk proportionality

or a combination of methods might be necessary for complex situations requiring both qualitative and quantitative analysis.

- **Hazard and Operability (HAZOP) Study:** A structured, team-based approach that systematically examines deviations from intended process conditions using guide words. This is often favoured for its rigor in complex gas processes.
- **What-If Analysis:** A brainstorming technique where the team asks "what if" questions about potential scenarios.
- **Checklists:** Utilising predefined lists of potential hazards relevant to industrial gas operations.
- **Failure Modes and Effects Analysis (FMEA):** Analysing potential equipment failures and their impact on safety.
- **Layer of Protection Analysis (LOPA):** A semi-quantitative method to evaluate the independence and effectiveness of safety layers.

3. Conducting a Process Safety Hazard Analysis

Prior to conducting of the Process Safety Analysis, the team leader should be adequately trained and competent in the methodologies used. The person should gather a team with diverse expertise (multidisciplinary team) which would ensures a comprehensive review of potential hazards from various perspectives, including:

- Process Engineering (knowledge of gas properties and process design)
- Operations (hands-on experience with the processes)
- Maintenance (understanding of equipment reliability)
- Safety (expertise in hazard identification and risk management)
- Instrumentation and Control (knowledge of safety interlocks and control systems)
- Subject Matter Experts (SMEs)

As the team gather, the following approach should be consider:

3.1 Defining the Scope and Objectives:

Clearly outlining what part of the process will be analysed and the specific goals of the PHA. For instance, is it a new plant design, part of an existing operation, or a modification arising from Management of change?

3.2 Gathering Process Information:

Collecting all relevant and up to date documentation, such as Piping and Instrumentation Diagrams (P&IDs), Process Flow Diagrams (PFDs), critical equipment specifications, operating procedures, safety data sheets (SDSs) for the gases involved, and any past incident reports within the organisation or industry.

3.3 Hazard Identification:

Systematically identifying potential hazards associated with the process and the specific properties of the industrial gases involved. Some of the common hazards in our industry:

- Flammable Gas Releases: Potential for fire and explosion with gases like hydrogen, acetylene, and propane.

- Oxidising Gas Enrichment: Risks associated with increased oxygen concentrations leading to enhanced combustion.
- Cryogenic Hazards: Dangers of cold burns and material embrittlement from liquefied gases like oxygen, nitrogen, argon, carbon dioxide, hydrogen and helium.
- Toxic Gas Exposure: Risks from gases like ammonia, chlorine, and carbon monoxide.
- High-Pressure Systems: Potential for mechanical failure and rapid release of energy.

3.4 Risk Assessment:

Evaluating the potential consequences (severity) of each identified hazard and the likelihood (frequency) of it occurring in order to prevent any potential for catastrophic consequences in the workplace . This risk assessment often involves qualitative or semi-quantitative methods to prioritize risks

		Consequences →				
		A	B	C	D	E
Likelihood →	V	Medium 5	High 10	High 15	Extreme 20	Extreme 25
	IV	Medium 4	Medium 8	High 12	High 16	Extreme 20
	III	Low 3	Medium 6	Medium 9	High 12	Extreme 15
	II	Low 2	Low 4	Medium 6	High 8	Extreme 10
	I	Negligible 1	Low 2	Medium 3	High 4	Extreme 5
Consequence scale 1		Description 1	Description 2	Description 3	Description 4	Description 5

Example of Risk matrix

3.5 Analysing Existing Safeguards:

Identifying and evaluating the effectiveness of existing safety measures designed to prevent or mitigate the identified hazards and residual risks after control measures are taken. This includes engineering controls (e.g., pressure relief valves, detection systems, interlock), administrative controls (e.g., operating procedures, emergency response plans, trainings), and PPE.

3.6 Developing Recommendations:

Based on the risk assessment and the analysis of existing safeguards, the PHA team develops recommendations for additional measures needed to reduce the risk to an acceptable level. Recommendations can be in the form of improving asset integrity, procedures, and training as well as up-to-date action item tracking lists and risk communication materials. While the recommendations

are to those hazard identified, it can also identify recommendations to production such as quality production yield, lost control arising from equipment damage from the catastrophic event and its emergency responses or even reduce the unplanned downtime.

3.7 Documenting the PHA:

Thoroughly documenting the entire PHA process, including who are the team leaders and members, the methodology used, hazards identified, risk assessments, existing safeguards, and recommendations. This documentation serves as a record of the analysis and a basis for follow-up actions.

3.8 Implementation of Recommendations

Recommendation identified without implementation would not improve on the safety of the operation. This can be broken down into 3 parts:

- **Prioritisation**

  Multiple actions may arise from the assessment. It is recommended that that critical actions are acted on given their higher risk level. Based on the risk matrix, this would help make objective decision to tackle accordingly.

- **Responsibility and Timeline**

  After actions have been taken into consideration to which has a higher priority, clear ownership with suitable completion date or time should be established. Taking also into consideration, high priority items should have shorter timelines to ensure being act on. This will create clear accountability so that actions are followed up to ensure it completion.

- **Tracking and completion**

  Recommendation follow up and implementation is key in ensuring that they are implemented and closed. Validation of the action is crucial ~~to~~ before closing, with proper documentation to ensure affected P&ID, SOP are updated. Summary of action and completion is recommended for clear visibility of its status.

4. Continuous Review and Revalidation

Hazard identification and risk assessment is not carried out only at the start of the project but throughout its lifecycle including Mothballing facilities and restarting of mothballed facilities. For it to remain effective, it is recommended that that the review is carried out periodically (every 5 years or as per organisation policy) or whenever there is a significant process modification/ Management of Change, new technology or lesson learnt from events that happened within the organisation or even the wider Industrial Gas industries.

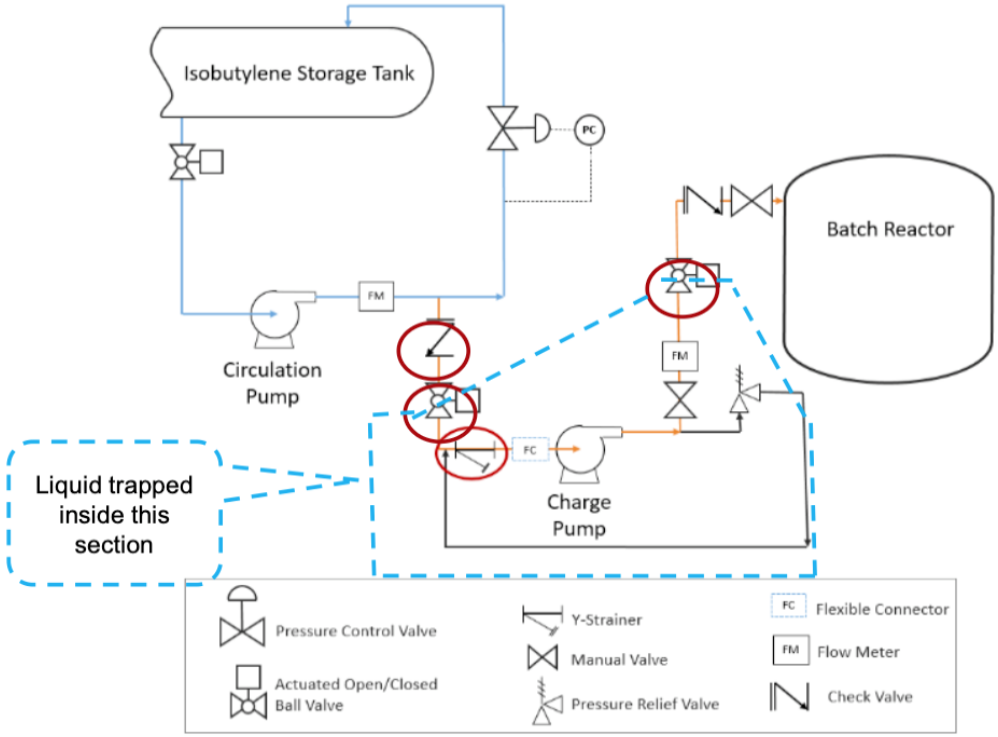
5. What can go wrong? Example of incident in the process industry

In 2019, an explosion followed a 10,000 lbs. (4500kg) release of flammable isobutylene from a failed Y-strainer. It fatally injured one worker and seriously injured two others. The incident also injured 28 and resulted in the operating company's bankruptcy. This example focuses on only one of many lessons learned from this incident--the tremendous pressure that occurs when trapped liquids expand.

The piping & instrumentation diagram (P&ID) for the Y-strainer piping had errors (Figure 1). The version used for the process hazards analysis (PHA) did not show the Y-strainer, a check-valve nor

the manually-activated isolation valves. These combined to make a section where liquids could be trapped. The facility completed an initial PHA and PHA revalidation. During both PHAs, the team did not detect the incorrect P&ID andtherefore failed to recognize the liquid expansionhazard.

The drawing also indicated the piping was all welded or flanged 304 stainless steel. The 3” diameter cast-iron Y-strainer was connected to the stainless piping by pipe-threaded joints which didn’t meet accepted piping specifications.



A simplified diagram showing the configuration that caused a large gas explosion. Courtesy of CCPS Beacon July 2024.

6. Learnings from the incidents

- The P&IDs are a key input to the Process Hazards Analysis (PHA) process. P&ID accuracy is critical to a thorough and accurate understanding of the process and its hazards.
- The PHA team reviews each section of the P&IDs, looking for things that could go wrong in that section and cause issues in that section or elsewhere.
- Good risk management practices and most process safety regulations require the P&IDs be current and accurate and used when a PHA is performed.
- PHAs are required to be revalidated or reviewed on a regular interval.
- One purpose of revalidations is to review changes that have occurred and to verify those changes are properly managed.

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