'Case Study Using Structured What If Technique on a Gas Sweetening Process'

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Learning from experience has long been recognised as a valued process. This paper examines the need, value of Process Hazard Analysis (PHA) in Process Safety Management (PSM) and steps followed at Dahej Manufacturing Division (DMD) - Reliance Industries Limited, India. It also goes into detail about how Process Hazard Analysis (PHA) study has helped prevent incidents. In the world of Process Safety, Process Hazard Analysis (PHA) is an essential tool to identify hazard and take corrective or preventive steps.

The aim of the Process Hazard Analysis program at DMD was to determine the most effective approach to implement and sustain PSM in an organisation. The aim was to prevent and manage the occurrence of major industrial catastrophes. A process hazard analysis study was conducted through series of extensive training by world leading organization in process safety management and handholding exercise. It involved various steps like Team Formation, Hazard Identification, Hazard Evaluation, Consequence Analysis, Human Factor, Facility Siting, Inherently Safer processes, Recommendation generation, Management Review and Final Report documentation.

“What-if” is a powerful Qualitative risk analysis tool, where process design can be challenged. “What-if” technique was adapted for Hazard Evaluation using Risk matrix based on consequence and frequency numbers, then followed by Validity of Barriers (Safeguards). From PHA study findings, Management of Change (MOC) failures were found contributing significantly and consistently to the process safety incidents.

The analysis enabled RIL-DMD to take suitable measures for protecting against Process Safety Incidents (PSI) resulting from MOC's implementation. Hence, an effective Management of Change (MOC) is vital for safe and reliable operations.

The case study will demonstrate hidden hazards underlying with Management of Change (For Process- High pressure separator to low pressure separator systems i.e. Typical CO2 Removal units by Amines) for ease of operation and how Process Hazard Analysis (PHA) helped to identify and mitigate the associated hazard.

Introduction

The chemical process industry (CPI) comprises the bulk manufacturing of oil and gas, petrochemical, food and pharmaceuticals. Chemical Process Industries (CPI) are often challenged with their operational practices with priority in safe operating processes. Due to the volume of hazardous substances handled in CPI, involving complex process design, such industrial processes may pose process hazards that could result in catastrophic outcomes (e.g., a major fire, explosion or toxic release) if the process or material is not managed with care. It is therefore critical to perform a Process Hazard Analysis (PHA) OR re-validating the PHA so as to identify process hazards as early as possible and apply measures to control the hazards.

The objective of a PHA re-validation is to produce an updated PHA methodology that adequately identifies and controls the process hazards. This ensures existing safeguards are adequate if any operational changes (especially Management of changes) occur during process operation. All the changes starting from the base line PHA (or commissioning HAZOP study) must be evaluated to confirm that any new hazards associated with the changes, have been considered in the updated PHA.

PHA (also known as Process Hazard Evaluation) is a method of technical risk assessment. It uses structured and systematic techniques to analyse industrial processes in order to identify hazardous situations or their initiating events. It assesses their potential impact if improperly or inadequately managed or left uncontrolled. When identifying a hazardous situation or condition that could lead to a major safety incident, following points should be considered:

- Process equipment’s and their ability to cope with deviations from normal operating conditions;
- Data accuracy of process monitoring instruments (e.g., temperature, pressure or flow sensor);
- Reliability of safety devices (e.g., pressure relief valve, check valve, interlocks, cut-off system);
- Integrity of primary containment (e.g., pipes, vessels, flexible hoses, gaskets or seals);
- Unplanned loss of utilities (e.g., loss of steam or cooling water);
- Compatibility between different materials that are introduced to the process;
- Compatibility of process materials with the process equipment’s material of construction;
- On-site activities undertaken by staff and/ or contractors and the possibility of human error; and
- Impact of external factors (e.g., vehicle impact, impact of incident at a neighbouring plant, or a significant change in environmental conditions).

Many major process accidents occur directly or indirectly related to process safety management elements and a lot of these accidents are in some way related to inadequate and / or inappropriate Management Of Change (MOC) which is one of the Process Safety Management (PSM) elements. The aim of the Process Hazard Analysis (PHA) at Dahej Manufacturing Division

(DMD) - Reliance Industries Limited, India. Was to determine the most effective approach to implement and sustain PSM in the organisation. Aim was to prevent and manage the occurrence of major industrial catastrophes.

"Structured What-if" is a powerful Qualitative risk analysis tool, where process design can be challenged. "Structured What-if" Technique was adapted for Hazard Evaluation using Risk matrix based on consequence and frequency numbers, then followed by Validity of Barriers (Safeguards). From PHA study findings, Management of Change (MOC) failures were found contributing significantly and consistently to the process safety incidents. The analysis enabled RIL-DMD to take suitable measures for protecting against Process Safety Incidents (PSI) resulting from MOC's implementation.

This case study will demonstrate hidden hazards underlying with Management of Change (For Process- High pressure separator to low pressure separator systems i.e. Typical CO_2 Removal units by Amines) for ease of operation and how Process Hazard Analysis (PHA) has helped to identify and mitigate the associated hazard.

Process Hazard Analysis… A Methodology

When is PHA Needed?

- New process and facilities (several reviews during different stages of development)
- Existing facilities
    - Base line PHA
    - Revalidation of previous review at least every five years
    - Technology and facilities changes e.g. MOC (Management of Change)

PHA combines science, skill, and judgment to: Methodically identify, evaluate, and develop methods to control significant hazards in the process.

Defining PHA: It's Importance

- Identifies recognized and unrecognized hazardous events
- Identifies hazardous materials and hazardous processes
- Identifies actions to eliminate and/or reduce risks involved with hazards
- Identifies consequences or impact on other PSM elements
- Seeks to achieve a multi-disciplined consensus on hazard control
- Documents results for future use

Steps required for PHA?

STEP:-1
PLANNING AND PREPERATION
Which process block to be selected?
Team Members selection, how?
Meeting Frequency?

Multi-disciplinary team
Operations, Maintenance and
Technical Services

STEP:-2
HAZARD IDENTIFICATION
Hazards associated with identified process block?

- Over pressurization, run Away reaction
- Toxic, Reactive, etc
- Chemical to Chemical Interaction
- Material of construction compatibility

STEP:-3
PROCESS HAZARD EVALUTION
Identification of hazardous event and its associated safeguards with different methodology, which?

- Structured What If / Checklist
- Failure Mode and Effect (FMEA)
- Hazard and Operability Study (HAZOP)
- Fault-Tree Analysis (FTA)
- Layer of Protection analysis

STEP:-4
CONSEQUENCE ANALYSIS
Evaluation of direct and undesirable event potentially hazardous event
(With the help of Softwares)

- Type of resulting event such as fire and explosion, toxic release
- Consequent of the event , estimates of distances to different levels

STEP:-5
RISK ASSESSMENT
Risk is product of severity of an event (consequence) and its likelihood (Frequency).

- Assessment of the risk by using risk matrix,
- If structured what-if is used frequency is based on experimental and historical data
  For guidance refer below case study.
  Important Note: - Lesser consequence event have much high frequency so overall risk always will be on higher side.

STEP:-6
VALIDITY OF EXISTING SAFEGUARD
Valid safeguards can by itself address the hazard (cause) or consequence if the barrier is effective, independent, and auditable.

- EFFECTIVE in preventing the incident outcome when it functions as designed,
- INDEPENDENT of the initiating event and the components of any other valid safeguard already claimed for the same scenario,
- AUDITABILE the assumed effectiveness in terms of consequence prevention and probability of failure on demand (PFD) must be capable of validation in some manner (by documentation, review, testing, etc.)

STEP:-7
DEVELOPING PHA RECOMMENDATION
After Risk Assessment and safeguards are not valid to reduce risk, development of recommendation is required

- Clear direction should be there for PHA recommendation, how much risk shall be reduced i.e. in terms of degree of risk.

STEP:-8
DOCUMENT PHA FINDING, IMPLEMENT ACTION ITEMS AND MAINTAIN HEALTH OF THE SAFEGUARD

- Implementation should be in fixed time frame for high consequences event.

Structured what-if methodology for identifying hazards

Structured What-If is typically a combination of two qualitative risk assessment techniques i.e. what-If and HAZOP study. Following approach is used during the analysis:-

- Structured "What-If" using "process deviations"
- Review "What-if" for using "equipment specific checklists and loss of containment checklists"
- Review "What-if" for transient operations - start-up and shut-down
- Review "What-if" for other scenarios related to typical industry and unit specific aspects such as Instrumentation, Chemical Hazards, Equipment Integrity, rupture/leak, Relief, etc.

What –if considered a foundation methodology because:

- Questions the design
- Identifies the effect of occurrences outside the process

Team members ask "what if" questions using brainstorming techniques like:

- What if Pressure goes high-high
- What if Level transmitter shows lower than actual
- What if High pressure switch does not actuate.
- What if pump seal leaks
- What if Compressor surges

Evaluation of Risk:

- What if Pressure goes high-high
- What if Level transmitter shows lower than actual
- What if High pressure switch does not actuate.
- What if pump seal leaks
- What if Compressor surges

Recommendations are developed from:

- Answers to the "what if" questions
- An evaluation of the protective devices and procedures in place

Safeguards to mitigate the Risk:

Safeguards have the role of risk reduction. Safeguards can be classified as:

- How they act: Active or passive
- How they reduce the risk of initiating event: Preventive or Mitigative

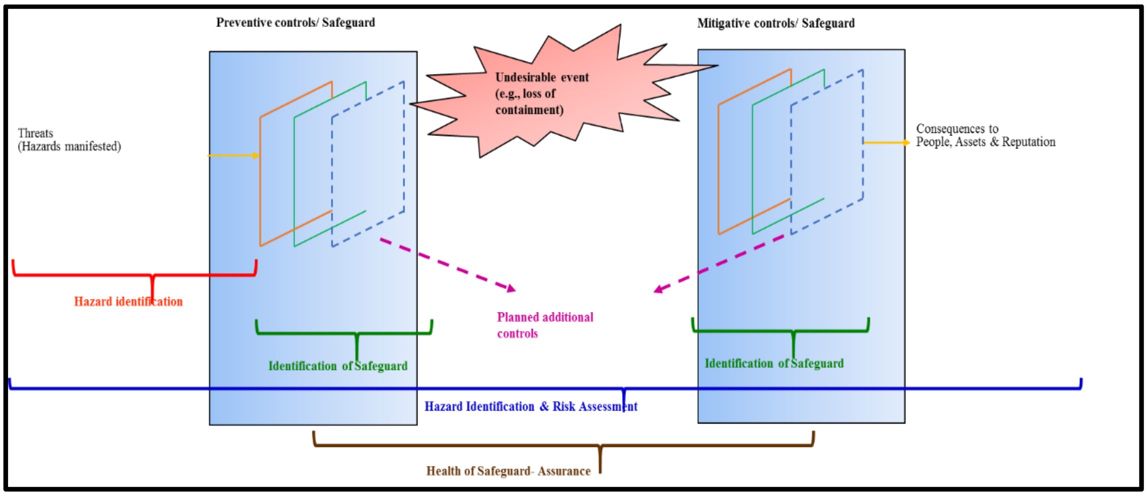

Figure 1: Hazard Identification and Risk assessment

Case Study Using Structured What-If Techniques

Process Description

Gas "Sweetening" means the removal of CO_2 from the sour gas stream in gas processing unit. The removal of carbon dioxide is made necessary to inhibit the freezing and resulting dew point problems that would result in the cryogenic section (in natural gas plant), if the CO_2 is left in the gas. To accomplish this sweetening, the gas is intimately contacted with an amine solution. Removal of CO_2 from gas occurs at high pressure, and regenerated at low pressure since amine is in close loop circulation.

For Removal of CO_2 with amine a High Pressure separator is used for absorption. Post absorption of CO2 in amine, it is transferred via level control valve to a low pressure separator for regeneration of amine (stripping of amine).

Low pressure separator is protected against high pressure with series of safety valves i.e. for gas breakthrough case as per original design by licensor of the unit.

History of the Changes

Frequent foreign material choking issues were observed in level control valve by the unit, resulting in frequent start–up, shut down and slowdown. Since no isolation valves were provided in original scheme, new set of isolation valves in up-stream and down-stream of the level control valve were provided. A low pressure rating valve was installed in the downstream of level control valve since a correct pressure rating valve was not available at site i.e. (Management of Change No – 1)

Now duration of start-up, shut down and slowdown has been reduced to half of its original time but to avoid any shut down of the unit, a bypass line was also provided along with control valve without evaluating associated hazard i.e. (Management of Change No – 2)

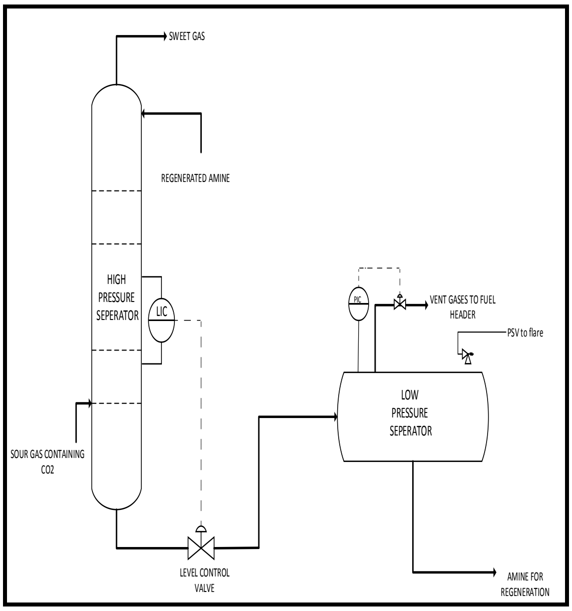

Figure 2: Original CO_2 removal unit

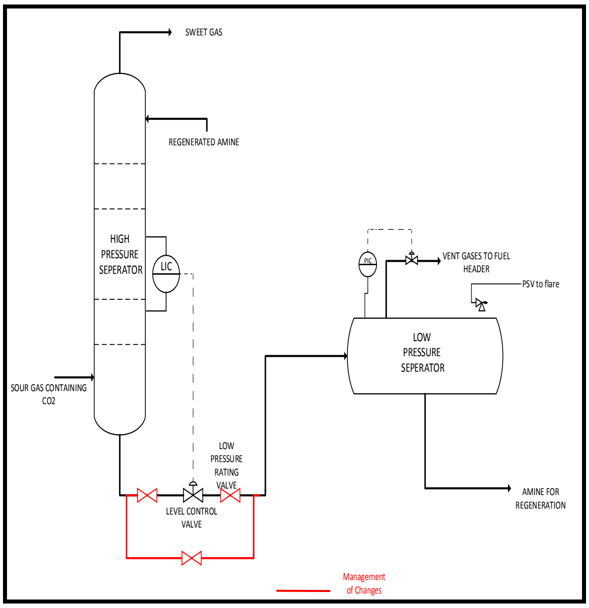

Figure 3: Modified CO_2 removal unit post management of changes

Structured What-if for the unit

Base line PHA study was initiated after couple of years of implementation of above described management of changes using structured what-if Technique.

Following What-if question asked by team (i.e. challenging the design) during process hazard analysis

What if → Level of the High Pressure Separator Goes Low?

What if →Level Control Valve opens fully when downstream isolation valve is close?

Hazard →Loss of containment can result to fire and explosion i.e. High pressure gas breakthrough during loss of liquid level into low pressure separator, while low pressure separator is designed for $1/10^{th}$ times of high pressure separator.

Cause→ Cause can be instrumentation failure like level indication failure and 2^{nd} listed what-if scenario, this event can happen during bypass operation of the level control valve at the time of maintenance job.

Consequence→a big incident can result into many causalities with fire and explosion.

Safeguards →

- Level Indication of High Pressure Separator →

  This is not valid safeguard as operator intervention is required, whenever operation of the unit with newly provided bypass line. A full SIF (Safety Instrumentation function) is required, which was not present. Not a valid safeguard. ×

- Pressure Indication of Low Pressure Separator →

  This is not valid safeguard as pressure control valve is not designed for full gas breakthrough case. Not a valid safeguard. ×

- Pressure Safety Valve on Low pressure Separator →

  Since capacity of the unit has increased and adding bypass gives additional load for gas breakthrough case, but pressure safety valves are not re-rated for full gas breakthrough case i.e high pressure to low pressure. ×

Frequency of the Initiating Event → Very-Very high as during disturbance of the plant operation, level control valve closes /opens frequently.

Risk → Very –Very High as Not a Single Safe Guard is Valid.

How to reduce risk (Methodology adopted) →

Active safeguards are engineering controls which reduce frequency or consequence of hazard e.g. Control Examples:

- Design Controls (e.g. guards, level alarms, automatic trips etc.)
- Operation Intervention Controls (e.g. operating within defined process envelop etc.)

Passive safeguards minimize the hazard through design features that reduce either the frequency or consequence of the hazard without the active functioning of any device e.g. Recovery Examples:

- A dyke around a storage tank of hazardous liquid prevent the spreading of liquid when overfill
- Blast wall to absorb the shock overpressure from explosion

Final recommendation →

- Change of level control valve downstream isolation valve to high pressure rating
- Automatic Level control / trip at low-low level of high pressure separator
- Re-rating of Pressure Relief System

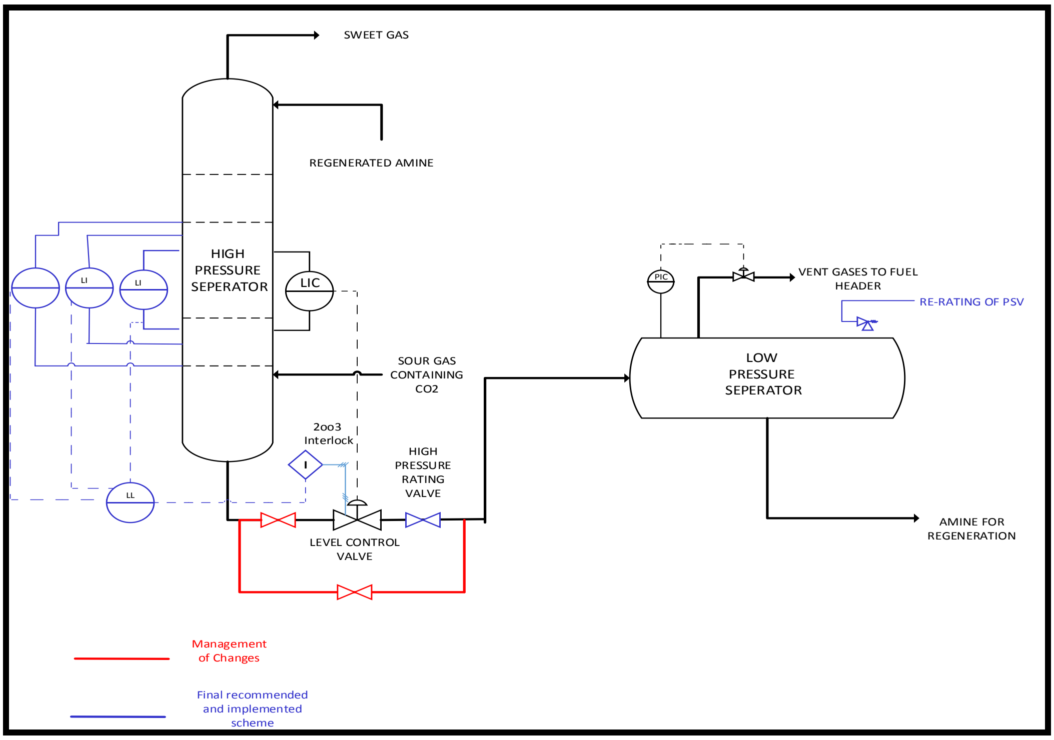

Figure 4: Modified CO_2 removal unit post Process Hazard Analysis

An Integrated approach for reducing risk →

For any risk scenario, to reduce risk as a rule of thumb, 3 no's of independent safeguards are required at active side and 2 no's of safeguard are required at passive side for valid safeguard.

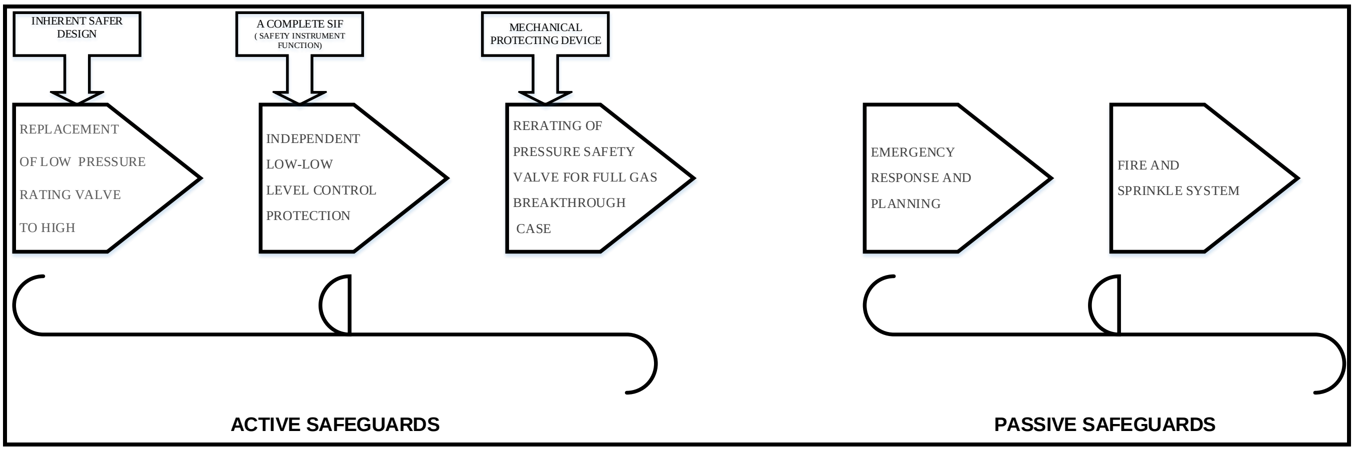

Figure 5: Reduction of Risk – Role of safeguards

LESSON LEARNED (Importance of integration of Management of Change and Process Hazard Analysis)

- What if analysis identifies→**Process hazards**
- Process hazards must have-→**Cause**
- If causes are not controlled→ **Consequence**
- Consequences are prevented by→ **Safeguards**
- Safeguards must be provided for→ **All Causes**
- Safeguards must be→ **Valid**

Management of Change (MOC) is one of the essential element in Process Safety Management (PSM) wheel. In chemical process industries (CPI), MOC is required to ensure that safety, health and environment are being maintained well by evaluating and controlling modifications to facility design/ operation.

Before doing any modification to the facility design and operations, hidden hazards through Process Hazard Analysis must be identified, recommended and implemented. So an Effective Management of Change (MOC) implementation along with Process Hazard Analysis is vital for safe and reliable operations.

Thus a major incident at manufacturing division has been avoided with Process hazard Analysis using Structured what –if Technique by a team experienced in hands-on operations, safety procedures, and engineering calculations.

References

- CCPS, 2008, Guidelines for the Management of Change for Process Safety, Centre for Chemical Process Safety, AIChE, New York, Untied States.
- WSH COUNCIL, 2017,Workplace Safety and Health Guidelines Process Hazard Analysis.