A COMPARISON OF THE HAZARD AND OPERABILITY (HAZOP) STUDY WITH MAJOR HAZARD ANALYSIS (MHA): A MORE EFFICIENT AND EFFECTIVE PROCESS HAZARD ANALYSIS (PHA) METHOD

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Abstract

The Hazard and Operability (HAZOP) study is the most commonly used process hazard analysis (PHA) method in the process industries. While the HAZOP method provides a more thorough and complete treatment than other classical PHA methods, HAZOP studies tend to be tedious and time-consuming which can compromise the quality of the work performed. Major Hazard Analysis (MHA) was developed in an attempt to overcome these disadvantages of the HAZOP method.

The HAZOP method requires PHA teams to consider a variety of deviations from design intent and brainstorm causes of the deviations. Unfortunately, it is difficult for PHA teams to select only those aspects of design intent that will result in the identification of issues within the scope and objectives of the PHA. Consequently, effort is often expended in HAZOP studies on issues that turn out to be unimportant. MHA starts with the direct identification of pertinent initiating events for hazard scenarios. PHA teams using MHA find it a more sensible and understandable approach. In addition, they are more willing to participate in the study since immediate dividends are evident from their work.

This paper presents comparisons of the results of PHAs performed using both MHA and HAZOP. Generally, MHA studies can be performed in substantially less time and identify more hazard scenarios than HAZOP studies.

While MHA was developed to address the types of hazards that arise from the release of toxic, reactive, flammable and explosive materials from processes, it has been extended to look at other hazards such as overpressurization and entrapment by moving equipment. In this form, it is called Direct Hazard Analysis (DHA) and is used in combination with the Hazard Identification (HAZID) method. Such applications are also described in this paper.

Introduction

Process Hazard Analysis (PHA) studies are performed to comply with the OSHA's Process Safety Management (PSM) standard, 29 CFR 1910.119, and the EPA's Risk Management Program (RMP) rule, 40 CFR Part 68 in the United States, and process safety regulations and company requirements in other countries around the world. Although various PHA methods are allowable under the regulations, the Hazard and Operability (HAZOP) method is commonly used.

Many thousands of HAZOP studies have been performed since the method was first developed in the 1960s. However, HAZOP study participants often find the studies tedious and time consuming[(1)]. While the method was developed to address both safety and operability scenarios, some companies do not want to spend time identifying operability scenarios. However, it is difficult to divorce their identification from the identification of safety scenarios. In a typical HAZOP study, at least half the time is spent on operability scenarios. The HAZOP method also depends for its success on the proper identification of design intent for the process. There are many aspects of design intent that may be important and it is a considerable challenge for teams to be sure they have addressed the important parts. Unfortunately, the more thorough the attempt made at performing a complete study, the more likely it is that the team will burn out and lose their motivation. Moreover, the HAZOP method identifies initiating events for hazard scenarios in an indirect way by first postulating a deviation from design intent. Novice team members sometimes have difficulty understanding this approach and are more comfortable with methods that directly address initiating events.

These issues make process plant personnel reluctant to participate in HAZOP studies. Consequently, an improved PHA approach, called Major Hazards Analysis (MHA), was developed to overcome problems with the HAZOP method[(2)].

Major Hazard Analysis

Process safety regulations focus on toxic, fire, explosion, and to a certain extent, reactivity hazards (called *major hazards* herein). These major hazards result from specific chemicals and they may adversely impact employees, the public and the environment.

Scenarios of interest that result from major hazards originate with loss of process containment. Causes of loss of containment can be direct, for example, valves left open or ruptures in lines or vessels. They may also be indirect, for example, runaway reactions resulting in releases through pressure relief devices or vessel and piping rupture. Therefore, MHA focuses brainstorming on such scenarios by using a structured framework to guide the identification of initiating events.

All PHA methods subdivide the process so that individual parts can be analyzed. MHA can use the systems and subsystems typical of What-If studies or the nodes (process lines and major vessels) used by the HAZOP method. This allows MHA to be conducted at various levels of detail according to the user's needs.

In order to provide guidance to the PHA team and help assure completeness, MHA uses specific categories and common examples of initiating events (causes) that can result in loss of containment. This focuses the team's brainstorming without narrowing their vision. A typical list of initiating event categories and examples is shown in Table 1. Such lists can be customized for specific facilities and/or types of processes. The scheme also prompts consideration of items not included in the lists.

This categorization includes equipment and human failures as well as external events. The logic of the approach is that there is a limited number of categories of initiating events that result in loss of containment and within each category there is a limited number of ways this may commonly happen. This enables the PHA team to use the scheme without being overburdened, while preserving their energy to consider items not in the scheme. The result of applying this categorization scheme using the MHA method is shown in Figure 1. This example includes the worksheet columns "Enabling Event/Condition" and "Scenario". These additions clarify the scenario and also provide valuable information for use in further analyses such as Layers of Protection Analysis (LOPA) or Quantitative Risk Analysis (QRA).

Other elements of the hazard scenarios are identified in the same way as for other PHA methods and they are recorded in similar worksheet columns.

Comparison of the MHA and HAZOP Methods

The MHA and HAZOP methods were compared directly by application to an ammonia plant and a urea handling process. Comparisons were also made by their individual application to other processes. The principal way in which the two methods differ is in how scenario initiating events are identified. Other scenario elements are identified in the same way. The comparisons resulted in the following findings:

1) Generally, more major hazard scenarios are identified using the MHA method.

In principle, both methods are capable of identifying the same major hazard scenarios. However, in the MHA method the approach is direct while in the HAZOP method the approach is indirect. In the HAZOP method, the PHA team must consider numerous parameters and deviations for a node in order to identify scenarios; both safety and operability scenarios are mixed together; and the scope of the node intention that should be considered is not well defined, possibly resulting in scenarios that may be missed. HAZOP study teams can become frustrated by these issues and lose their focus. In the MHA method, the team stays focused on just those causes of hazardous material releases from the process. Teams are provided with a clear road map to follow, albeit one they can adjust to the circumstances. At any time they know where they stand and what they are doing. This improved focus and more clearly understood method results in a higher level of performance by the team and a better hazard analysis. However, if a team also intends to include operability scenarios in the study then the HAZOP method would be favored.

2) The time required for an MHA study is substantially less than for a HAZOP study.

Not only are operability scenarios eliminated in the MHA method, but also less time is spent in extraneous discussions. The MHA method focuses attention immediately on the causes of hazard scenarios whereas the HAZOP method encourages the wide-ranging identification of causes of process deviations which may or may not result in major hazard scenarios. The HAZOP method also can be repetitive with the same hazard scenarios arising in multiple ways.

3) The MHA method is more readily understood by PHA teams.

The MHA method systematically identifies each hazard scenario element beginning with the initiating event. This fits the conceptual framework of PHA team members exactly. In contrast, the HAZOP method begins with the consideration of deviations from design intent. Causes of deviations are identified as candidate initiating events for major hazard scenarios. Of course, in describing the progression of these initiating events to a consequence of concern, the deviation reappears as part of the scenario and team members are sometimes confused by this aspect of the HAZOP method. Furthermore, teams are also often confused by the process of generating and using deviations from design intent to identify hazard scenarios.

Each node in a HAZOP or MHA study contains a set of hazard scenarios. In a HAZOP study, they appear under different parameters and deviations. In a MHA study, they appear in the order of the different categories of initiating events. Most PHA team members find the latter approach more logical.

4) The MHA method provides more flexibility than the HAZOP method.

Both methods provide a framework and structure for the identification of hazard scenarios. However, the HAZOP method constrains the assignment of scenarios to particular process deviations in a node. The MHA method allows the identification of hazard scenarios as a set for each node without unduly constraining the identification of hazard scenarios.

5) There is less ambiguity in MHA.

The HAZOP method can be used to identify both hazards and hazard scenarios. Indeed, some practitioners decide which hazards are present and identify ways they can occur (scenarios) as the study proceeds. However, the HAZOP method will not readily identify all process hazards that may be present and, unless the types of hazards to be addressed are defined in the study scope and objectives, scenarios may be missed or identified inconsistently for different types of hazards. Furthermore, scenarios outside the intended scope and objectives may be included. A hazard type may be obvious in one part but not another part of the process and may be missed unless team members are instructed to look systematically at a defined set of hazards. In contrast, MHA is structured to look exclusively at the major hazards of flammability, explosivity, toxicity and reactivity that are covered by process safety regulations. Hazards are the starting point for the MHA method whereas they are secondary in the HAZOP method.

6) MHA study worksheets are simpler to use.

In a MHA study, all the hazard scenarios for a node appear in a single worksheet, unlike in a HAZOP study where they are organized by process parameters and deviations into multiple worksheets. Not only are the MHA worksheets easier to understand, but also making entries for different hazard scenarios with common elements is facilitated by their presence in the same worksheet. There is less jumping around the worksheets while conducting the study. Furthermore, the segmentation of worksheets to address multiple modes of operation is easier with the MHA method than the HAZOP method.

7) The MHA method is more readily accepted than the HAZOP method.

Novice teams require coaching as they begin to use the HAZOP method and may question its efficacy as a study proceeds. MHA is more readily accepted and even experienced PHA teams usually express a preference for it.

An example of some completed worksheets from a HAZOP study on an ammonia plant are shown in Figure 2. These can be contrasted with completed MHA worksheets for the same node of the process in Figure 3. Worksheet columns are shown up to Safeguards. The HAZOP worksheets contain numerous operability scenarios. Some arise as consequences of initiating events that also have safety and/or environmental consequences. In other cases, they arise from initiating events that have neither safety nor environmental consequences. The MHA worksheets do not document the operability scenarios and focus on the safety and environmental scenarios. In all cases where safety or environmental scenarios are identified in the HAZOP worksheets, they are also identified in the MHA worksheets. We have found that MHA will also identify scenarios that have been missed by HAZOP.

The addition of Scenarios and Enablers columns to the MHA worksheet adds valuable information for the hazard scenarios. While this can also be done in

HAZOP, it is less likely teams will be willing to do so because of the extra effort needed in a study that is already considered to be lengthier than desirable.

Direct Hazard Analysis

The MHA method is intended to address the four major hazards usually of concern in process safety and their impacts on people and the environment. However, some PHA practitioners apply PHA methods to other types of hazards. Therefore, in an extension of the MHA method called Direct Hazard Analysis (DHA) other hazard types are addressed. Each hazard type uses a structured list of categories of initiating events and ways they can occur. An example of such a list is provided in Table 2 for the hazard of over-pressurization. Such lists can be developed for any hazard.

An important precursor to a DHA study, indeed for many PHA studies, is the performance of a Hazard Identification (HAZID) study in which hazards in each area of the process are identified using a checklist of hazards. A HAZID worksheet is usually completed (see Figure 4). Process materials are considered, material safety data sheets and other documents are reviewed, and known hazards are listed. The HAZID study allows a determination to be made of which hazards will be addressed using PHA and which PHA techniques should be used for which types of hazards. Other hazards are managed through other occupational health and safety programs, for example, using simple checklists or Job Hazard Analysis.

Conclusions

The MHA method has been designed specifically to address the types of hazards covered by process safety regulations and their impacts on people and the environment. MHA focuses the PHA team's attention on causes of loss of containment involving hazardous materials. In contrast, the HAZOP method focuses the team on process deviations that may or may not result in loss of containment. Consequently, MHA is a more efficient way of addressing major hazards. Furthermore, the structured approach to identifying loss of containment scenarios provides confidence in the relative completeness of the method compared to the HAZOP method.

By constraining team deliberations to those scenarios of interest, the MHA method helps preserve the most precious resource available to the team, namely their intellectual energy. Moreover, the MHA method offers structure comparable to HAZOP, while providing more specific guidance and without restricting brainstorming of major hazard scenarios. PHA teams prefer MHA because it more directly addresses issues of concern than the HAZOP method. Inexperienced PHA practitioners are likely to do a better job with it.

One further advantage offered by MHA is the ease with which current PHA studies can be converted into MHA format. The format of MHA worksheets is very similar to those of other PHA techniques and information can be copied easily into the MHA format. This can be done when PHAs are revalidated. The revalidation can then address the analysis of process changes as well as the enhancement of the original PHA results by the use of MHA.

Since MHA is a spreadsheet technique like other PHA methods, existing PHA recording tools can be used to perform MHA studies. The figures used to illustrate the method in this paper are screen captures from PHAWorks®, Primatech's PHA software package.

References

1. P. Baybutt, "On the Ability of Process Hazard Analysis to Identify Accidents", Process Safety Progress, Vol. 22, No. 3, pps. 191 - 194, September, 2003.

2. P. Baybutt, Major Hazards Analysis - An Improved Process Hazard Analysis Method, Process Safety Progress, Vol. 22, No. 1, pps. 21 - 26, March, 2003.

Table 1. Initiating Event Categories For Major Hazard Analysis / Hazardous Material Release.

Leaks / ruptures
- Fracture: e.g. breaking open of a containment system by the propagation of a crack
- Puncture: e.g. a perforation or hole in a containment system as a result of impact
- Relief device stuck open
- Seal / gasket / flange failure
- Corrosion / erosion
- Fouling / plugging
- Flow surge or hydraulic hammer
- Equipment failure
- Others?

Incorrect actions or inactions by people
- Errors of omission, e.g. operator does not close a valve
- Errors of commission, e.g. operator closes the wrong valve
- Extraneous acts, e.g. operator closes two block valves instead of just one
- Violations, e.g. operator disables an alarm
- Others?

Exceeding process limits
- Over / under pressuring
- Over / under heating
- Over / under cooling
- Over / under filling
- Incorrect composition?
- Flow upset
- Reverse flow
- Loss of feed
- Other?

Control systems failures
- Instrumentation
- Logic solver
- Final elements
- Communications and control interfaces
- Signal and data lines
- Infrastructure
- Environment
- Others?

Reactivity

- Loss of control of an intended reaction
- Starting another unintended reaction
- Unintended side reaction or series of reactions
- Water ingress
- Air ingress
- Spontaneously reactive
- Inadvertent mixing of chemicals
- Physical processing of chemicals that releases heat
- Others?

Structural failures

- Equipment supports
- Foundations / floors
- Cyclic loading
- Pressure fluctuations
- Others?

Utility failures

- Electric power
- Instrument air
- Plant nitrogen
- Cooling water
- Steam
- Others?

Natural external events

- Flooding
- Lightning
- High winds
- Others?

Human external events

- Vehicle impacts
- Dropped objects from lifting devices
- Others?

Knock-on effects

- Incidents within the process
- Incidents in adjacent processes

Multiple failures including common cause failures

- Combinations of equipment failures
- Combinations of human failures
- Combinations of external events
- Combinations of any of these

Others

- Incorrect location / position / elevation
- Incorrect timing / sequence / order
- Anything else?
- Anything unusual?

Table 2. Initiating Event Categories For Direct Hazard Analysis / Over-pressurization

Equipment failures
- Blocked outlet
- Regulator failure
- Compressor / pump over-speed
- Heat exchanger failure
- Equipment isolation failure
- Blocked-in line
- Others?

Human failures
- Instrument calibration error
- Pump misoperated
- Incorrect valve positions set
- Equipment not isolated
- Bypass opened
- Metering, loading or charging error
- Others?

External events
- External fire
- Exposure to excessive solar radiation
- Loss of cooling
- Overheating
- Others?

Figure 1. MHA Worksheet.

NODE: (1) INLET LINE TO HEXANE STORAGE TANK, TK-101							
INITIATING EVENTS	SCENARIO	CONSEQUENCES	SAFEGUARDS	ENABLERS	S	L	R
1. Line leak at flange	Release of hexane into sewer system	1.1. Possible environmental contamination	Periodic walk-throughs by operators per procedure SOP-99-005	Failure of water treatment system	4	3	8
2. Mechanic leaves drain valve, MV-78, open	Release of hexane into dike and sewer	2.1. As for 1.1	Mechanic check	Failure of water treatment system	3	4	8
		2.2. Possible fire and exposure of operators	Deluge system	Presence of operators Ignition source	2	4	7
		2.3. Possible explosion impacting process personnel	Personnel are restricted in tank farm	Ignition source	1	4	4
		2.4. Possible explosion impacting public	Buffer zone around plant	Ignition source	1	5	5

Figure 2. Example of HAZOP Worksheets for an Ammonia Plant.

PHAWorks - [EXAMPLE - HAZOP: Node 1, Parameter Flow]

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Node: (1) Gas line from Pressure Controller, PIC-1, to Desulfurizers, V-101 and V-102, including steam heater E-001.

Parameter: Flow **Intention:** 14 - 16MM SCFH

GW	DEVIATION	CAUSES	CONSEQUENCES	CAT	SAFEGUARDS	S
No	No / Low Flow	1. Line leak due to corrosion	1.1. Release of hydrocarbons to atmosphere	ENV	1.1.1. Flow Alarms, FA-001 and FA-002 1.1.2. Low flow and low pressure DCS alarms from Flow Transmitter, FT-1, and Pressure Transmitter, PT-1 1.1.3. Emergency Shutdown Procedure for Ammonia Plant, ERP-001 1.1.4. Cathodic protection of gas line	
			1.2. Potential fire from release of hydrocarbons and exposure to operators	SAF	1.2.1. Same As 1.1.1 to 1.1.4 1.2.2. Fire monitors in the area 1.2.3. LEL monitors and alarm	
			1.3. Potential plant shutdown due to loss of natural gas and process fuel to process	OPR	1.3.1. Same As 1.1.1 to 1.1.4	
		2. Leak due to flange failure	2.1. Release of hydrocarbons to atmosphere	ENV	2.1.1. Same As 1.1.1 to 1.1.3 2.1.2. Monthly PM on flanges	
			2.2. Potential fire from release of hydrocarbons and exposure to operators	SAF	2.2.1. Same As 1.1.1 to 1.1.3, 1.2.2, 1.2.3 and 2.1.2	
			2.3. Potential plant shutdown due to loss of natural gas and process fuel to process	OPR	2.3.1. Same As 1.1.1 to 1.1.3, 2.1.2	
		3. Blind left in line by mechanic after maintenance	3.1. Unable to start operation.	OPR	3.1.1. Start-Up Operating Procedures, OP-AP-001 3.1.2. Energy Control Forms (LOTO) and Safe Work Permits	
		4. Operator leaves 8" block valves closed after maintenance	4.1. Same As 3.1			
		5. Loss of instrument air resulting in Pressure Control Valve, PV-1, failing closed	5.1. Release of hydrocarbons to atmosphere	ENV	5.1.1. Same As 1.1.1 to 1.1.3 5.1.2. Emergency procedures for loss of instrument air, Ammonia Plant ERP-IA-001	
			5.2. Potential fire from release of hydrocarbons and exposure to operators	SAF	5.2.1. Same As 1.1.1 to 1.1.3, 1.2.2, 1.2.3 and 5.1.2	
			5.3. Potential plant shutdown due to loss of natural gas and process fuel to process	OPR	5.3.1. Same As 1.1.1 to 1.1.3 and 5.1.2	
		6. Loss of gas supply	6.1. Potential plant shutdown due to loss of natural gas and process fuel to process	OPR	6.1.1. Same As 1.1.1 to 1.1.3	
		7. Freezing conditions due to severe winter weather resulting in blocked inlet line	7.1. Potential release of hydrocarbons to atmosphere due to activation of PSV-002 on plant upset	ENV	7.1.1. Same As 1.1.1 to 1.1.3 7.1.2. Internet access available in the control room to monitor severe weather	
			7.2. Potential fire from release of hydrocarbons and exposure to operators	SAF	7.2.1. Same As 1.1.1 to 1.1.3, 1.2.2, 1.2.3, and 7.1.2	
			7.3. Potential plant shutdown due to reduced flow of natural gas and process fuel to process	OPR	7.3.1. Same As 1.1.1 to 1.1.3, and 7.1.2	
As Well As	Contamination	8. Contamination due to natural gas being off specification	8.1. Potential plant upset	OPR	8.1.1. Mass spectrometer analyzer and alarm on inlet gas stream 8.1.2. Barton Analyzer 8.1.3. Desulfurizers, V-101 and V-102	

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PHAWorks - [EXAMPLE - HAZOP: Node 1, Parameter Temperature]

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Node: (1) Gas line from Pressure Controller, PIC-1, to Desulfurizers, V-101 and V-102, including steam heater E-001.

Parameter: Temperature **Intention:** Ambient temperature (25°F to 60°F)

GW	DEVIATION	CAUSES	CONSEQUENCES	CAT	SAFEGUARDS	S
Less	Lower Temperature	1. Loss of steam to steam heater, E-001, resulting in liquid drop out in auxiliary boiler	1.1. Potential disposal concerns for liquid hydrocarbon	ENV	1.1.1. DCS line temperature alarm	
			1.2. Potential plant upset (auxiliary boiler trips)	OPR	1.2.1. Same As 1.1.1	
					1.2.2. Auxiliary boiler Level Alarm, LA-1001	
					1.2.3. Auxiliary boiler Level Indicator, LI-1001, DCS alarm	

PHAWorks - [EXAMPLE - HAZOP: Node 1, Parameter Pressure]

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Node: (1) Gas line from Pressure Controller, PIC-1, to Desulfurizers, V-101 and V-102, including steam heater E-001.

Parameter: Pressure **Intention:** 500 - 600 psig

GW	DEVIATION	CAUSES	CONSEQUENCES	CAT	SAFEGUARDS	S
More	Higher Pressure	1. Line overpressure due to Pressure Control Valve, PV-1, failing open	1.1. Release of hydrocarbons to the atmosphere through activation of Pressure Safety Valve, PSV-100	ENV	1.1.1. Flow Alarms, FA-001 and FA-002	
					1.1.2. Emergency Shutdown Procedure for Ammonia Plant, ERP-001	
					1.1.3. Pressure Safety Valve, PSV-100	
			1.2. Potential fire from release of hydrocarbons and exposure to operators	SAF	1.2.1. Same As 1.1.1 to 1.1.2	
					1.2.2. Fire monitors in the area	
					1.2.3. LEL monitors and alarm	
			1.3. Potential plant upset	OPR	1.3.1. Same As 1.1.1 to 1.1.2	

<u>Figure 3. Example of MHA Worksheets for an Ammonia Plant.</u>

PHAWorks - [EXAMPLE - MHA: System 1, Subsystem 1 Gas line from Pressure Controller, PIC-1, to Desulfurizers, V-101 and V-102, including steam ...

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Node: (1) Gas line from Pressure Controller, PIC-1, to Desulfurizers, V-101 and V-102, including steam heater E-001.

INITIATING EVENTS	SCENARIOS	CONSEQUENCES	CAT	SAFEGUARDS	ENABLERS	S
1. Line leak due to corrosion	1.1. Loss of natural gas and process fuel flow to process during normal operation and release of hydrocarbons	1.1.1. Atmospheric release	ENV	1.1.1.1. Flow Alarms, FA-001 and FA-002	1.1.1.1. PM inspections not performed regularly	
				1.1.1.2. Low flow and low pressure DCS alarms from Flow Transmitter, FT-1, and Pressure Transmitter, PT-1		
				1.1.1.3. Emergency Shutdown Procedure for Ammonia Plant, ERP-001		
				1.1.1.4. Cathodic protection of gas line		
		1.1.2. Potential fire and exposure to operators	SAF	1.1.2.1. Same As 1.1.1.1 to 1.1.1.4	1.1.2.1. Ignition source from vehicles in the area	
					1.1.2.2. Presence of operators in the area	
				1.1.2.2. Fire monitors in the area		
				1.1.2.3. LEL monitors and alarm		
2. Leak due to flange failure	2.1. Loss of natural gas and process fuel flow to process during normal operation and release of hydrocarbons	2.1.1. Atmospheric release	ENV	2.1.1.1. Same As 1.1.1.1 to 1.1.1.3	2.1.1.1. PM inspections conducted with an out-of-date flange list	
				2.1.1.2. Monthly PM on flanges		
		2.1.2. Potential fire and exposure to operators	SAF	2.1.2.1. Same As 1.1.1.1 to 1.1.1.3, 1.1.2.2, 1.1.2.3, and 2.1.1.2	2.1.2.1. Ignition source from vehicles in the area	
					2.1.2.2. Presence of operators in the area	
3. Line overpressure due to Pressure Control Valve, PV-1, failing open	3.1. Release of hydrocarbons through activation of Pressure Safety Valve, PSV-100	3.1.1. Atmospheric release	ENV	3.1.1.1. Same As 1.1.1.1, 1.1.1.3	:None identified	
				3.1.1.2. Pressure Safety Valve, PSV-100		
		3.1.2. Potential fire and exposure to operators	SAF	3.1.2.1. Same As 1.1.2.2, 1.1.2.3	3.1.2.1. Ignition source from vehicles in the area	
					3.1.2.2. Presence of operators in the area	
4. Loss of steam to steam heater, E-001	4.1. Liquid drop out in auxiliary boiler due to lower than expected temperature	4.1.1. Potential disposal concerns for liquid hydrocarbon	ENV	4.1.1.1. DCS line temperature alarm	4.1.1.1. DCS line temperature alarm is disabled	

5. Loss of instrument air resulting in Pressure Control Valve, PV-1, failing closed	5.1. Loss of natural gas and process fuel flow to process during normal operation and release of hydrocarbons	5.1.1. Atmospheric release	ENV	5.1.1.1. Same As 1.1.1.1 to 1.1.1.3	5.1.1.1. Instrument air pressure is not monitored by DCS
				5.1.1.2. Emergency procedures for loss of instrument air, Ammonia Plant ERP-IA-001	
		5.1.2. Potential fire and exposure to operators	SAF	5.1.2.1. Same As 1.1.1.1 to 1.1.1.3, 1.1.2.2, 1.1.2.3, and 5.1.1.2	5.1.2.1. Ignition source from vehicles in the area
					5.1.2.2. Presence of operators in the area
6. Freezing conditions due to severe winter weather resulting in blocked inlet line	6.1. Reduced flow of natural gas and process fuel to process and release of hydrocarbons due to activation of PSV-002 on plant upset	6.1.1. Atmospheric release	ENV	6.1.1.1. Same As 1.1.1.1 to 1.1.1.3	6.1.1.1. Ambient temperature indicator in the control room is out of service
				6.1.1.2. Internet access available in the control room to monitor severe weather	
		6.1.2. Potential fire and exposure to operators	SAF	6.1.2.1. Same As 1.1.1.1 to 1.1.1.3, 1.1.2.2, 1.1.2.3, 6.1.1.2	6.1.2.1. Ignition source from vehicles in the area
					6.1.2.2. Presence of operators in the area
7. Vehicle impact resulting in line rupture	7.1. Loss of natural gas and process fuel flow to process during normal operation and release of hydrocarbons	7.1.1. Atmospheric release	ENV	7.1.1.1. Same As 1.1.1.1 to 1.1.1.3	7.1.1.1. Lack of traffic signage throughout the facility
				7.1.1.2. Equipment adjacent to road has bollards	
		7.1.2. Potential fire and exposure to operators	SAF	7.1.2.1. Same As 1.1.1.1 to 1.1.1.3, 1.1.2.2, 1.1.2.3, 7.1.1.2	7.1.2.1. Ignition source from vehicles in the area
					7.1.2.2. Presence of operators in the area

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Figure 4. Example HAZID Worksheet.

SYSTEM: (1) TANK FARM					
HAZARDS	CAT	MATERIALS / SITUATIONS	C	RECOMMENDATIONS	BY
1. Flammable	P	Hexane	3	1.1. Address in PHA	SAF
2. Toxic	P	Ammonia	4	2.1. Address in PHA	SAF
3. Simple asphyxiant	O	Nitrogen gas	2	3.1. Use checklist	ENG
4. Elevated work areas	O	Maintenance on tanks	1	4.1. Use checklist	ENG