Safety Report

Executive Summary

The proposed new HCN plant and new AMS (ammonium sulphate) plant at the Cassel Works site, as owned by the Lucite Company, are going to be built as a replacement for the existing ageing HCN plant and AMS plant.
The new HCN replacement plant is going to source its methane and ammonia as the raw materials via pipeline, from a partner with which there is a long-term agreement to ensure the supply.
Sulfuric acid will be supplied by the SAR plant on the Cassel Works site as shown in Figure 1.
The AMS plant serves the purpose of reusing the waste ammonia. Crystallized ammonium sulphate will be produced.
Key findings from HAZOP/HAZID study:

1. The natural gas supplied at 50-55bar will be cooled by isentropic expansion through a turbine. As a result of the HAZOP study, it's been proposed to design a turbine with variable-number-of-stages through bypass to accommodate the need of turndown of the plant.
2. It's been proposed to design safety interlock systems for the maintenance of equipment to prevent catastrophic events due to human errors in following maintenance procedures. Such safety interlock systems need to be designed for maintenance of units containing flammable or toxic materials such as HCN reactor, absorber, distillation column.
3. Waste-heat boiler should be designed to adapt to the need of turndown of the plant, either by adjusting outlet temperature at maximum flowrate, or by variable number of cooling stages bypass approach. This is to prevent overcooling of the reactor product gas, which would increase the entrainment of HCN in ammonium sulphate.
4. It has been proposed to redesign the vaporization mechanism for ammonia as found out by the HAZOP Study. The heating medium is cold and cannot achieve its purpose, it's proposed to use the stream after compression by CM-001 for vaporizing NH3, BL-001 should be parallel to AC-001 in which case AC-001 serves as by-pass cooling
5. It has been proposed to review methods and codes to process and detoxify unavoidable release of HCN from the condensate tank in unsteady operating conditions such as startup
6. It has been proposed to review design codes in regard to flowrate control, to do relevant studies and propose reliable solutions to control the flowrate of sulfuric acid to

A-001 so that all residual NH3 can be absorbed to prevent unabsorbed NH3 causing HCN polymerization

Our team has been engaged by Lucite through a lump sum turnkey contract including the design, erection & commissioning of the plants. As part of the design process at the current design stage, our steam has carried out a HAZID and HAZOP study to ensure the safety and feasibility and operability of our design.
The present report is the HAZOP&HAZID study report for the plant facilities, based on information available regarding design and site conditions, as well as reasonable assumptions. The report details the methodology, execution and results of the HAZOP & HAZID study. The study was carried out by the design team members as part of the ongoing design process.

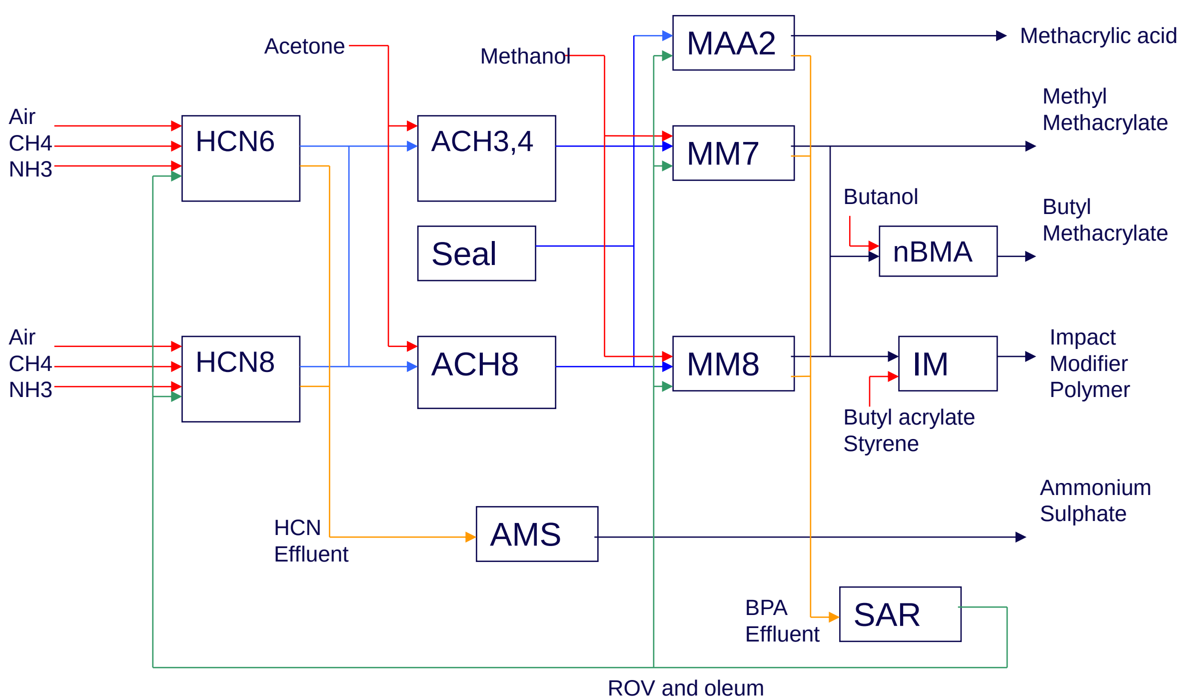


Figure 1 overall scheme of the Cassel Works site

Conclusions

For HAZID study:
The plant PFD was divided into 4 sections, and a total of 48 entries of HAZID study were performed. A total of 12 recommendations were made. All recommendations have been closed.
For HAZOP study:
Three unit-operations selected from the plant P&ID were divided and grouped into 12 nodes. The HAZOP parameters were used 68 times, guidewords 162 times. A total of 193 causes were identified. A total of 49 Recommended actions were made, all of which so far is open, waiting to be closed before 31st, May, 2022, which is the design finish day as determined in the project schedule.

Table of Contents

Introduction

Facility Description

The facility consists of an HCN plant and a AMS plant designed to reuse the waste ammonium sulphate.
Followings are the descriptions of the facilities:

- The HCN plant expands natural gas through mechanical/isentropic expansion with a turbo expander, which cools the natural gas to condense the heavy components,

- the flash column after which separates gas and liquid and thus purification of natural gas to reduce heavy carbons is achieved. The bottom product from the flash column is used for preheating and making 5bar steam for de-aeration of water used to make 20 bar steam.

- HCN is synthesized via the Andrussow process. The raw materials, methane, ammonia and air are premixed in the initial section of the reactor R-001 which is narrower, as shown in the figure below. In the narrower section, a flow distorting device is added to enhance mixing, at the trapezoidal section, a flow distributor is added to distribute the flow more evenly, at the wider cylindrical section, another flow distributor is added at left side to further evenly spread the flow across the cross section. The catalyst is a 1.2 mm thick gauze consisting of 48 layers of platinum nets. The platinum nets consist of platinum wires with a diameter of 0.0025cm spaced at 0.03cm as prescribed by the paper: Modeling catalytic gauze reactors: HCN Synthesis
 (N. Waletzko, L. D. Schmidt ,1988)

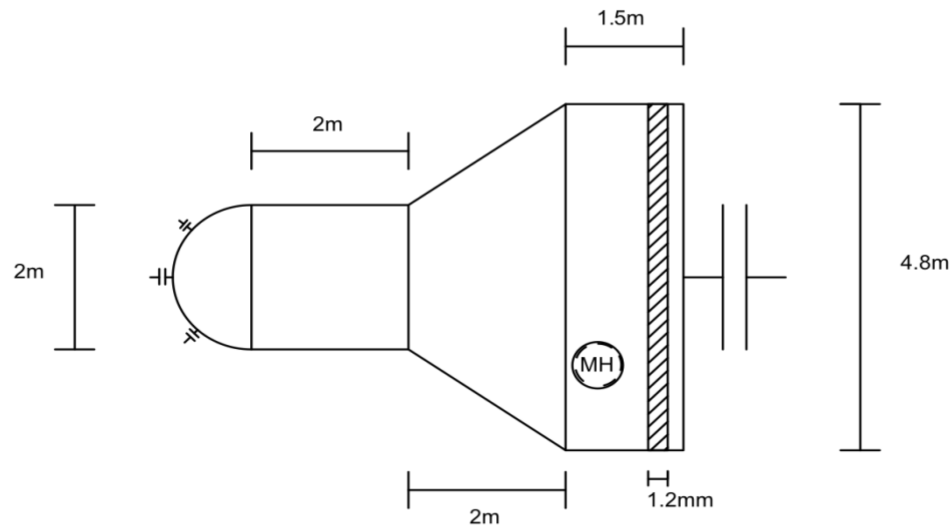


Figure 2 The reactor R-001, inlet is on the left, outlet is on the right, outlet is to be integrated with the main boiler

•The reaction is exothermic and self-sustaining. The high temperature product gas at 1100 C° is passed through the waste heat boiler WH-001 to make 20 bar steam and rapidly cool the product gas to circa. 150°. The waste heat boiler consists of heat exchanging pipes connected to a steam drum. There is a superheating section, a boiling section and an economizer section in the waste heat boiler. The pressure of the steam outlet is controlled at 20 bars through PCV-006. WH-001 is integrated with R-001, meaning no piping between them is needed.

•The cooled product gas from the waste-heat boiler is further cooled to condense majority of the water vapor in the mixture prior to entering the ammonia absorber A-001.The absorber is a packed column absorber, with dilute sulfuric acid as the absorbing agent.

•The top product of A-001 is passed to the HCN absorber A002 which is a packed column absorber with cooled recycled water as the absorbent.
•The bottom product of A-001 is passed to the crystallizer EV-001 to crystalize ammonium sulphate.
•The top product of A-002 contains toxic and flammable materials which are passed to the preheating furnace F-001 for incineration and as energy sources for making steam.

•Negative pressure condition for the whole system is created by a fan FN-001 located on the outlet of the preheating furnace- the waste gas line.
•The bottom product of A-002 is passed to the distillation column for DC-001 to extract

99.5% pure HCN, which is cooled to 5 C° for stabilization and prevention of polymerization.

Objectives

The objectives of the HAZID/HAZOP study are the followings:

•For HAZID

1. To identify potential hazards and likely mechanisms of exposure
2. To identify potential consequences and existing safeguards
3. To recommend actions and further directions of investigation

•For HAZOP

1. To identify deviations from design intention.
2. To identify the causes of deviation and the consequences
3. To recommend actions and further directions of investigation

Scope of Work

•The Scope of Work for HAZID study included both the whole of HCN plant and AMS plant at the Cassel Works site.

•The Scope of Work for HAZOP study includes three unit-operations:

1. The Reactor R-001 and its peripherals
2. The Waste Heat boiler and its peripherals
3. The ammonium absorber

The HAZOP study was carried out to identify problems in regard to process hazard and operability, as discovered through considering the potential mechanisms of deviations from design intent.
The HAZID study was carried out to identify hazards associated with materials and processes and natural hazards.

List of Referenced Documents

Documents used during the Second semester study are as follows in table 1:

Table 1 List of documents/drawings used

S. NO.	Documents/Drawings title	Documents/Drawings No.	Rev.
1	Andrussow HCN Plant HAZID workbook		
2	HAZID PFD Markup		
3	HAZOP workbook		
4	HAZOP node list		
5	HAZOP P&ID Markup		
6	HAZOP Guidewords and matrix table		

Basis of HAZOP Study

HAZOP Technique

Safety in design of chemical plants typically relies on compliance of various standards and codes, as well as the extensive experience of professional specialists and engineers. However, perfectly safe design can hardly be expected even from the most experienced engineers, due to the shear complexity of large chemical plants, and the fact that the various codes and standards are limited in comprehensiveness by the extent of existing knowledge.

In response to this reality, HAZOP techniques were invented. In this technique, every part of the design is questioned, mainly by identifying potential causes of deviations from design intent. It's conducted by a team with members drawn from miscellaneous backgrounds, who would use their imagination to formally and systematically question and identify the causes and consequences of deviations from design intent in every part of the plant.

HAZOP study is a living study that live through the design, erection, commissioning and operating stage. HAZOP study must be conducted whenever there is new design or modification to the existing facilities.

HAZOP Methodology

The 3 unit-operations under the scope of study were grouped into 12 nodes, each marked up with a unique color and a node number.

Appropriate grouping of plant elements into nodes helps make the HAZOP study much more manageable and comprehensive. Too large of a node would make the HAZOP study unmanageable and difficult to trace. Too small of a node will cause too much unnecessary spending of time and human capital resources.
Appropriate node grouping is the first crucial step in a successful HAZOP study.

Generally, as a rule of thumb, the following can be classified as a node:

1. A major line in or out of a major equipment, plus the peripherals on the line
2. A major equipment itself, plus its peripherals

Once the nodes are created, a table of parameters and guidewords need to be prepared, as well as any other relevant documents such as material safety data sheets, functional design& specification etc.

Once all the documents have been prepared, the HAZOP study is conducted through an iterative process as illustrated in the following figure:

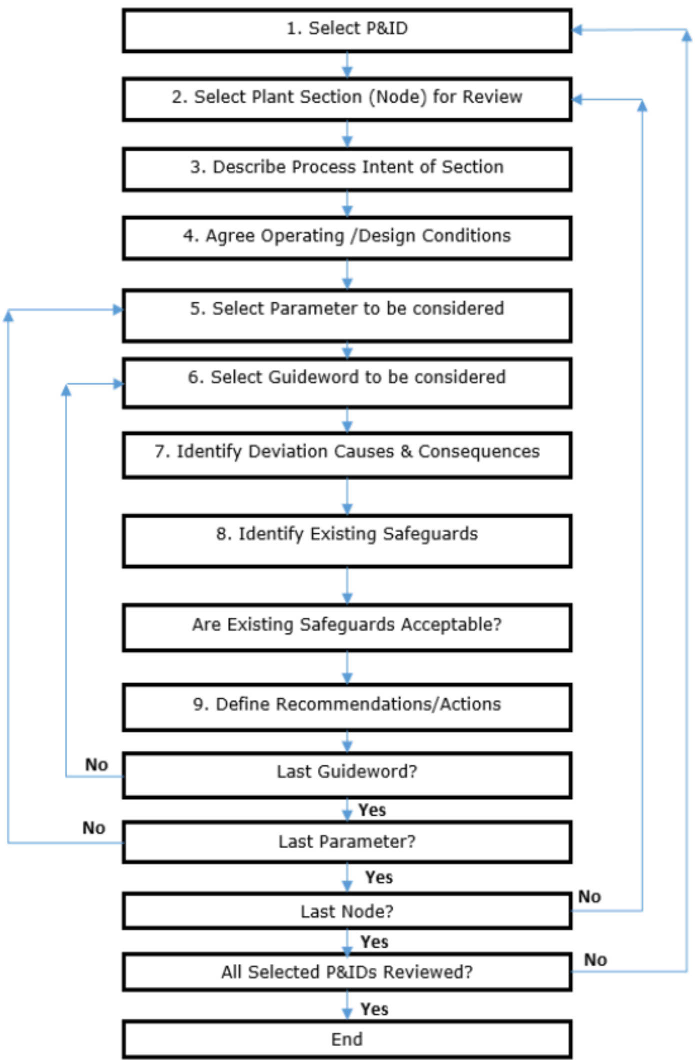


Figure 3 the iterative HAZOP process

Below is the table of parameters and guidewords used in the HAZOP study:

Table 2 Table of parameters and guidewords for the HAZOP study

Parameters		Guidewords								
		No	Less	More	As Well As	Part Of	Reverse	Other Than	Early	Late
Primary	Flow	No Flow	Less Flow	More Flow	Misdirect Flow		Reverse Flow			
	Temperature		Lower Temperature	Higher Temperature		Cryogenic				
	Pressure	Vacuum	Lower Pressure	Higher Pressure						
	Level	No Level	Lower Level	Higher Level						
	Composition		Less Concentration	More Concentration	Contamination			Wrong Material		
Auxiliary	Phase	No Mixing			More Phases	Phase Missed	Phase Change			
	Reaction	No Reaction	Less Reaction	More Reaction	Side Reaction		Reverse Reaction	Unexpected Reaction		
	Fire & Explosion				Mixing with Air			Ignition Source		
	Mechanical Integrity	Inability to Maintenance	Lack Maintenance	Relief Device	High Vibration	Corrosion / Erosion	Leakage	Critical Instrument		
	Utilities	Loss Utilities			Contamination Utilities					
	Abnormal Operation	Step Missed	Act too Late	Act too Earlier	Startup /Shutdown	Initial Start-up	Maintenance	Safety Sampling		
	Human Factors					Human Factor				
	Facilities Siting				Facilities Siting					
	Worker Safety	Worker Safety								
	External Impact				External Force			Extreme Weather		
	Plant Interface				Process Interface					
	Incident Review				Incident Lessons					

HAZOP Assumptions

Throughout the HAZOP study, the following assumptions were made:
i)Maintenance were not considered as adequate safeguards/ recommendations.
ii)Regular maintenance and inspection of the facilities and instruments will be done for the plant to an acceptable standard.
iii) In the case there is a bypass line, the node based on the major line will extend across the bypass line and not terminate at the equipment being bypassed.
iv) Emergency shut down systems and safety inter-lock systems are expected to work.
v) Mechanical protection devices (PSVs, rupture discs) are expected to work.
vi) Plant will be well maintained and operated in accordance with acceptable standards.
vii) Single check valve is adequate unless reverse flow may cause pressure to exceed test pressure.
viii) The following items were not considered:
o Spares for maintenance.
o Simultaneous occurrence of two unrelated incidents
o Simultaneous failure of more than one independent protection devices o Operator's negligence (except common human error)
o Natural calamity (e.g., flood, earthquake)
o Objects falling from sky
o Sabotage
ix) The following were deemed appropriate as protection/safeguard:
o Interlock / shutdown system / trip

o Alarm system for operator action
o Mechanical protection device
o Sample monitoring system
o Operating instruction and operating manuals

Basis of HAZID Study

General

The HAZID study is a high-level qualitative assessment of the risk of exposure of hazards arising from the materials used, as well as from the processes, equipment and others such as maintenance, manual operations and working at height. The HAZID study plays an important role at the initial stages of design, as it helps make design decisions based on the study results.

The HAZID study also draws the expertise from people with miscellaneous backgrounds, as a systematic approach to identify the potential mechanisms of exposure of hazards, to identify existing safeguards and to propose recommended actions or further directions of investigation.

HAZID Methodology

The HAZID study was carried out by the design team as part of the ongoing design process.

First, the PFD for plant will be divided into manageable logical sections, typically 3-5 sections.

Next, a list of HAZID guidewords were prepared for each of the following sources of Hazards, as shown in table 3 below.

1. Materials used
2. Equipment Used
3. The plant processes
4. Others

Next, documents such as material safety datasheets and HAZID workbook needs to be prepared, any other documents if available should also be included for the HAZID study.

Once all the documents have been prepared, the HAZID study is conducted through an iterative process as shown in the figure below.

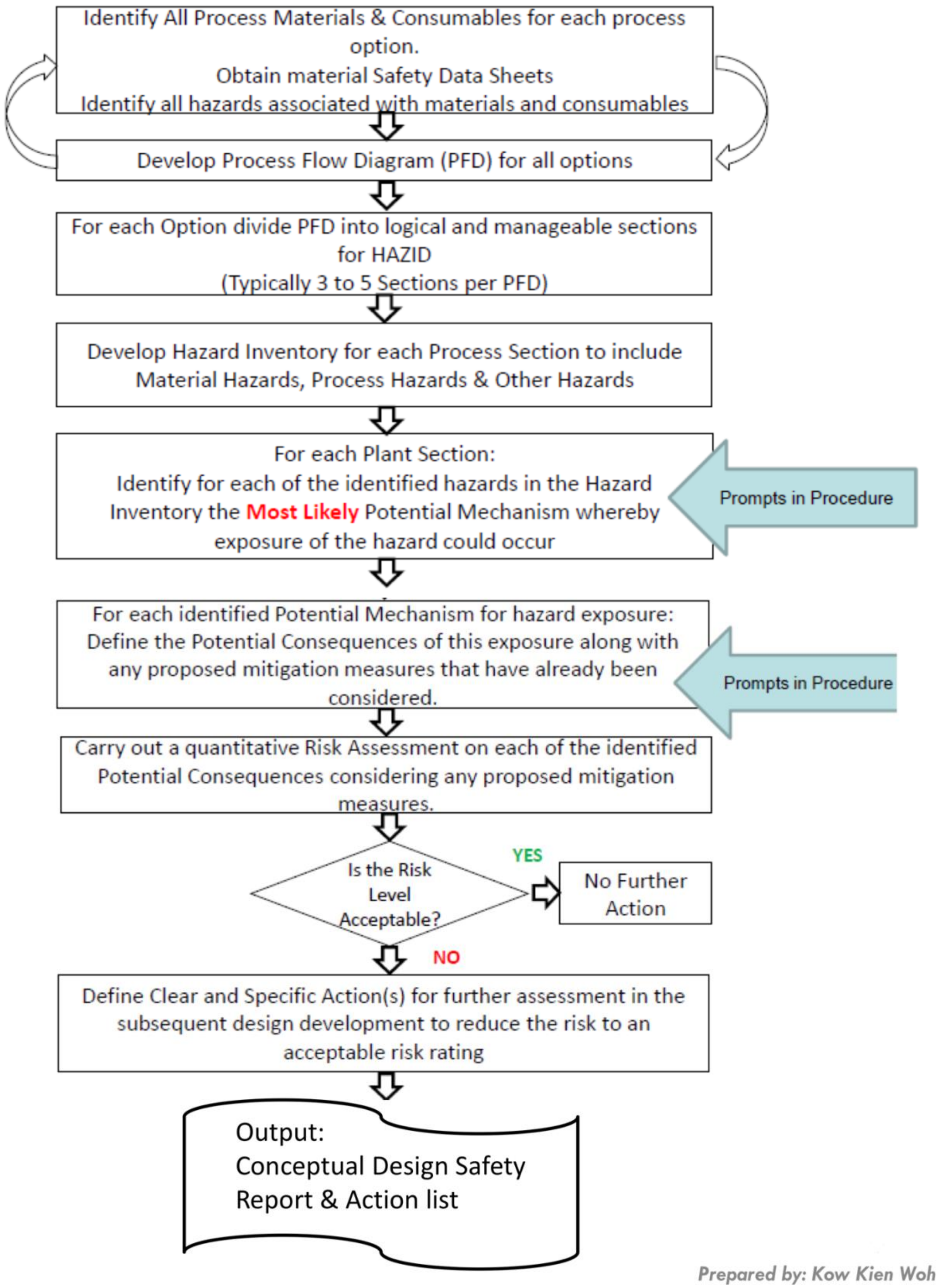


Figure 4 the iterative HAZID process

Table 3 Lists of guidewords for each of the hazard sources

Material	Flammable Materials	Process	Exothermic Reaction
	Toxic Substances		Endothermic Reaction
	Gases under High Pressure		Runaway Reaction
	Liquids under High Pressure		Catalyst Poisoning
	Hot Fluids		Explosive Reaction
	Cryogenic Fluids		High Pressure
	Oxidising Materials		Low Pressure/Vacuum
	Reactive/Unstable Materials		Pressure Cycling
	Explosive Substances		High Temperature
	Corrosive Materials		Low Temperature
	Poisonous Materials		Temperature Cycling
	Biological Hazardous Materials		
	Ecotoxic Materials		
	Combustible Dusts		
Equipment	High Speed Rotational Equipment	Other	Ground Conditions
	Equipment Under Pressure		Transport/Traffic
	Equipment at High Temperature		Natural Hazards
	Equipment at Low Temperature		Manual Operations
	Lifting Equipment		Sampling
	Ionising Radiation Present		Maintenance
	General Non-Ionised Radiation Present		Working At Height
			Noise

Risk Rating

The risk of each consequence was evaluated after taking into consideration the existing mitigation controls in place, according to the rules shown in the picture below. The risk for each consequence is the probability of its occurrence after taking into consideration the existing proposed mitigation controls, times the severity of the consequence which doesn't change after taking into consideration of the existing mitigation controls in place.

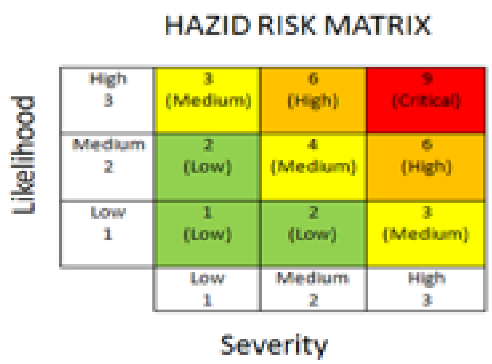


Figure 5 Risk matrix

HAZID Assumptions

Throughout the HAZID study, the following assumptions were made:

i) Regular maintenance and inspection are not considered adequate as recommended actions, so no recommendation was made about them.
ii) Regular maintenance and inspection as well as operation of the plant will be conducted in accordance with acceptable standards.
iii) Emergency shut down systems and safety inter-lock systems are expected to work.
iv) Mechanical protection devices (PSVs, rupture discs) are expected to work.

v) Single check valve is adequate unless reverse flow may cause pressure to exceed
test pressure.
vi) The following items were not considered:
o Spares for maintenance.
o Simultaneous occurrence of two unrelated incidents
o Simultaneous failure of more than one independent protection devices o
o Sabotage
vii) The following were deemed appropriate as protection/safeguard:
o Interlock / shutdown system / trip
o Alarm system for operator action
o Mechanical protection device
o Sample monitoring system
o Operating instruction and operating manuals

4. List of corrective actions from HAZID Study

1.1 Review design codes & requirements for fittings and flanges to accommodate thermal expansion and propose solution
1.2 Review appropriate design codes to mitigate the risk of flooding and hurricane, and give suggestions about plant layout design
2.1 Review Design code for elimination of electric spark in the initial mixing section the reactor R-001. Make sure mechanical sources of ignition all are eliminated as well
2.2 Review design requirements for safety interlock in the maintenance of equipment containing flammable and toxic gases and propose solutions
2.3 Review Design code for elimination of electric spark in the initial mixing section the reactor R-001. Make sure mechanical sources of ignition all are eliminated as well
3.1 Review Safety-interlock design standards and codes, and propose solutions to install safety interlock system to eliminate human error in following procedures while doing maintenance for equipment and pipelines containing flammable gases
3.3 Review design codes in regard to flowrate control, do relevant studies and propose reliable solutions to control the flowrate of sulfuric acid so that all residual NH3 can be absorbed
3.4 Review design codes in regard to flowrate control, do relevant studies and propose reliable solutions to control the flowrate of sulfuric acid so that all residual NH3 can be absorbed
3.5 Review appropriate design codes to mitigate the risk of flooding and hurricane, and give suggestions about plant layout design
4.1 Review methods and codes to process and detoxify unavoidable release of HCN from the condensate tank in unsteady operating conditions such as startup

4.2 Review appropriate design codes to mitigate the risk of flooding and hurricane, and give suggestions about plant layout design

5.List of corrective actions from HAZOP STUDY

1. Review safety interlock design requirements for equipment and pipelines containing HCN or flammable gases or other hazardous materials present on the plant to eliminate the risk from human errors in following procedures when doing maintenance work.
2. Change TCV-002 to fail open, low temperature is safer than high temperature
3. Change TCV-003 to fail open, low temperature is safer than high temperature, there are other valves need to be made fail open or close omitted here.
4. Use the stream after compression by CM-001 for vaporizing NH_3, BL-001 should be parallel to AC-001 in which case AC-001 serves as by-pass cooling
5. Add a mixing device to ensure proper mixing of feed streams prior to reaction
6. Review design requirements for variable power turbine (e.g., variable number of stages of turbine), so that the turbo expander can adapt to the need of turndown of the plant
7. There is a lack of a control loop to control the temperature of product gas into the ammonia absorber A-001 using cooling water flowrate (the flow rate is fixed as shown on the P&ID. Add such a control mechanism to ensure majority of H_2O is condensed and separated prior to entering A-001, so that less power would be required to concentrate ammonium sulphate subsequently.
8. Add a control mechanism that controls the inlet gas temperature by regulating cooling water using FCV-014.
9. Investigate the stability of H_2SO_4 and H_2O supply and decide if storage tank is needed to ensure stable supply.

HAZOP Selected for a high-risk section

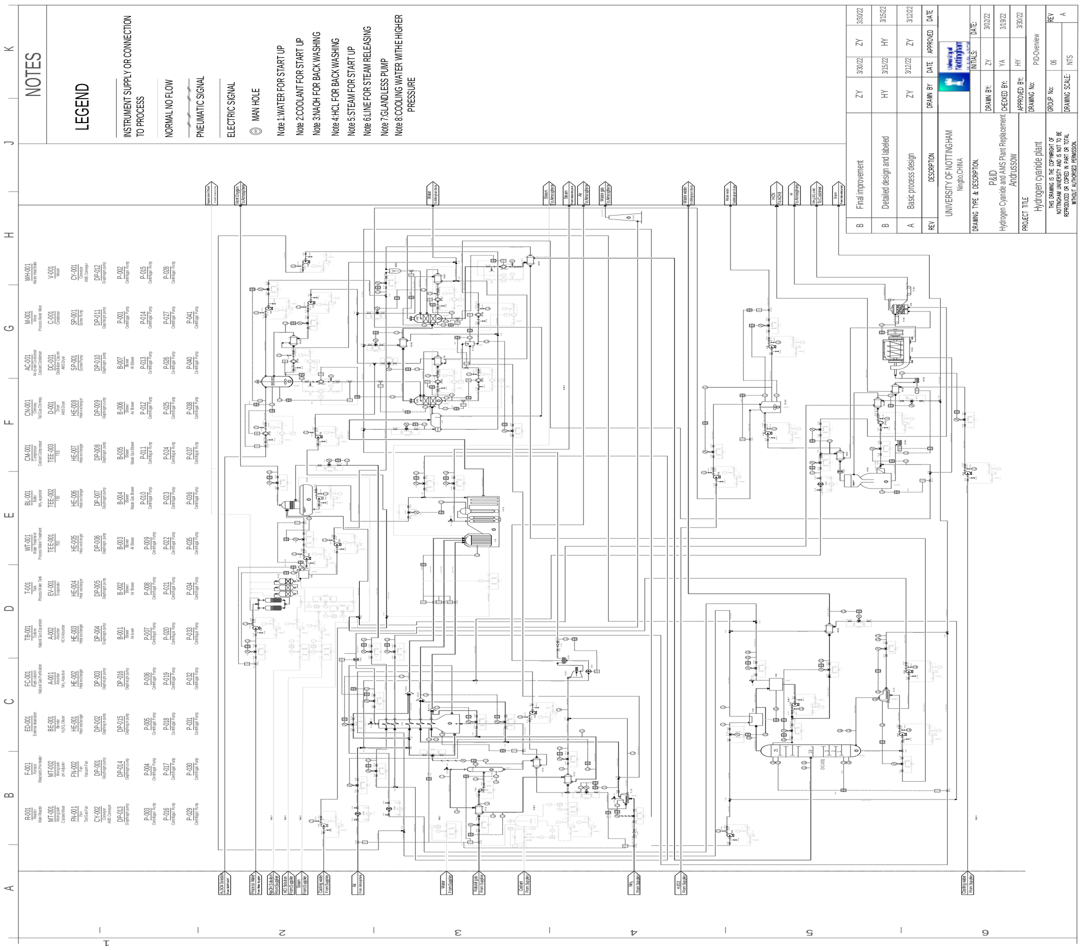
Project:	HCN Plant Replacement at the Cassel Works Site for Lucite Company	Session Date:	21, April, 2022
Section Description:	R-001, the reactor for producing HCN via the andrussow process	Section/Node No:	Node 4
Design Intention:	To produce HCN from the raw materials safely, smoothly and efficiently	Revision No:	
Drawings No.:			

Ref. No.	Parameter	Guideword	Cause	Consequence	Safeguards	Rec. No.	Recommendation	Action By
1	Flow	No	No flow in node 1, 2, 3	See HAZOP for node 1,2,3				
2		Less	Less flow in either of node 1,2,3	See HAZOP for node 1,2,3				
3		More	More flow in either of node 1,2,3	See HAZOP for node 1,2,3				
4		As well as	Leakage from reactor	Reactor designed to appropriate standard for preventing leakage of High temp HCN gas mixture				
5		Reverse	Reverse flow by diffusion from reactor during plant shutdown	Maintennance personnel poisoning by HCN	None	4.01	Review safety interlock design requirments for equipments and pipelines containing HCN	J. X. Lyu
6	Temperature	More	More Temperature in either of node 1,2,3	Overheating of reactor causing meltdown and HCN leakage, leadnig to life losses or personnel injury	Emergency shut down that shut down all three feedlines when temperature is too high; cooling water is constantly cooling the product gas			
7		Less	Less Temperature in either of node 1,2,3	See HAZOP for node 1,2,3				
8		Part of	Low temperature natural gas is fed into reactor	Disruption of production	Preheating furnace to control feed inlet temperature			

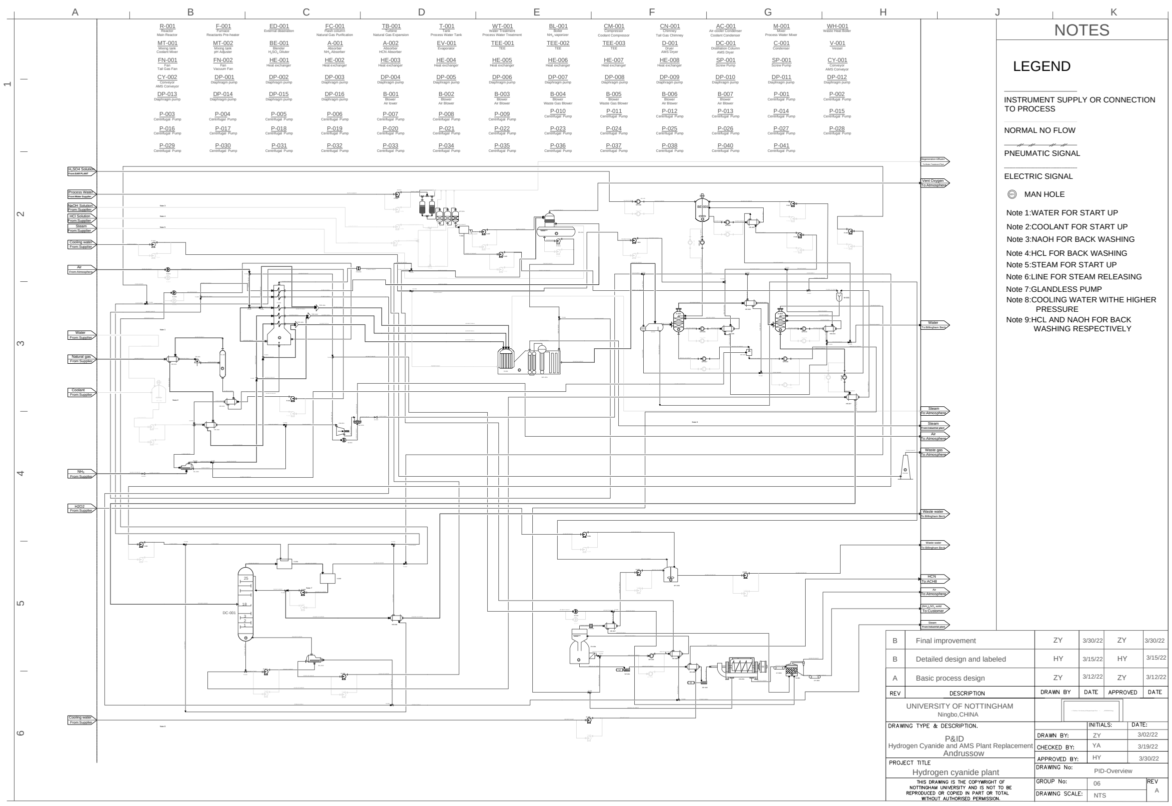
Project:	HCN Plant Replacement at the Cassel Works Site for Lucite Company				Session Date:		21, April, 2022	
Section Description:	R-001, the reactor for producing HCN via the andrussow process				Section/Node No:		Node 4	
Design Intention:	To produce HCN from the raw materials safely, smoothly and efficiently				Revision No:			
Drawings No.:					Revision Date:			
9	Reaction	No	Feed streams are not adquately mixed	Disruption of production	None	4.02	Add a mixing device to ensure proper mixing of feed streams prior to reaction	Y. A. Guo
10		Less		Decreased product quality				
11		As well as	Side reaction	Decreased yield				
12	Pressure	Less	Turbine not designed to output the same pressure under different turndown ratios	Pressure not enough to power enough flowrate	None	4.03	Review design requirements for variable power turbine (e.g. variable number of stages of turbine)	J. J. Sun
13		More	Turbine not designed to output the same pressure under different turndown ratios	Pressure not enough to power enough flowrate	None	4.03	Review design requirements for variable power turbine (e.g. variable number of stages of turbine)	J. J. Sun
			Pressure build-up unexpectedly	explosion	There is a huge fan FN-001 that creates negative pressure in the whole system			
14	Concentration	Less	Low HCN concentration because of not enough residence time	Low productivity	Residence time in catalyst designed to a reasonble margin of excess			
15	Fire & Explosion	Other than	Ignition source	Fire & Explosion	Equipments and pipelines designed to appropriate standard for prevention of mechanical spark and electrical spark			

Project:	HCN Plant Replacement at the Cassel Works Site for Lucite Company					Session Date:		21, April, 2022	
Section Description:	R-001, the reactor for producing HCN via the andrussow process					Section/Node No:		Node 4	
Design Intention:	To produce HCN from the raw materials safely, smoothly and efficiently					Revision No:			
Drawings No.:						Revision Date:			
16	Mechanical integrity	No	Inability to Maintenance	All the way up to Fire& explosion	Clearly defined maintenance procedures and schedules and resonsibilities				
17		Less/Lack Maintenance	Lack of Maintenance	All the way up to Fire& explosion	Clearly defined maintenance procedures and schedules and resonsibilities				
18		Part of	corrosion/errosion	All the way up to Fire& explosion	Clearly defined maintenance procedures and schedules and resonsibilities as well as corrosion allowance for equipments and pipelines				
19		Reverse	Leakage	All the way up to Fire& explosion	Clearly defined maintenance procedures and schedules and resonsibilities				
20	Human factors	Part of	Mistakes when doing maintenance work	Fire& explosion and poisoning	None	4.04	Review safety interlock design requirments for equipments and pipelines containing HCN or flammable gases or other hazardous materials present on the plant	Z. Y. Chai	

Appendix 1: HAZOP P&ID Markup



Appendix 2: HAID PFD Markup

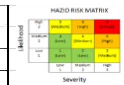


Appendix 3: HAZOP Worksheet

0		HCN Plant replacement at the Cassel Works Site			P&ID Title/Description		Andrussow process P&ID			P&ID No. Rev No.:	
Group No.:		6	Meeting Attendees	H. Y. CHEN , Y. K. WANG , L. S. WEI , J. J. SUN , Y. A. GUO , Z. Y. CHAI , J. X. LYU						HAZOP Meet Date	
Design Intent/Process Outline:		Soomth & safe production of HCN									
Node No	**Parameter**	**Guideword**	**Cause**	**Consequence**	**Current Safeguards**	**Action No.**	**Recommendations/Action**	**Action Assigned To:**	**Required Completion Date**	**Status Open/Closed**	**Action Outcome**
1	Flow	No	FCV-003 fail-close	Disruption of production	Bypass maintenance line is in place to enable replacing the control valve						
				Forming NOx that pollutes the environment							
				Forming HNO3 that while mxied with H2SO4 corrodes equipments		1.01	Review requirements for equipments in contact with HNO3	H. Y. Chen	31st May, 2022	OPEN	
			FT-007 fail	Disruption of production	Regular maintenance and replacement						
				Forming NOx that pollutes the environment							
				Forming HNO3 that while mxied with H2SO4 corrodes equipments							
			ESD-002 or ESD-010 shut down	Disruption of production	Other ESDs will simultaneouly shut down Ammonia and Air supplies						
				Forming NOx that pollutes the environment							
				Forming HNO3 that while mxied with H2SO4 corrodes equipments							
		Less	FCV-003 fail-close	Disruption of production	Bypass maintenance line is in place to enable replacing the control valve						
				Forming NOx that pollutes the environment							
				Forming HNO3 that while mxied with H2SO4 corrodes equipments		1.01	Review requirements for equipments in contact with HNO3	H. Y. Chen	31st May, 2022	OPEN	
			FT-007 fail	Disruption of production	Regular maintenance and replacement						
				Forming NOx that pollutes the environment							
				Forming HNO3 that while mxied with H2SO4 corrodes equipments							
		More	FCV-003 fail	Disruption of production	Bypass maintenance line is in place to enable replacing the control valve						
			FT-007 fail	Disruption of production	Regular maintenance and replacement						
		As well as	Leakage of natural gas from valves and flanges	Forming flammable mixture leading to fire and explosion	Flanges and valves designed to approriate standard for handling natural gas						
		Reverse	Reverse flow by diffusion from reactor during plant shutdown	Maintennance personnel poisoning by HCN	None	1.02	Review safety interlock design requirments for equipments and pipelines containing HCN	Y. K. Wang	31st May, 2022	OPEN	
		Other than	N/A								
	Temperature	Less	control loop TIC-002 fail	Decreased product quality	Bypass maintenance line is in place to enable replacement						
		More	control loop TIC-002 fail	Decreased product quality	Bypass maintenance line is in place to enable replacement						
			TCV-002 fail close	Overheating of reactor causing meltdown and HCN leakage, leadnig to life losses	Regular maintenance and replacement	1.03	Change TCV-002 to fail open, low temperature is safer than high temperature	L. S. Wei	31st May, 2022	OPEN	
		Part of	Natural gas coming out of FC-001 is of low temperature	Reduced life span and reliability of eqiupments under cryogenic condition	Equipments and pipelines in contact with cryogenic substance designed to appropriate standard						
	Pressure	Less	Turbine not designed to output the same pressure under different turndown ratios	Pressure not enough to power enough flowrate	None	1.04	Review design requirements for variable power turbine (e.g. variable number of stages of turbine)	J. J. Sun	31st May, 2022	OPEN	
		More	Turbine not designed to output the same pressure under different turndown ratios	Pressure not enough to power enough flowrate	None	1.04	Review design requirements for variable power turbine (e.g. variable number of stages of turbine)	Y. A. Guo	31st May, 2022	OPEN	
	Level		N/A								
	Composition	As well as	N/A								
		Other than	N/A								
	Fire & Explosion	As well as	Mixing with air	Fire & Explosion	Pipelines and equipments designed to appropriate standard for sealing						
		Other than	Ignition source	Fire & Explosion	Equipments and pipelines designed to appropriate standard for prevention of mechanical spark and electrical spark						
	Mechanical integrity	No	Inability to Maintenance	All the way up to Fire& explosion	Clearly defined maintenance procedures and schedules and resonsibilities						
		Less/Lack Maintenance	Lack of Maintenance	All the way up to Fire& explosion	Clearly defined maintenance procedures and schedules and resonsibilities						
		Part of	corrosion/errosion	All the way up to Fire& explosion	Clearly defined maintenance procedures and schedules and resonsibilities as well as corrosion allowance for equipments and pipelines						
		Reverse	Leakage	All the way up to Fire& explosion	Clearly defined maintenance procedures and schedules and resonsibilities						
	Human factors	Part of	Mistakes when doing maintenance work	Fire& explosion and poisoning	None	1.05	Review safety interlock design requirments for equipments and pipelines containing HCN or flammable gases or other hazardous materials present on the plant	Z. Y. Chai	31st May, 2022	OPEN	
2	Flow	No	the cascade control loop involving FCV-004 & LCV-002 fails	Disruption of production	Bypass maintenance line is in place to enable replacement						
			The temperature of the stream out of HE-003 would be too low to vaporise ammonia, because the said stream is cooled by the bottom product of natural gas expansion		None	2.01	Use the stream after compression by CM-001 for vaporizing NH3,BL-001 should be parallel to AC-001 in which case AC-001 serves as by pass cooling	J. X. Lyu	31st May, 2022	OPEN	
		Less	the cascade control loop involving FCV-004 & LCV-002 fails	Disruption of production	Bypass maintenance line is in place to enable replacement						
		More	the cascade control loop involving FCV-004 & LCV-002 fails	Disruption of production	Bypass maintenance line is in place to enable replacement						
		As well as	Leakage of ammonia	Personnel poisoning & fire & explosion	Pipelines and equipments designed to appropriate standard for sealing						
		Reverse	Reverse flow by diffusion from reactor during plant shutdown	Maintennance personnel poisoning by HCN	None	2.02	Review safety interlock design requirments for equipments and pipelines containing HCN	Y. K. Wang	31st May, 2022	OPEN	
	Temperature	Less	control loop containing TCV-003 fails	Disruption of production	Bypass maintenance line is in place to enable replacement						
		More	control loop containing TCV-003 fails	Decreased product quality	Bypass maintenance line is in place to enable replacement						
			TCV-003 fail close	Overheating of reactor causing meltdown and HCN leakage, leadnig to life losses	Regular maintenance and replacement	2.03	Change TCV-003 to fail open, low temperature is safer than high temperature	Y. A. Guo	31st May, 2022	OPEN	
	Pressure	Less	Reactor pressure is low	N/A							
		More	Reactor pressure is High	N/A							
	Fire & Explosion	As well as	Mixing with air	Fire & Explosion	Pipelines and equipments designed to appropriate standard for sealing						
		Other than	Ignition source	Fire & Explosion	Equipments and pipelines designed to appropriate standard for prevention of mechanical spark and electrical spark						
	Mechanical integrity	No	Inability to Maintenance	All the way up to Fire& explosion	Clearly defined maintenance procedures and schedules and resonsibilities						
		Less/Lack Maintenance	Lack of Maintenance	All the way up to Fire& explosion	Clearly defined maintenance procedures and schedules and resonsibilities						
		Part of	corrosion/errosion	All the way up to Fire& explosion	Clearly defined maintenance procedures and schedules and resonsibilities as well as corrosion allowance for equipments and pipelines						
		Reverse	Leakage	All the way up to Fire& explosion	Clearly defined maintenance procedures and schedules and resonsibilities						
	Human factors	Part of	Mistakes when doing maintenance work	Fire& explosion and poisoning	None	2.04	Review safety interlock design requirments for equipments and pipelines containing HCN or flammable gases or other hazardous materials present on the plant	J. X. Lyu	31st May, 2022	OPEN	
3	Flow	No	Fan P-013 Failure	Dsiruption of production	Backup pump is installed in parallel						
			FCV-001 fail-close		Bypass maintenance line is in place to enable replacement						
		Less	Fan P-013 Failure	Dsiruption of production	Backup pump is installed in parallel						
			FCV-001 fail		Bypass maintenance line is in place to enable replacement						
		More	FCV-001 fail	Disruption of production	Bypass maintenance line is in place to enable replacement						
		As well as	N/A								
		Reverse	Reverse flow by diffusion from reactor during plant shutdown	Maintennance personnel poisoning by HCN	None	3.01	Review safety interlock design requirments for equipments and pipelines containing HCN	J. X. Lyu	31st May, 2022	OPEN	
	Temperature	Less	control loop containing TCV-001 fails	Disruption of production	Bypass maintenance line is in place to enable replacement						
		More	control loop containing TCV-001 fails	Decreased product quality	Bypass maintenance line is in place to enable replacement						
			TCV-001 fail close	Overheating of reactor causing meltdown and HCN leakage, leadnig to life losses or personnel injury	Regular maintenance and replacement	3.02	Change TCV-001 to fail open, low temperature is safer than high temperature	L. S. Wei	31st May, 2022	OPEN	
	Pressure	Less	Reactor pressure is low	N/A							
		More	Reactor pressure is High	More fan power is needed	Reactor pressure and fan power designed approriate values						
	Mechanical integrity	No	Inability to Maintenance	Congested pipe line	Clearly defined maintenance procedures and schedules and resonsibilities						
		Less/Lack Maintenance	Lack of Maintenance	Congested pipe line	Clearly defined maintenance procedures and schedules and resonsibilities						
		Reverse	Leakage	decreased efficiency	Clearly defined maintenance procedures and schedules and resonsibilities						
	Human factors	Part of	Mistakes when doing maintenance work	Fire& explosion and poisoning	None	3.03	Review safety interlock design requirments for equipments and pipelines containing HCN or flammable gases or other hazardous materials present on the plant	Y. K. Wang	31st May, 2022	OPEN	
4	Flow	No	No flow in node 1, 2, 3	See HAZOP for node 1,2,3							
		Less	Less flow in either of node 1,2,3	See HAZOP for node 1,2,3							
		More	More flow in either of node 1,2,3	See HAZOP for node 1,2,3							
		As well as	Leakage from reactor	Reactor designed to appropriate standard for preventing leakage of High temp HCN gas mixture							
		Reverse	Reverse flow by diffusion from reactor during plant shutdown	Maintennance personnel poisoning by HCN	None	4.01	Review safety interlock design requirments for equipments and pipelines containing HCN	J. X. Lyu	31st May, 2022	OPEN	
	Temperature	More	More Temperature in either of node 1,2,3	Overheating of reactor causing meltdown and HCN leakage, leadnig to life losses or personnel injury	Emergency shut down that shut down all three feedlines when temperature is too high; cooling water is constantly cooling the product gas						
		Less	Less Temperature in either of node 1,2,3	See HAZOP for node 1,2,3							
		Part of	Low temperature natural gas is fed into reactor	Disruption of production	Preheating furnace						
	Reaction	No	Feed streams are not adquately mixed	Disruption of production	None	4.02	Add a mixing device to ensure proper mixing of feed streams prior to reaction	Y. A. Guo	31st May, 2022	OPEN	
		Less		Decreased product quality							
		As well as	Side reaction	Decreased yield	Optimised feed ratio to maximise yield						
	Pressure	Less	Turbine not designed to output the same pressure under different turndown ratios	Pressure not enough to power enough flowrate	None	4.03	Review design requirements for variable power turbine (e.g. variable number of stages of turbine)	H. Y. Chen	31st May, 2022	OPEN	
		More	Turbine not designed to output the same pressure under different turndown ratios	Pressure not enough to power enough flowrate	None	4.03	Review design requirements for variable power turbine (e.g. variable number of stages of turbine)	J. J. Sun	31st May, 2022	OPEN	
			Pressure build-up unexpectedly	explosion	There is a huge fan FN-001 that creates negative pressure in the whole system						
	Concentration	Less	Low HCN concentration because of not enough residence time	Low productivity	Residence time in catalyst designed to a reasonble margin of excess						
	Fire & Explosion	Other than	Ignition source	Fire & Explosion	Equipments and pipelines designed to appropriate standard for prevention of mechanical spark and electrical spark						
	Mechanical integrity	No	Inability to Maintenance	All the way up to Fire& explosion	Clearly defined maintenance procedures and schedules and resonsibilities						
		Less/Lack Maintenance	Lack of Maintenance	All the way up to Fire& explosion	Clearly defined maintenance procedures and schedules and resonsibilities						
		Part of	corrosion/errosion	All the way up to Fire& explosion	Clearly defined maintenance procedures and schedules and resonsibilities as well as corrosion allowance for equipments and pipelines						
		Reverse	Leakage	All the way up to Fire& explosion	Clearly defined maintenance procedures and schedules and resonsibilities						
	Human factors	Part of	Mistakes when doing maintenance work	Fire& explosion and poisoning	None	4.04	Review safety interlock design requirments for equipments and pipelines containing HCN or flammable gases or other hazardous materials present on the plant	Z. Y. Chai	31st May, 2022	OPEN	
5	Level	No	LCV-004 fail close	Uncooled HCN gas, runnaway polymerisation, fire & explosion	None	5.01	Make LCV-004 fail open	L. S. Wei	31st May, 2022	OPEN	
			Pump P-011 failure	Uncooled HCN gas, runnaway polymerisation, fire & explosion	Backup pump is installed in parallel						
		Less	Pump P-011 failure	Uncooled HCN gas, runnaway polymerisation, fire & explosion	Backup pump is installed in parallel						
			Control valve LCV-004 failure	Uncooled HCN gas, runnaway polymerisation, fire & explosion	Bypass maintenance line is in place to enable replacement						
		More	Flow of product gas reduces	N/A							
	Temperature	Less	lower temperature of cooled product gas because of plant turndown	Cause HCN to condense- might lead to High concentration of HCN in ammonium sulphate	Inlet water is always pretreated with steam in the deaerator to nearly boiling point						
		More	Higher temperature of cooled product gas because of varying plant turndown ratio	High temperature in ammonia absorber, Low concentration in HCN absorber, Low productivity	there is a second cooling stage after the waste heat boiler WH-001 to condense H2O in the gas mixture						
	Pressure	Less	Turbine not designed to output the same pressure under different turndown ratios	Pressure not enough to power enough flowrate	None	5.02	Review design requirements for variable power turbine (e.g. variable number of stages of turbine)	L. S. Wei	31st May, 2022	OPEN	
		More	Turbine not designed to output the same pressure under different turndown ratios	Pressure not enough to power enough flowrate	None	5.02	Review design requirements for variable power turbine (e.g. variable number of stages of turbine)	J. J. Sun	31st May, 2022	OPEN	
			Pressure build-up unexpectedly	explosion	There is a huge fan FN-001 that creates negative pressure in the whole system						
	Fire & Explosion	Other than	Ignition source	Fire & Explosion	Equipments and pipelines designed to appropriate standard for prevention of mechanical spark and electrical spark						
	Mechanical integrity	No	Inability to Maintenance	All the way up to Fire& explosion	Clearly defined maintenance procedures and schedules and resonsibilities						
		Less/Lack Maintenance	Lack of Maintenance	All the way up to Fire& explosion	Clearly defined maintenance procedures and schedules and resonsibilities						
		Part of	corrosion/errosion	All the way up to Fire& explosion	Clearly defined maintenance procedures and schedules and resonsibilities as well as corrosion allowance for equipments and pipelines						
		Reverse	Leakage	All the way up to Fire& explosion	Clearly defined maintenance procedures and schedules and resonsibilities						
	Human factors	Part of	Mistakes when doing maintenance work	Fire& explosion and poisoning	None	5.03	Review safety interlock design requirments for equipments and pipelines containing HCN or flammable gases or other hazardous materials present on the plant	J. J. Sun	31st May, 2022	OPEN	
6	Flow	No	LCV-004 fail close	Uncooled HCN gas, runnaway polymerisation, fire & explosion	None	6.01	Make LCV-004 fail open	Y. A. Guo	31st May, 2022	OPEN	
			Pump P-011 failure	Uncooled HCN gas, runnaway polymerisation, fire & explosion	Backup pump is installed in parallel						
		Less	Pump P-011 failure	Uncooled HCN gas, runnaway polymerisation, fire & explosion	Backup pump is installed in parallel						
			Control valve LCV-004 failure	Uncooled HCN gas, runnaway polymerisation, fire & explosion	Bypass maintenance line is in place to enable replacement						
		More	Flow of product gas reduces	N/A							
	Pressure	Less	Pump P-011 failure	Unable to reach 20 bar requirement of steam	Backup pump is installed in parallel						
		More	N/A								
	Temperature	Less	lower temperature of cooled product gas	Cause HCN to condense- might lead to High concentration of HCN in ammonium sulphate	Inlet water is always pretreated with steam in the deaerator to nearly boiling point						
		More	Higher temperature of cooled product gas	High temperature in ammonia absorber, Low concentration in HCN absorber, Low productivity	there is a second cooling stage after the waste heat boiler WH-001 to condense H2O in the gas mixture						
	Mechanical integrity	Part of	corrosion/errosion	Spilled water hazrad	Clearly defined maintenance procedures and schedules and resonsibilities as well as corrosion allowance for equipments and pipelines						
		Reverse	Leakage	Spilled water hazrad	Clearly defined maintenance procedures and schedules and resonsibilities						
7	Pressure	Less	Control valve PCV-006 fail	Steam not produced to 20 bar standard	Bypass maintenance line is in place to enable replacement						
		More	PIC-006 set point incorrect	Reactor gas not adquately cooled	PIC alarm range appropriately defined						
	Phase	More	water fills steam drum	Steam produced is substandard							
	Mechanical integrity	Part of	corrosion/errosion	Spilled water hazrad	Clearly defined maintenance procedures and schedules and resonsibilities as well as corrosion allowance for equipments and pipelines						
		Reverse	Leakage	Spilled water hazrad	Clearly defined maintenance procedures and schedules and resonsibilities						
8	Flow	No	No flow in node 1, 2, 3	See HAZOP for node 1,2,3							
		Less	Less flow in either of node 1,2,3	See HAZOP for node 1,2,3							
		More	More flow in either of node 1,2,3	See HAZOP for node 1,2,3							
	Temperature	Less	lower temperature of gas entering absorber	Cause HCN to condense- might lead to High concentration of HCN in ammonium sulphate	Inlet cooling water is always pretreated with steam in the deaerator to nearly boiling point						
		More	Higher temperature of gas entering absorber	High temperature in ammonia absorber, Low concentration in HCN absorber, Low productivity	there is a second cooling stage after the waste heat boiler WH-001 to condense H2O in the gas mixture	8.01	There is a lack of a control loop to control the temperature of product gas into the ammonia absorber A-001 using cooling water flowrate . Add such a control mechanism to ensure majority of H2O is condensed and separated prior to entering A-001	J. J. Sun	31st May, 2022	OPEN	
	Pressure	Less	Turbine not designed to output the same pressure under different turndown ratios	Pressure not enough to power enough flowrate	None	8.02	Review design requirements for variable power turbine (e.g. variable number of stages of turbine)	Y. A. Guo	31st May, 2022	OPEN	
		More	Turbine not designed to output the same pressure under different turndown ratios	Pressure not enough to power enough flowrate	None	8.02	Review design requirements for variable power turbine (e.g. variable number of stages of turbine)	Z. Y. Chai	31st May, 2022	OPEN	
			Pressure build-up unexpectedly	explosion	There is a huge fan FN-001 that creates negative pressure in the whole system						
	Fire & Explosion	As well as	Mixing with air	Fire & Explosion	Pipelines and equipments designed to appropriate standard for sealing						
		Other than	Ignition source	Fire & Explosion	Equipments and pipelines designed to appropriate standard for prevention of mechanical spark and electrical spark						
	Mechanical integrity	No	Inability to Maintenance	All the way up to Fire& explosion	Clearly defined maintenance procedures and schedules and resonsibilities						
		Less/Lack Maintenance	Lack of Maintenance	All the way up to Fire& explosion	Clearly defined maintenance procedures and schedules and resonsibilities						
		Part of	corrosion/errosion	All the way up to Fire& explosion	Clearly defined maintenance procedures and schedules and resonsibilities as well as corrosion allowance for equipments and pipelines						
		Reverse	Leakage	All the way up to Fire& explosion	Clearly defined maintenance procedures and schedules and resonsibilities						

Appendix 4 : HAZID Worksheet

PROJECT:	HCN Plant replacement at the Cassel Works Site	**HAZID DATE:**	
PFD DRAWING No.		**PROJECT GROUP No.:** **PARTICIPANTS:**	
FACILITY SECTION No.:	1	**PARTICIPANTS SIGNATURES:**	
FACILITY SECTION DESCRIPTION		**REVISION:**	



					Hazard Consequence Ranking Assuming Controls in Place			**Action/Consideration in Design Process to Mitigate Hazard Consequences**				
No.	**Specific Hazard From Hazard Inventory**	**Potential Mechanism(s) for Hazard Exposure**	**Potential Hazard Consequences**	**Proposed Mitigation Controls In Place**	**Likelihood (Dropdown)**	**Severity (Dropdown)**	**Risk Rating**	**Unique Action No.**	**Description of Actions/Consideration**	**Action Assigned To:**	**Action Required Completion Date**	**Issue Status (Open/Closed)**
1	Flammable Materials	Leakage of natural gas from pipelines under high pressure	Fire and explosion	Appropriate design codes for high pressure natural gas pipe line	1	3	3					
2	Toxic Substances	Leakage of ammonia from pipelines	Personnel injury or fatality	Appropriate design codes for ammonia liquid and gas pipe line	1	3	3					
3	Gases under High Pressure	Natural gas pipeline rupture	Fire and explosion	Appropriate design codes for high pressure natural gas pipeline	1	3	3					
4	Hot Fluids	High temperature of preheating furnace surface	Personnel burning injury	Appropriate design codes for high temp surface insulation	1	2	2					
5	Cryogenic Fluids	Low temperature natural gas after expansion causes pipeline to become brittle and unable to adpat to thermal expansion	Fire and explosion	Appropriate design codes for low temperature pipeline	3	3	9	1.1	Review design codes & requirements for fittings and flanges to accommodate thermal expansion and propose solutions	H. Y. Chen	21st April, 2022	CLOSED
6	Explosive Substances	Leakage of natural gas from pipelines forming explosive mixture with air	Fire and explosion	Appropriate design codes for natural gas pipe lines.	1	3	3					
7	High Speed Rotational Equipment	Mechanical fatigue of flanges caused by vibration of the turbo expander	Fire and explosion	Appropriate design codes for flanges under constant vibration	1	3	3					
8	Equipment at High Temperature	High temperature of preheating furnace surface	Personnel burning injury	Appropriate design codes for high temp surface insulation	1	2	2					
9	High Temperature	High temperature of preheating furnace surface	Personnel burning injury	Appropriate design codes for high temp surface insulation	1	2	2					
10	Low Temperature	Low temperature of flash column and pipelines out of it	Personnel freezing injury	Appropriate design codes for low temp surface insulation	1	1	1					
11	Natural Hazards	Hurricane and flood	Damage to facility leading to gas leakage and explosion	Appropriate design codes for plant layout, spacing.	1	3	3	1.2	Review appropriate design codes to mitigate the risk of flooding and hurricane, and give suggestions about plant layout design	Y. K. Wang	21st April, 2022	CLOSED
12	Maintenance	Maintenance procedures not correctly followed due to human error	Personnel injury or fatality	Safety interlocks appropriately designd to eliminate human error in following procedures while doing maintenance	1	3	3					
13	Noise	Large noise may be produced when the pumps and turbines are working.	Personnel hearing loss	Appropriate design codes for plant layout and safety training	1	2	2					

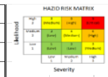
PROJECT:		**HAZID DATE:**		
PFD DRAWING No.	HCN Plant replacement at the Cassel Works Site	**PROJECT GROUP No.:** **PARTICIPANTS:**		
FACILITY SECTION No.:		**PARTICIPANTS SIGNATURES:**		
FACILITY SECTION DESCRIPTION	2	**REVISION:**		

					Hazard Consequence Ranking Assuming Controls in Place			Action/Consideration in Design Process to Mitigate Hazard Consequences				
No.	**Specific Hazard From Hazard Inventory**	**Potential Mechanism(s) for Hazard Exposure**	**Potential Hazard Consequences**	**Proposed Mitigation Controls In Place**	**Likelihood (Dropdown)**	**Severity (Dropdown)**	**Risk Rating**	**Unique Action No.**	**Description of Actions/Consideration**	**Action Assigned To:**	**Action Required Completion Date**	**Issue Status (Open/Closed)**
1	Flammable Materials	Gas mixture leakage from flange due do weakening of flange under high temperature	Fire & explosion	Appropriate design codes for flanges under high temperature	1	3	3					
2	Toxic Substances	Gas mixture leakage from flange due do weakening of flange under high temperature	Personnel injury or fatality	Appropriate design codes for flanges under high temperature	1	3	3					
3	Hot Fluids	Hot reactor outer surface causes burning injury or autoignition of substances	Personnel injury or fatality; Fire& explosion	Appropriate design codes for high temp surface insulation	1	3	3					
4	Reactive/Unstable Materials	HCN polymerises and decomposes quickly under high temperature	Overheating of equipment, loss of productivity	Rapid cooling of reactor product gas, by integrating reactor R-001 with WH-001, so that no pipeline between them is required and and the hot gas can arrive the heat exchaging site at the shortest time	1	3	3					
5	Explosive Substances	Ignition of the explosive mixture formed by air, methane and ammonia.	Fire and explosion	Mixing is only conducted at the reactor entrance, so the extent of sections of equipment containing the explosive mixture is minimised	3	3	9	2.1	Review Design code for elimination of electric spark in the initial mixing section the reactor R-001. Make sure mechanical sources of ignition all are eliminated as well	Y. A. Guo	21st April, 2022	CLOSED
6	Poisonous Materials	Maintenance procedures not correctly followed due to human error	personnel injury or fatality	Regular traning of personnel on safety issues, managemenet conducted to acceptable standards	3	3	9	2.2	Review design requirements for safety interlock in the maintenance of equipment containing flammable and toxic gases and propose solutions	J. J. Sun	21st April, 2022	CLOSED
7	Equipment at High Temperature	Overheating of the reactor as a result of excess heat produced by the reaction compounded by high preheating temperature	Melting of the reactor	Temperature of the reactor R-001 is controlled by regulating extent of preheating; ESD system that shuts down all raw materials input and thus stop the reaction when the temperature exceeds limit	1	3	3					
8	Exothermic Reaction	Overheating of the reactor as a result of excess heat produced by the reaction compounded by high preheating temperature	Melting of the reactor	Temperature of the reactor R-001 is controlled by regulating extent of preheating; ESD system that shuts down all raw materials input and thus stop the reaction when the temperature exceeds limit	1	3	3					
9	Runaway Reaction	Overheating of the reactor as a result of excess heat produced by the reaction compounded by high preheating temperature	Melting of the reactor	Temperature of the reactor R-001 is controlled by regulating extent of preheating; ESD system that shuts down all raw materials input and thus stop the reaction when the temperature exceeds limit	1	3	3					
10	Catalyst Poisoning	Carburation of the catalyst surface over a period of months of continued use	Incomplete reaction leading to loss of productivity	The catalyst will be heated under vacuum condition every several months to clean the surface of carburation	1	2	2					
11	Explosive Reaction	Ignition of the explosive mixture formed by air, methane and ammonia.	Fire and explosion	Mixing is only conducted at the reactor entrance, so the extent of sections of equipment containing the explosive mixture is minimised	3	3	9	2.3	Review Design code for elimination of electric spark in the initial mixing section the reactor R-001. Make sure mechanical sources of ignition all are eliminated as well	J. X. LYU	21st April, 2022	CLOSED
12	High Temperature	High temperature in the main reactor and its surface due to the high reaction temperature leading to reduced material and structural integrity of the reactor and wasteheat boiler	Fire and explosion; personnel burning injury	The internal surfaces and high temp section of the heat exchanging tubes of R-001 and WH-001 wil be shielded by ceramic materials to reduce the thermal burden	1	3	3					
13	Natural Hazards	Hurricane and flood	Damage to facility leading to gas leakage and explosion	Appropriate design codes for plant layout, spacing.	1	3	3					
14	Maintenance	Maintenance procedures not correctly followed due to human error	Personnel injury or fatality	Safety interlocks appropriately designd to eliminate human error in following procedures while doing maintenance	1	3	3					

PROJECT:	HCN Plant replacement at the Cassel Works Site	**HAZID DATE:**		
PFD DRAWING No.		**PROJECT GROUP No.:** **PARTICIPANTS:**		
FACILITY SECTION No.:	3	**PARTICIPANTS SIGNATURES:**		
FACILITY SECTION DESCRIPTION		**REVISION:**		

					Hazard Consequence Ranking Assuming Controls in Place			Action/Consideration in Design Process to Mitigate Hazard Consequences					
No.	**Specific Hazard From Hazard Inventory**	**Potential Mechanism(s) for Hazard Exposure**	**Potential Hazard Consequences**	**Proposed Mitigation Controls In Place**	**Likelihood (Dropdown)**	**Severity (Dropdown)**	**Risk Rating**	**Unique Action No.**	**Description of Actions/Consideration**	**Action Assigned To:**	**Action Required Completion Date**	**Issue Status (Open/Closed)**	**Action Outcome**
1	Flammable Materials	Leakage of gas mixtures containing hydrogen, HCN, forming explosive mixture with air	Fire & explosion	Appropriate design codes for gas pipelines and equipment to prevent leakage;Regular inspection and maintenance, crossion allowance.	2	3	6	3.1	Review Safety interlock design standards and codes, and propose solutions to install safety interlock system to eliminate human error in following procedures while doing maintenance for equipments and pipelines containing flammable gases	Z. Y. Chai	21st April, 2022	CLOSED	
2	Toxic Substances	Leakage of gas mixtures containing HCN	Personnel injury or fatality	Appropriate design codes for gas pipelines and equipment to prevent leakage;Regular inspection and maintenance, crossion allowance.	3	3	9	3.2	Review Safety interlock design standards and codes, and propose solutions to install safety interlock system to eliminate human error in following procedures while doing maintenance for equipments and pipelines containing HCN	L. S. Wei	21st April, 2022	CLOSED	
3	Reactive/Unstable Materials	HCN polymerises due to significant proportions of NH3 present, which would be the result of not enough H2SO4 solutions	blockage of pipelines by polymerised HCN, overheating, and possibly leakage and explosion	A reliable mechanism designed in accordance with approprite codes to control the flowrate of dilute sulphuric acid solution so that all ammonia can be absorbed	3	2	6	3.3	Review design codes in regard to flowrate control, do relevant studies and propose reliable solutions to control the flowrate of sulphuric acid so that all residual NH3 can be absorbed	Y. K. Wang	21st April, 2022	CLOSED	
4	Corrosive Materials	Sulphric acid corrosion to pipelines and flanges	Leakage of flammable materials and toxic gases from A-002, especially at the top section where sulphuric acid concentration is higher, leading to fire & explosion or personnel poisoning and fatality	Appropriate design codes for A-002 to handle sulphric acid; corrosion allowance designed to appropriate standard	1	3	3						
5	High Speed Rotational Equipment	The centrifuge CN-001 rotates while personnel is doing maintenance work inside.	Personnel fatality	Make sure the centrifuge machine is equiped with safety interlock system that prohibits the running of the machine when the door is open or when there is person inside.	1	3	3						
6	Runaway Reaction	HCN polymerises due to significant proportions of NH3 present, which would be the result of not enough H2SO4 solutions	blockage of pipelines by polymerised HCN, overheating, and possibly leakage and explosion	A reliable mechanism designed in accordance with approprite codes to control the flowrate of dilute sulphuric acid solution so that all ammonia can be absorbed	3	2	6	3.4	Review design codes in regard to flowrate control, do relevant studies and propose reliable solutions to control the flowrate of sulphuric acid so that all residual NH3 can be absorbed	Y. A. Guo	21st April, 2022	CLOSED	
7	Natural Hazards	Hurricane and flood	Damage to facility leading to gas leakage and explosion	Appropriate design codes for plant layout, spacing.	1	3	3	3.5	Review appropriate design codes to mitigate the risk of flooding and hurricane, and give suggestions about plant layout design	H. Y. Chen	21st April, 2022	CLOSED	
8	Maintenance	Maintenance procedures not correctly followed due to human error	Personnel injury or fatality	Safety interlocks appropriately designd to eliminate human error in following procedures while doing maintenance	1	3	3						
9	Noise	Large noise may be produced when the pumps and the centrifuge are working.	Personnel hearing loss	Appropriate design codes for plant layout and safety training	1	1	1						

PROJECT:	HCN Plant replacement at the Cassel Works Site	**HAZID DATE:**	
PFD DRAWING No.		**PROJECT GROUP No.: PARTICIPANTS:**	
FACILITY SECTION No.:	4	**PARTICIPANTS SIGNATURES:**	
FACILITY SECTION DESCRIPTION		**REVISION:**	



					Hazard Consequence Ranking Assuming Controls in Place			Action/Consideration in Design Process to Mitigate Hazard Consequences					
No.	**Specific Hazard From Hazard Inventory**	**Potential Mechanism(s) for Hazard Exposure**	**Potential Hazard Consequences**	**Proposed Mitigation Controls In Place**	**Likelihood (Dropdown)**	**Severity (Dropdown)**	**Risk Rating**	**Unique Action No.**	**Description of Actions/Consideration**	**Action Assigned To:**	**Action Required Completion Date**	**Issue Status (Open/Closed)**	**Action Outcome**
2	Toxic Substances	Release of HCN during startup when thec distillation column DC-001 condensate tank at the top is overpressured	Poisoning of personnel and fatality	Appropriate design codes for condenser pressure control	3	3	9	4.1	Review methods and codes to process and detoxify unavoidable release of HCN from the condensate tank in unsteady operating conditions such as startup	J. X. LYU	21st April, 2022	CLOSED	
3	Hot Fluids	Burning injury to peresonnel due to contact with high temp bottom product surface	personnel minor injury	Appropriate design codes for high temp surface insulation	1	1	1						
4	Reactive/Unstable Materials	HCN polymerises due to too much sulphuric acid present or too long of a residence time	Fire & explosion, fatality	Appropriate design codes for sulphuric acid concentration, make sure bottom product is near boiling point to eliminate a significant presence of HCN	1	3	3						
5	Explosive Substances	HCN polymerises due to too much sulphuric acid present or too long of a residence time	Fire & explosion, fatality	Appropriate design codes for sulphuric acid concentration, make sure bottom product is near boiling point to eliminate a significant presence of HCN	1	3	3						
6	Corrosive Materials	Equipment and pipeline rupture due to corrosion from H2SO4	leakage of HCN leading to fatality	Appropriate design codes for equipments and pipelines to tolerate the sulphuric acid present , croosion allowance designed to appropriate standard	1	3	3						
9	Runaway Reaction	HCN polymerises due to too much sulphuric acid present or too long of a residence time	Fire & explosion, fatality	Appropriate design codes for sulphuric acid concentration, make sure bottom product is near boiling point to eliminate a significant presence of HCN	1	3	3						
10	Natural Hazards	Hurricane and flood	Damage to facility leading to gas leakage and explosion	Appropriate design codes for plant layout, spacing.	1	3	3	4.2	Review appropriate design codes to mitigate the risk of flooding and hurricane, and give suggestions about plant layout design	H. Y. Chen	21st April, 2022	CLOSED	
11	Maintenance	Maintenance procedures not correctly followed due to human error	Personnel injury or fatality	Safety interlocks appropriately designd to eliminate human error in following procedures while doing maintenance	1	3	3						
12	Noise	Large noise may be produced when the pumps and turbines are working.	Personnel hearing loss	Appropriate design codes for plant layout and safety training	1	1	1						