## **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.

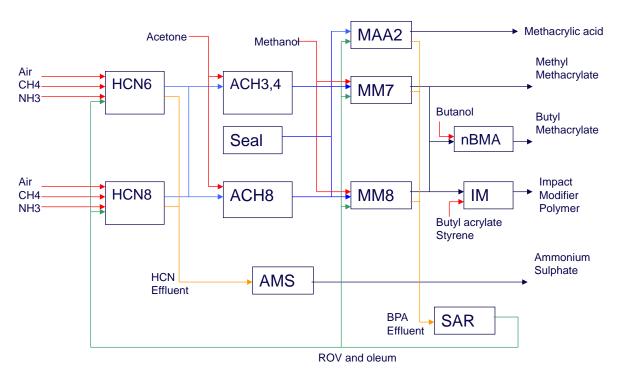


Figure 1 overall scheme of the Cassel Works site

#### **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 31<sup>st</sup>, May, 2022, which is the design finish day as determined in the project schedule.

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#### 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)

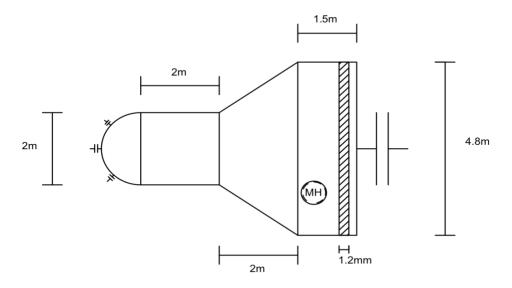


Figure 2 The reactor R-001, inlet is on the left, outlet is on the right, outlet is to be integrated with the main boiler

- •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:

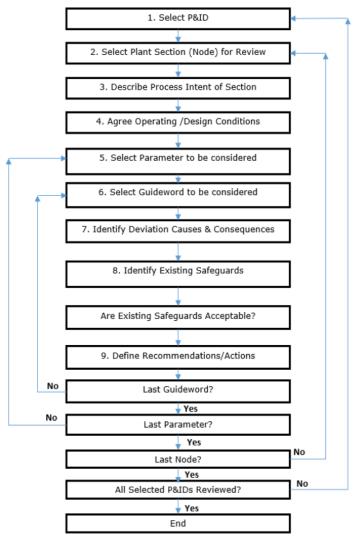


Figure 3 the iterative HAZOP process

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

Table 2 Table of parameters and guidewords for the HAZOP study

Daran	neters	Guidewords								
FdIdi	neters	No	Less	More	As Well As	Part Of	Reverse	Other Than	Early	Late
	Flow	No Flow	Less Flow	More Flow	Misdirect Flow		Reverse Flow			
	Temperature		Lower Temperature	Higher Temperature		Cryogenic				
Primary	Pressure	Vacuum	Lower Pressure	Higher Pressure						
	Level	No Level	Lower Level	Higher Level						
	Composition		Less Concentration	More Concentration	Contamination			Wrong Material		
	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					
Auxiliary	Abnormal Operation	Step Missed	Act too Late	Act too Earlier	Startup /Shutdown	Initial Start-up	Maintenance	Safety Sampling		
/ oxiliary	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.

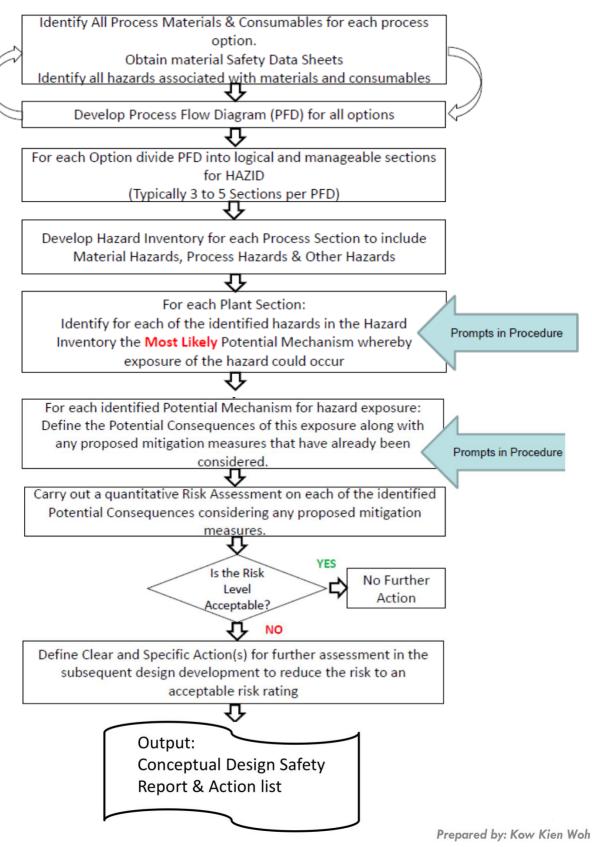


Table 3 Lists of guidewords for each of the hazard sources

	Flammable Materials		Exothermic Reaction
	Toxic Substances		Endothermic Reaction
	Gases under High Pressure		Runaway Reaction
	Liquids under High Pressure		Catalyst Poisoning
	Hot Fluids		<b>Explosive Reaction</b>
	Cryogenic Fluids	Process	High Pressure
<u>a</u>	Oxidising Materials	ÖÖ	Low Pressure/Vacuum
Material	Reactive/Unstable Materials	جّ	Pressure Cycling
/lat	Explosive Substances		High Temperature
	Corrosive Materials		Low Temperature
	Poisonous Materials		Temperature Cycling
	Biological Hazardous Materials		
	Ecotoxic Materials		
	Combustible Dusts		
		<u> </u>	
	High Speed Rotational Equipment		Ground Conditions
	Equipment Under Pressure		Transport/Traffic
Ħ	Equipment at High Temperature		Natural Hazards
пе	Equipment at Low Temperature	e	Manual Operations
<u>.ē</u>	Lifting Equipment	Other	Sampling
Equipment	Ionising Radiation Present		Maintenance
ш	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.

#### 

HAZID RISK MATRIX

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 NH3, 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 H2O 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 H2SO4 and H2O supply and decide if storage tank is needed to ensure stable supply.

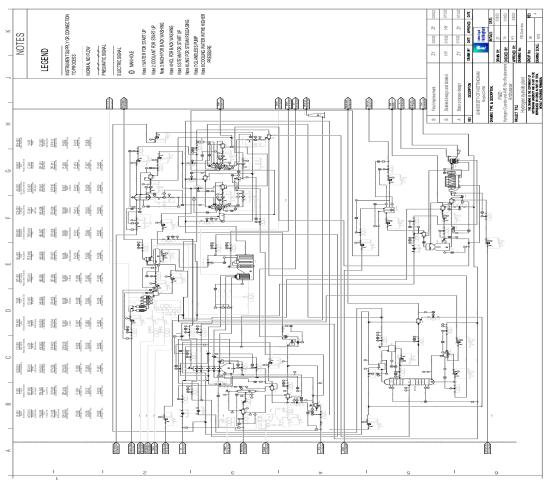
**HAZOP Selected for a high-risk section** 

Proje Section De Design Ir	escription:	R-001, the read	tor for producing HCN vi	ks Site for Lucite Company a the andrussow process ely, smoothly and efficiently	Section	on Date: n/Node No: sion No:		21, April, 2022 Node 4	
Drawin		To produce Treit II	on the raw materials sai	ery, smoothly and emolency	ine.	310111101			
Ref. No.	Parameter	Guideword	Cause	Consequence	Safeguards	Rec. No.	Reco	ommendation	Action By
1		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	Flow	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	design equipme	safety interlock requirments for ents and pipelines taining HCN	J. X. Lyu
6		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	Temperature	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 to control feed inlet temperature				

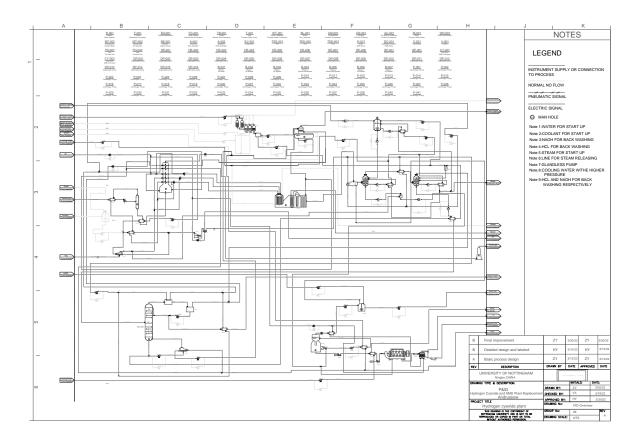
Proje		HCN	Plant Repla	cement at the Cassel Wo	rks Site for Lucite Com	pany		Session Date:		21, April, 2022	
Section De				ctor for producing HCN vi			S	ection/Node No:		Node 4	
Design Ir	ntention:	To pro	oauce HCN f	rom the raw materials sa	tely, smoothly and effi	ciently		Revision No:			
Drawin	gs No ·							Revision Date:			
	g3 NO		No		Disruption of production			Revision Date.			
9					production					king device to	
	React	ion	Less	Feed streams are not adquately mixed	Decreased product quality	1	None	4.02	feed stre	oper mixing of eams prior to action	Y. A. Guo
10											
11			As well as	Side reaction	Decreased yield						
12			Less	Turbine not designed to output the same pressure under different turndown ratios	Pressure not enough to power enough flowrate	1	None	4.03	requireme power t variable nu	ew design nts for variable urbine ( e.g. imber of stages urbine)	J. J. Sun
	Pressu	ure		Turbine not designed to output the same pressure under different turndown ratios	Pressure not enough to power enough flowrate	1	None	4.03	requireme power t variable nu	ew design nts for variable urbine ( e.g. imber of stages urbine)	J. J. Sun
13			More	Pressure build-up unexpectedly	explosion	001 th negative p	huge fan FN- at creates oressure in the e system				
, .	Concentr	ration	Less	Low HCN concentration because of not enough residence time	Low productivity	catalyst o	nce time in designed to a le margin of xcess				
14						Equipment	s and pipelines				
	Fire & Exp	plosion	Other than	Ignition source	Fire & Explosion	designed t	to appropriate for prevention nical spark and				
15						electi	rical spark				

Proj	ect:				l Works Site for Lucite Con			Session Date		21, April, 2022	
Section De	escription:				CN via the andrussow pro		-	ction/Node I		Node 4	
Design Ir	ntention:		To produce I	ICN from the raw materia	ils safely, smoothly and eff	iciently		Revision No			
Drawin	ıgs No.:						R	evision Date	2:		
16			No	Inability to Maintenance	All the way up to Fire& explosion	Clearly defined main procedures and sche resonsibilitie	dules and				
17			Less/Lack Maintenance	Lack of Maintenance	All the way up to Fire& explosion	Clearly defined main procedures and sche resonsibilitie	dules and				
18	Mechanical ir	ntegrity	Part of	corrosion/errosion	All the way up to Fire& explosion	Clearly defined main procedures and sche- resonsibilities as well a allowance for equipn pipelines	dules and is corrosion				
19			Reverse	Leakage	All the way up to Fire& explosion	Clearly defined main procedures and sche- resonsibilitie	dules and				
20	Human fa	ctors	Part of	Mistakes when doing maintenance work	Fire& explosion and poisoning	None		4.04	requirme and pipeli or flamm hazardou	fety interlock design ents for equipments ines containing HCN able gases or other is materials present on the plant	Z. Y. Chai

# Appendix 1: HAZOP P&ID Markup



# **Appendix 2: HAID PFD Markup**



**Appendix 3: HAZOP Worksheet** 

		nia Plant regioners K	est at the Cased Minis Giv Marring Ministers	6.Y. (MR. Y. E. WANG, L. S. Y	PARTY VINCENSITION AND A V. O	PM, 13	indranes proces PEO			PATRICULAR SANCES	
Marija Ka	Parameter	Sounds & safe produ	Comm	Consequence (in-option of production	Current Surleyands	=	Recommendation/Action	Artise Assigned for	Required Completion Series	Spany Clause	Artist Bultoma
			PCs (65) fall-rises	Foreign Silv that polices the analysement	Replace multiplication fine is in plane to analysis replacing the control ratios						
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	-			ant rollin smale approach		H					
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			FT 667-bal	Personal State of Contraction Personal State of Contraction Contractions	Regular maintaneous and registerates						
		_	November 1	Forming MACE that while moved path Markets commisse applyments Disruption of production	Agues maintenance the b. it plans to enable replacing the commi	H					
		New	FEREN	Disruption of production	Regular maintaneous and registerates						
		An earlier Secure	usings of natural gas from saless and fanges. Secures fee by diffusion from nature during plant shutches.	Planning flammatic minute leading to the and arginoles Maintenance parameter planning to mile	apprises aunties for handing referred pas	1.60	Name and Contract the Contract of the Contract	r. K. Wang	State May, 2000		
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	Impress	No.	November 100 del del November del risse	Internation of teacher reading Sharfleating of teacher reading realistions and rick ballage, basing to the teach	Popular Institution (is a in paint in enable replement Repular maintenance and replement	141	Change Title 662 to fail span, the temperature is safer than high temperature.	- 5 Wa	Inst Rep. 2000		
		Part of	Natural par coming out of PC-001 is of the temperature	Sentured No sper and relability of equipments under orpoperio consisten	Equipments and pipelines in compan with organic submence designed to appropriate shandard						
	hear		Lettine ser Analysed to surpor the same pressure under different surrolleen sales	Procure not prough to proce prough floorate	None	1.61	Review design requirements for variable present surface ( e.g. servicino number d'atagos d'surface)	1.3.6an	Store Mary, 2000		
		***	Luttine not designed to extract the serie prosecute under different surreless notice	Procure tot prough to power prough financia		1.61	Benies design requirements for variable present surtices ( a.g. seriable number of stages of turbine)	- a Gas	Start May, 2000		
	Composition	te sales and stan	NA NA Managasthus	Fra A. Espinaise	Ppalmas and apalpmann, designed	F					
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		hearts.	unings	ali the may up to Fraik explanion	disserts for equipments and opinios -liter's definal maintainers providings and schadules and	H					
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			the named months long through the color & volve (40) has		Agus nathanana ka k a pian Kanata salaman						
		-	The temperature of the street not of 100 data security to ten her to reporte attraction, because the seed of team is recently the bettern product of natural pas	Stangeries of production	None	241	Use the intreast after compression. By CH, 60% for separating birth, Nr. 60% should be paradial to MI. 60% in which need AI. 60% serves as by pass	- X 1ga	Store Mary, 2000		
	~	Table Marco	Consider a solve dela finale	Despite d'probete Despite d'probete	Agus commune de a 2 personales de analis teplementes Agus contravars de la 9 plans de analis teplement		-				
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H			Section in code ( ) ( )	Sandar brass (3)		L	gases or other harantines materials. present on the plant				
	-	fire Armin	who has a star of rade (C)	Non-Hallin for halls (3).) Number designed to appropriate premient for precenting ballage of High temp thirt gas mature.							
		house	Secure fee by diffusion from reactor sharing plant abundance	Maintenance personnel polanting by NOs	tions.	8.61	facious safety interfect design requirements for equipments and pipelines containing milk	1 A Spe	lose May 2000		
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		tion ion ion ion ion ion ion ion	una Temperatura in althor of nata (A).) una temperatura natural pas la fail otto natura	See Habilith for note 1,3,3 Benuption of production securities of production bennessed product quality from recent years	Controlled the control of the shall does at three feetines shall be presented to the high coding safer is constantly coding the shalled gas.	10		Y. A. Gar			
			have Temperature in elities of note (2,2,3) use temperature natural gas a fine last lasterial fixed presents are not elitystolig missel. Solic hardies.  Solic hardies.  Solic hardies.  Solic hardies.  Solic hardies.	Nac Hallish for nation 1,3,10  White points of production  White points of production  White received product quality  White received particles  Products that principl to procee  principl formatic	Controlled the control of the shall does at three feetines shall be presented to the high coding safer is considerily coding the shalled gas.	440	Add a mining dealer to entering proper mining of the property of the Parkette Parkette Parkette Parkette Parket	X.B. Gas	Start May, 2000		
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	Assertion Protector Genomeration		have Temperature in elities of note (2,2,3) use temperature natural gas a fine last lasterial fixed presents are not elitystolig missel. Solic hardies.  Solic hardies.  Solic hardies.  Solic hardies.  Solic hardies.	Nac Hallish for nation 1,3,10  White points of production  White points of production  White received product quality  White received particles  Products that principl to procee  principl formatic	Company to the first that of the control of the con	440	Add a mixing dealers to amount projects on the project of the proj	X.B. Gas	Start May, 2000	77.	
			have Temperature in elities of note (2,2,3) use temperature natural gas a fine last lasterial fixed presents are not elitystolig missel. Solic hardies.  Solic hardies.  Solic hardies.  Solic hardies.  Solic hardies.	Nac Hallish for nation 1,3,10  White points of production  White points of production  White received product quality  White received particles  Products that principl to procee  principl formatic	Controlled the control of the shall does at three feetines shall be presented to the high coding safer is considerily coding the shalled gas.	40	Add a mixing dealers to amount projects on the project of the proj	X.B. Gas	Start May, 2000		
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	Process  Security Sec	Note the second	The second of the control of the con	Security of the control of the contr	The second of th	A40	Service of the control of the contro	1.4 day	Too Rep. (600)		
	Process  Security Sec	Note the second	The second of the control of the con	Security of the control of the contr		A40	Service of the control of the contro	1.4 day	Too Rep. (600)		
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	Process  Security Sec		The second of the control of the con	Security of the control of the contr		A40		1.4 day	Too Rep. (600)		
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# Appendix 4 : HAZID Worksheet

	PROJECT:	HCN Plant replacement at the Cassel Works Site	HAZID DATE:			AZID RISK MATRI	_					
	PFD DRAWING No.		PROJECT GROUP No.: PARTICIPANTS:		Dood Aspen	ofice (sign) and	**)					
	FACILITY SECTION No.:	1	PARTICIPANTS SIGNATURES:			1 3 Live (Live) Pro-	i.e					
	FACILITY SECTION DESCRIPTION		REVISION:			Severity 11	φ. 1					
					Marred Conseque	nce Ranking Assum	las Controls in		4 1 40 11 11 1			
						Place	•			Design Process to Mitigate H	azaru consequence	
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	(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					
1	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	Cryagenic Fluids	Low temperature natural gas after expansion causes: pipeline to become brittle and unable to adpart to thermal expansion	Fire and explosion	Appropriate design codes for low temperature pipeline	1	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					
	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	Y. K. Wang	21st April, 2022	Crosso
									trocking and nurricane, and give suggestions about plant layout design			
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					
			1			1			1	1	1	1

	PROJECT:		HAZID DATE:		н	AZID RISK MATRIX	K					
	PFD DRAWING No.	HCN Plant replacement at the Cassel Works Site	PROJECT GROUP No.:		P 7 m	and Orders in	_					
	FACILITY SECTION No.:		PARTICIPANTS: PARTICIPANTS SIGNATURES:		3 -	inel (traduct le	1					
						ew Medium in	Ť					
	FACILITY SECTION DESCRIPTION	2	REVISION:			Severity						
					Mazard Conseque	nce Ranking Assum Place	ing Controls in		Action/Consideration in D	lesign Process to Mitigate H	azard Consequences	i
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	Action No.			Companion Date	(open/closed)
		sange under nign temperature										
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					
		sange under nign temperature										
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					
		acting the or acting the same of the same										
	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	1	3	3					
		temperature		UU1, so that no pipeline between them is required and and the not gas can arrive the heat exchaging site at the shortest time								
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	Y. A. Guo	21st April, 2022	CLOSED
									mechanical sources of ignition all are eliminated as well			
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	J. J. Sun	21st April, 2022	CLOSED
									toxic gases and propose solutions			
7	Equipment at High Temperature	Overheating of the reactor as a result of excess heat produced by the reaction compounded by high	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	1	3	3					
		preheating temperature		the reaction when the temperature exceeds limit								
s	Exothermic Reaction	Overheating of the reactor as a result of excess heat produced by the reaction compounded by high	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	1	3	3					
		preheating temperature		the reaction when the temperature exceeds limit								
9	RunawayReaction	Overheating of the reactor as a result of excess heat produced by the reaction compounded by high	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	1	3	3					
		preheuting temperature		the reaction when the temperature exceeds limit								
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	initial mixing section the reactor R-001. Make sure	J. X. LYU	21st April, 2022	CLOSED
									mechanical sources of ignition all are eliminated as well			
12	High Temperature	High temperature in the main reactor and its surface due to the high reaction temperature leading to	Fire and explosion; personnel burning injury	The Internal surfaces and high temp section of the heat exchanging tubes of R 001 and WH-001 will be shielded by ceramic materials to reduce the thermal	1	3	3					
		reduced material and structural integrity of the reactor and wasteheat boiler		burden								
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					
				-								
		1										

	PROJECT:	HCN Plant replacement at the Cassel Works Site	HAZID DATE:		н	AZID RISK MATRIX							
	PFD DRAWING No.		PROJECT GROUP No.: PARTICIPANTS:		Pico da Angle da	And Distance of							
	FACILITY SECTION No.:	2	PARTICIPANTS SIGNATURES:		3 1	Seed (Seed Pro-	Burno .						
	FACILITY SECTION DESCRIPTION		REVISION:		_	Severity							
					Hazard Conseque	nce Ranking Assumi Place	ing Controls in		Action/Consideration in I	Design Process to Mitigate H	azard Consequence	5	
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	(Open/Closed)	Action Outcome
1	Flammable Materials	Leakage of gas mintures containing hydrogen, HCN, forming explosive mixture with air	Res & explosion	Appropriate design codes for gas plantines and equipment to a revent leakage/Regular impection and maintenance, crossion allowance.	2	3	Ġ.	2.1	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. Chal	21st April, 2022	CLOSED	
2	Toxic Substances	Leakage of gas mintures containing HCN	Personnel injury or fatality	Appropriate design codes for gas playtines and equipment to a revent leakage, Regular impection and maintenance, crossion allowance.	2	3	•	2.2	Review Safety-Interlock design standards and codes, and propose solutions to install safety interlock system to silminate-human error in following procedures while doing maintenance for equipments and pipelines containing BICN	L. S. Wei	21st April, 2022	CLOSED	
2	Reactive/Unstable-Materials	HCN polymerises due to significant proportions of NHQ present, which would be the result of not enough HOSO4 solutions	blockage of pipelines by polymerised HCN, overheating, and possibly leakage and explosion	Annilable mechanism designed in accordance with appropries codes to control the flowrate of dilute sulphunic acid solution so that all ammonia can be absorbed	2	2	•		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	Compsive Materials	Sulphric acid corrosion to pipelines and flanges	Leakage of flammable materials and toxic gases from A-002, especially at the top section where sulphunic acid concentration is higher, leading to fine & explosion or personnel polisoning and totality.	Appropriate design codes for A 002 to handle sulphric acid; corresion allowance designed to appropriate standard	1	1	2						
s	High Speed Rotational Equipment	The centifuge CN-001 natates while personnel is doing maintenance worklinside.	Personnel fatality	Make use the centrifuge machine is equiped with safely interfact system that prohibits the running of the machine when the door is open or when there is person incide.	1	1	2						
c	Runsway Reaction	HCN polymerises due to significant proportions of NHQ present, which would be the result of not enough HGSO4 solutions	blockage of pipelines by polymerised HCN, overheating, and possibly leakage and explosion	Annibile mechanism designed in accordance with appropries codes to control the flowrate of dilute sulpharic acid solution so that all ammonia can be absorbed	3	2	6	2.4	Review design codes in regard to flowrate control, do refevant studies and propose reliable solutions to control the flowrate of sulphunic acid so that all residual NHA can be absorbed	Y. A. Guo	21st April, 2022	CLOSED	
,	Natural Hazards	Hurricane and flood	Damage to facility leading to gas leakage and explosion	Appropriate design codes for plant layout, spacing.	1	3	a	2.5	Review appropriated esign 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		Safety interlocks appropriately designd to eliminate/human error in following procedures while doing maintenance		a	2						
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						

	PROJECT:	HCN Plant replacement at the Cassel Works Site	HAZID DATE:		H.	AZIO RISK MATRIX							
	PFD DRAWING No.		PROJECT GROUP No.:		g 7 m	test Natural In	_						
			PARTICIPANTS:		3		_						
	FACILITY SECTION No.:		PARTICIPANTS SIGNATURES:		3 1	LEVE CAND PRO-	W.						
	FACILITY SECTION DESCRIPTION		REVISION:			Severity							
					Hazard Conseque	nce Ranking Assumi Place	ing Controls in		Action/Consideration in I	Design Process to Mitigate H	azard Consequence	s	
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	(Open/Closed)	Action Outcome
2		Refease of HCN during startup when their distillation column DC-001 condensate tank at the top is overpressured	Poisoning of personnel and fatality	Appropriate design codes for condenser pressure control	2	2	٥	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	I.X.LYU	21st April, 2022	CLOSED	
3		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	ı						
4	Reactive/Unstable Materials	HCN polymerises due to too much sulphuric acid present or too long of a residence time	Fire& explosice, fatality	Appropriate design codes for subphuric acid concentration, make sure bossom product is near boiling point to eliminate a significant presence of eCN	1	2	2						
s		HCN polymerises due to too much sulphuric acid present or too long of a residence time	Rire& explosice, fatality	Appropriate design codes for sulphuric acid concentration, make sure bottom product is near boiling point to eliminate a significant presence of eCN	1	2	à						
6	Corrodive Materials	Equipment and pipeline rupture due to corrosion from HGSON	leakage of HCN leading to fatality	Appropriate design codes for equipments and pipelines to tolerate the sulphuric sold present, crossion allowance designed to appropriate standard.	1	2	à						
9		HCN polymerises due to too much sulphuric acid present or too long of a residence time	Fire& explosice, fatality	Appropriate design codes for subphuric acid concentration, make sure bossom product is near boiling point to eliminate a significant presence of eCN	1	2	2						
10	Natural Hazards	Hurricane and Sood	Damage to facility leading to gas leakage and explosion	Appropriate design codes for plant layout, spacing.	i	2	2	4.2	Review appropriate design codes to mitigate the risk of Sooding and hurricane, and give suggestions about plant layout design	H.Y. Ches	21st April, 2022	CLOSED	
11	Maintenance	Maintenance procedures not correctly followed due to burnan error	Personnel lejury or farality	Safety interfacia: appropriately designd to eliminate human error in fallowing procedures while doing maintenance	1	2	2						
12		Large noise may be produced when the pumps and turbines are working.	Personnel hearing loss	Appropriate design codes for plant layout and safety training	i	i							