# 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.

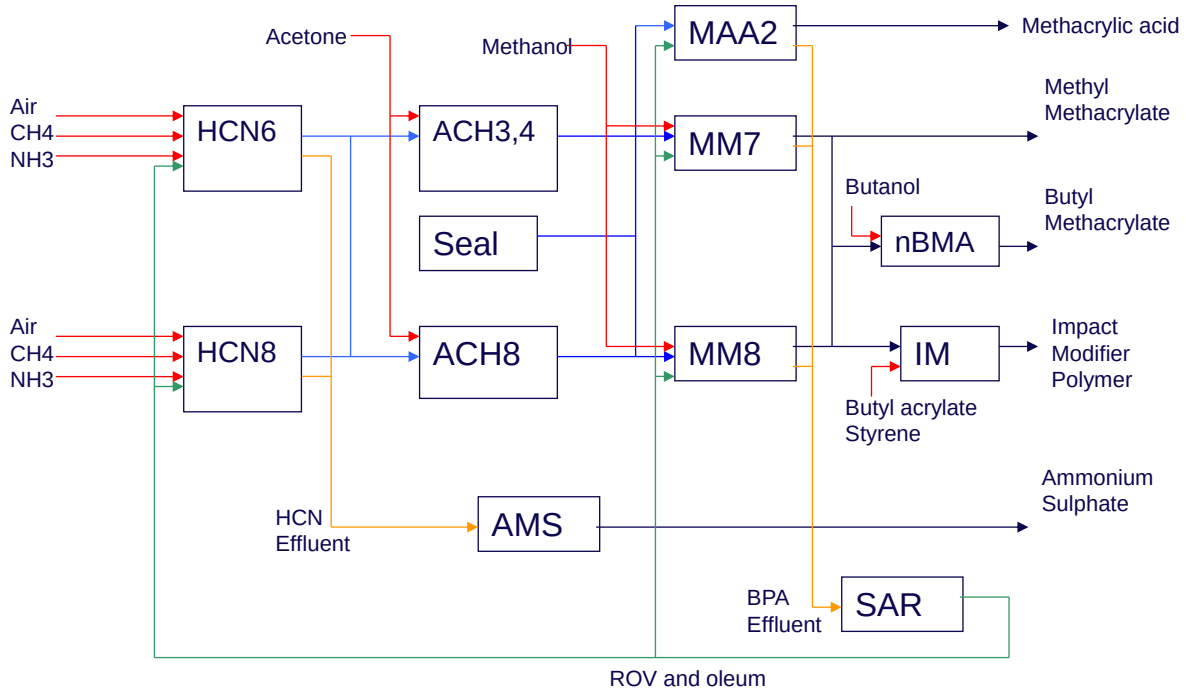


*Figure 1 overall scheme of the Cassel Works site*

## 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$^{st}$, 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)

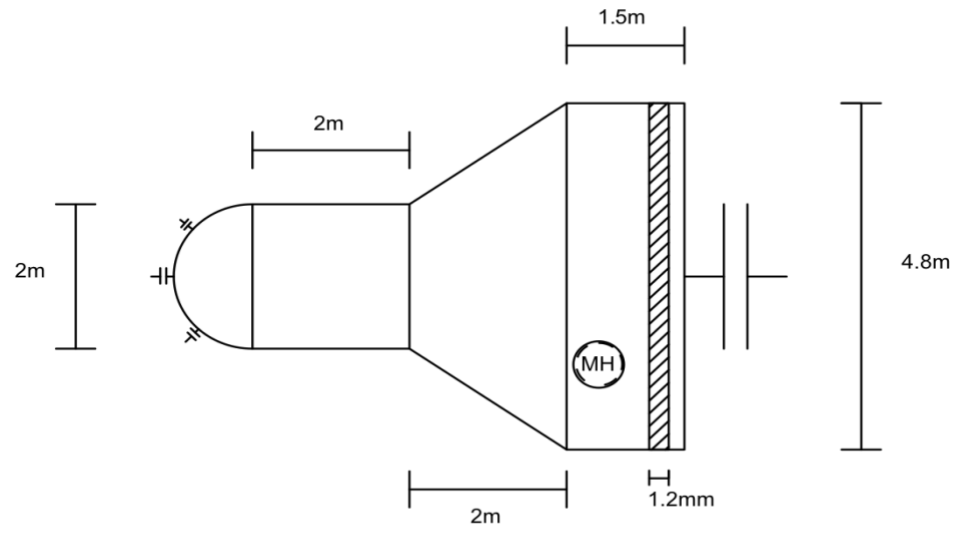


*Figure 2 The reactor R-001, inlet is on the left, outlet is on the right, outlet is to be integrated with the main boiler*

•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:

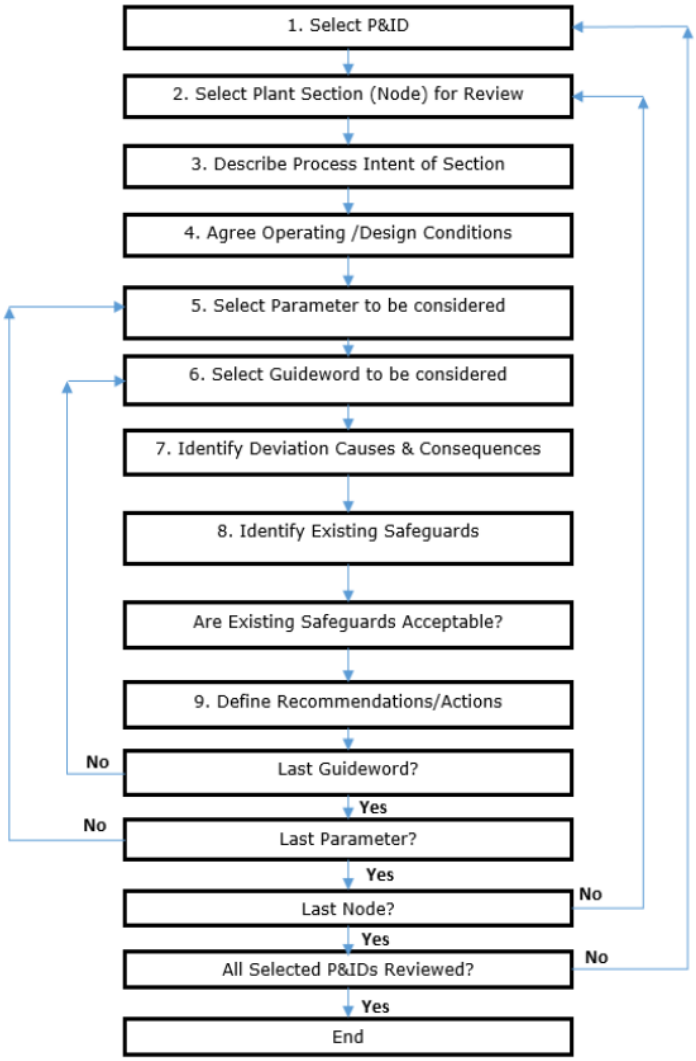


*Figure 3 the iterative HAZOP process*

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.

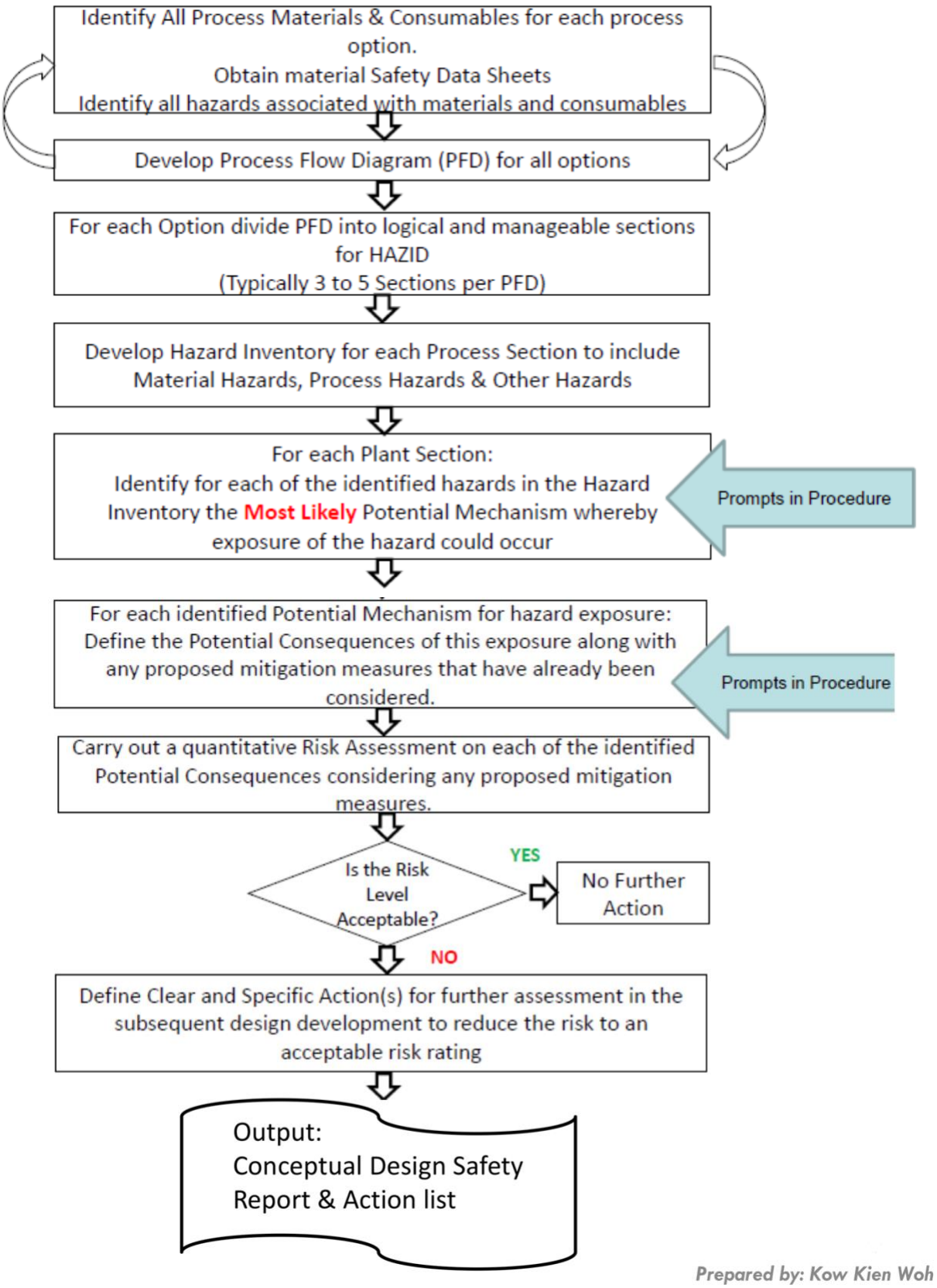


*Figure 4 the iterative HAZID process*

*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.

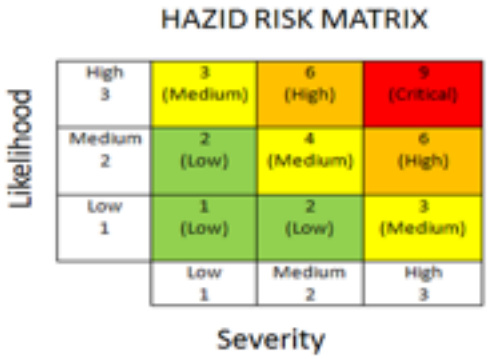


*Figure 5 Risk matrix*

## 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 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

| 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 | | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
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| 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 | | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
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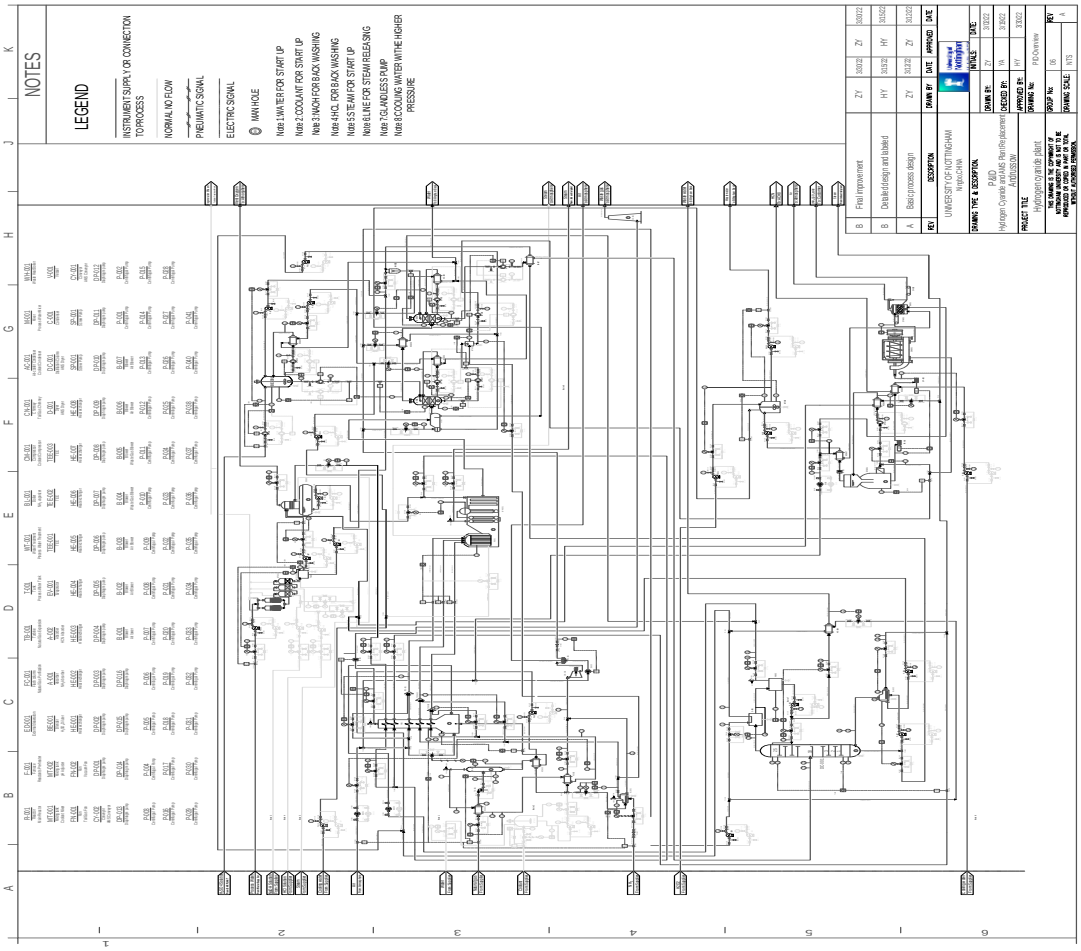
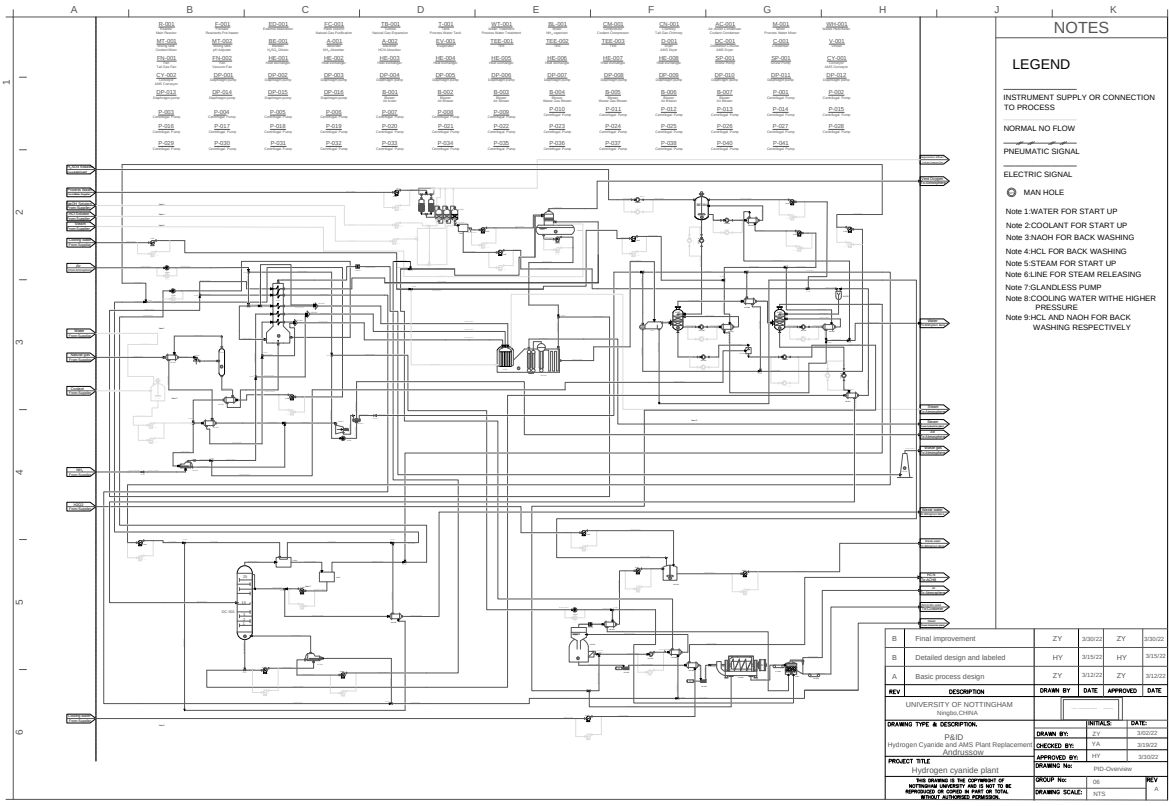
| Design Intention: | To produce HCN from the raw materials safely, smoothly and efficiently | | | | Revision No: | | | |
| Drawings No.: | | | | | Revision Date: | | | |
| 16 | Mechanical integrity | No | Inability to Maintenance | All the way up to Fire& explosion | Clearly defined maintenance procedures 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

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **C** | | **Ni1A Plant replacement at the Cassel Works Site** | | | **Ni1A: Title/Description** | | Reference process Ni1A | | | | | **Ni1A-R-L- Rev No.:** | | |
| **Group No.:** | | **A** | **Flashing Dissolvers** | | **R = f ( HAZ , + ve , Mobile , L , % MAC , C , t MAC , + ve , Mobile , R = f ( HAZ , + ve , t MAC , C , % MAC )** | | | | | | | **PLCHIP Risk Rank** | | |
| **Sludge Centrifuge Dissolver** | | **Nickel(II) salts production of Ni1A** | | | | | | | | | | | | |
| **Node No.** | **Parameter** | **Synthesised** | **Cause** | **Consequence** | **Current Safeguards** | **Action No.** | **Measure/recommendation/Action** | **Action Assigned To:** | **Required Completion Date** | **Action Status/Closed** | **Action Comment** | | | |
| | | | | Disruption of production | | | | | | | | | | |
| | | | FDA-003 fail-close | Running Mini-Dist pollutes the downstream | Pumps maintenance this is in place to enable replacement in the event of failure | | | | | | | | | |
| | | | | Running HMCO that while motor runs HCNm normales equipment | | 1.001 | Review requirements for equipments in contact with HMCO | N. H. Chen | Start May, 2022 | | | | | |
| | | | | Disruption of production | | | | | | | | | | |
| | | | P1-007 fail | Running Mini-Dist pollutes the downstream | Regular maintenance and replacement | | | | | | | | | |
| | | | | Running HMCO that while motor runs HCNm normales equipment | | | | | | | | | | |
| | | | | Disruption of production | | | | | | | | | | |
| | | | FDA-002 or FDA-012 shut down | Running Mini-Dist pollutes the downstream | What FDAs will simultaneously shut down, tolerance and for supplies | | | | | | | | | |
| | | | | Running HMCO that while motor runs HCNm normales equipment | | | | | | | | | | |
| | | | | Disruption of production | | | | | | | | | | |
| | | | FDA-003 fail-close | Running Mini-Dist pollutes the downstream | Pumps maintenance this is in place to enable replacement in the event of failure | | | | | | | | | |
| | | | | Running HMCO that while motor runs HCNm normales equipment | | 1.001 | Review requirements for equipments in contact with HMCO | N. H. Chen | Start May, 2022 | | | | | |
| | | | | Disruption of production | | | | | | | | | | |
| | | | P1-007 fail | Running Mini-Dist pollutes the downstream | Regular maintenance and replacement | | | | | | | | | |
| | | | | Running HMCO that while motor runs HCNm normales equipment | | | | | | | | | | |
| | | | FDA-003 fail | Disruption of production | Pumps maintenance this is in place to enable replacement in the event of failure | | | | | | | | | |
| | | | P1-007 fail | Disruption of production | Regular maintenance and replacement | | | | | | | | | |
| | | As well as | Leakage of hydrocarb gas from valves and flanges | Running Flammability Indices is below to the shut explosion | Regular and routine inspection of equipments maintain for hazardous area zones | | | | | | | | | |
| | | Baseline | Baseline Box-by-diffusion from reactor during plant shutdown | Performance & personnel protection by HCN | None | 1.002 | Review safety checklist during maintenance activities and isolation containing HCN | N. H. Wang | Start May, 2022 | | | | | |
| | | Other | Acids | N/A | | | | | | | | | | |
| | Temperature | Less | cannot keep TIC-002 fail | Decreased product quality | Pumps maintenance this is in place to enable replacement | | | | | | | | | |
| | | | cannot keep TIC-002 fail | Decreased product quality | Pumps maintenance this is in place to enable replacement | | | | | | | | | |
| | | More | TIC-002 fail-close | Overheating of reactor causing explosion and HCN leakage, leaks | Regular maintenance and replacement | 1.003 | Change TCV-003 to fail-open, for temperature to Lower than high temperature | L. S. Wei | Start May, 2022 | | | | | |
| | | Rate of | Acid and gas cooking out of TC-002 at low temperature | Reduced life span and reliability of equipments under cryogenic conditions | Equipments and pipelines to always with cryogenic conducting is designed to appropriate standard | | | | | | | | | |
| | Pressure | Less | Turbine not designed to output the same pressure under different turbulent rates | Pressure not enough to power through Reverse | None | 1.004 | Review design requirements for variable power turbine ( e.g. variable number of stages of turbine) | C. J. Sun | Start May, 2022 | | | | | |
| | | More | Turbine not designed to output the same pressure under different turbulent rates | Pressure not enough to power through Reverse | None | 1.005 | Review design requirements for variable power turbine ( e.g. variable number of stages of turbine) | C. H. Sun | Start May, 2022 | | | | | |
| | Level | Less | N/A | | | | | | | | | | | |
| | Composition | More | N/A | | | | | | | | | | | |
| | Fire & Explosion | No well as | Mixing with air | Fire & Explosion | Pipelines and equipments designed to appropriates standard for sealing | | | | | | | | | |
| | | Other than | Ignition source | Fire & Explosion | Equipments and pipelines designed to appropriates standard for the prevention of mechanical spark and electrical spark | | | | | | | | | |
| | Mechanical Integrity | No | Inability to Maintenance | All the way up to Freak explosion | Clearly defined maintenance procedures and schedules and responsibilities | | | | | | | | | |
| | | Less/Lack Maintenance | Lack of Maintenance | All the way up to Freak explosion | Clearly defined maintenance procedures and schedules and responsibilities | | | | | | | | | |
| | | Rate of | corrosion/abrasion | All the way up to Freak explosion | Clearly defined maintenance procedures and schedules and responsibilities as well as corrosion allowance for equipments and pipelines | | | | | | | | | |
| | | Reverse | Leakage | All the way up to Freak explosion | Clearly defined maintenance procedures and schedules and responsibilities | | | | | | | | | |
| | Human factors | Rate of | Mistakes when doing maintenance work | Freak explosion and poisoning | None | 1.007 | Review safety checklist design requirements for equipments and pipelines containing HCN or flammable gases or other hazardous materials present on the plant | C. Y. Chui | Start May, 2022 | | | | | |
| | | | | | | | | | | | | | | |
| | | No | Ni(OH)2 (s) + 2HCl (aq) → NiCl2 (aq) + 2H2O (l) | Disruption of production | None | 2.001 | Use this stream after compression for HCl production, Ni(OH)2 (s) + 2HCl (aq) → NiCl2 (aq) + 2H2O (l) which is the parallel to R2, 2001 to which I may AS-IVC series, as my pure feeding | C. S. Lin | Start May, 2022 | | | | | |
| | Flow | Less | FDA-004 & v12v-002 fails | Disruption of production | Pumps maintenance this is in place to enable replacement | | | | | | | | | |
| | | More | FDA-004 & v12v-002 fails | Disruption of production | Pumps maintenance this is in place to enable replacement | | | | | | | | | |
| | | As well as | Leakage of ammonia | Personnel poisoning & fire & explosion | Pipelines and equipments designed to appropriates standard for sealing | | | | | | | | | |
| | | Baseline | Baseline Box-by-diffusion from reactor during plant shutdown | Performance & personnel protection by HCN | None | 2.002 | Review safety checklist during maintenance activities and isolation containing HCN | N. H. Wang | Start May, 2022 | | | | | |
| | Temperature | Less | N/A | Disruption of production | Pumps maintenance this is in place to enable replacement | | | | | | | | | |
| | | More | Mixing may containing TCH-004 fail-close | Decreased product quality | Pumps maintenance this is in place to enable replacement | | | | | | | | | |
| | | | TCH-004 fail-close | Overheating of reactor causing explosion and HCN leakage, leaks | Regular maintenance and replacement | 2.003 | Change TCH-004 to fail-open, for temperature to Lower than high temperature | C. H. Sun | Start May, 2022 | | | | | |
| | Pressure | Less | Reactor pressure is low | N/A | | | | | | | | | | |
| | | More | Reactor pressure is high | N/A | | | | | | | | | | |
| | Composition | No | N/A | | | | | | | | | | | |
| | Mechanical Integrity | No | Inability to Maintenance | N/A | | | | | | | | | | |
| | | Less/Lack Maintenance | Lack of Maintenance | N/A | | | | | | | | | | |
| | | Rate of | corrosion/abrasion | All the way up to Freak explosion | Clearly defined maintenance procedures and schedules and responsibilities as well as corrosion allowance for equipments and pipelines | | | | | | | | | |
| | | Reverse | Leakage | All the way up to Freak explosion | Clearly defined maintenance procedures and schedules and responsibilities | | | | | | | | | |
| | Human factors | Rate of | Mistakes when doing maintenance work | Freak explosion and poisoning | None | 2.004 | Review safety checklist design requirements for equipments and pipelines containing HCN or flammable gases or other hazardous materials present on the plant | C. H. Liu | Start May, 2022 | | | | | |
| | | | | | | | | | | | | | | |
| | Flow | No | Apt-3143-0 failure | Disruption of production | Backup pump is installed in parallel | | | | | | | | | |
| | | | FDA-005 fail-close | | Pumps maintenance this is in place to enable replacement | | | | | | | | | |
| | | Less | Apt-3143-0 failure | Disruption of production | Backup pump is installed in parallel | | | | | | | | | |
| | | | FDA-005 fail | | Pumps maintenance this is in place to enable replacement | | | | | | | | | |
| | | More | FDA-005 fail | Disruption of production | Pumps maintenance this is in place to enable replacement | | | | | | | | | |
| | | Other than | Acids | N/A | | | | | | | | | | |
| | | Baseline | Baseline Box-by-diffusion from reactor during plant shutdown | Performance personnel poisoning by HCN | None | 2.005 | Review safety checklist design requirements for equipments and pipelines containing HCN | C. H. Liu | Start May, 2022 | | | | | |
| | Temperature | Less | N/A | Disruption of production | Pumps maintenance this is in place to enable replacement | | | | | | | | | |
| | | More | Mixing may containing TCH-004 fail-close | Decreased product quality | Pumps maintenance this is in place to enable replacement | | | | | | | | | |
| | | | TCH-004 fail-close | Overheating of reactor causing explosion and HCN leakage, leaks | Regular maintenance and replacement | 2.006 | Change TCH-004 to fail-open, for temperature to Lower than high temperature | L. S. Wei | Start May, 2022 | | | | | |
| | Pressure | Less | Reactor pressure is low | N/A | | | | | | | | | | |
| | | More | Reactor pressure is high | None but Lower is cooled | Reactor pressure and flammable chemical atomization sensor | | | | | | | | | |
| | Composition | No | Inability to Maintenance | Unopposed pipe line | Clearly defined maintenance procedures and schedules and responsibilities | | | | | | | | | |
| | Mechanical Integrity | Less/Lack Maintenance | Lack of Maintenance | Unopposed pipe line | Clearly defined maintenance procedures and schedules and responsibilities | | | | | | | | | |
| | | Reverse | Leakage | Decreased efficiency | Clearly defined maintenance procedures and schedules and responsibilities | | | | | | | | | |
| | Human factors | Rate of | Mistakes when doing maintenance work | Freak explosion and poisoning | None | 2.007 | Review safety checklist design requirements for equipments and pipelines containing HCN or flammable gases or other hazardous materials present on the plant | C. H. Wang | Start May, 2022 | | | | | |
| | | | | | | | | | | | | | | |
| | Flow | No | No flow in index n, or -n | Use ceased for node n-0.1 | | | | | | | | | | |
| | | Less | Less flow in either of index n or -n | Use ceased for node n-0.2 | | | | | | | | | | |
| | | More | More flow in either of index n or -n | Use ceased for node n-0.3 | | | | | | | | | | |
| | | As well as | Leakage from reactor | Reactor designed to appropriate standard for sealing and with high tensile HCN gas tolerance | | | | | | | | | | |
| | | Baseline | Baseline Box-by-diffusion from reactor during plant shutdown | Performance personnel poisoning by HCN | None | 3.001 | Review safety checklist design requirements for equipments and pipelines containing HCN | C. S. Lin | Start May, 2022 | | | | | |
| | Temperature | More | Many Temperature in either of index n or -n | Overheating of reactor causing explosion and HCN leakage, leaking to life losses or personnel injury | Reactor designed to appropriate standard for sealing and with high tensile HCN gas tolerance. Cooling water is constantly cooling the reactor unit | | | | | | | | | |
| | | Less | Less Temperature in either of index n or -n | Use ceased for node n-0.4 | | | | | | | | | | |
| | | Rate of | Less temperature cannot get to the reaction | Disruption of production | Increasing furnace | | | | | | | | | |
| | Separation | Less | Fluid streams are not adequately mixed | Decreased product quality | None | 3.002 | Add a mixing device to ensure proper mixing of fluid streams for reaction | Y. A. Guo | Start May, 2022 | | | | | |
| | | No well as | Risky reaction | Decreased yield | Decreased flash alarm to maximize | | | | | | | | | |
| | Pressure | Less | Turbine not designed to output the same pressure under different turbulent rates | Pressure not enough to power through Reverse | None | 3.003 | Review design requirements for variable power turbine ( e.g. variable number of stages of turbine) | C. Y. Chen | Start May, 2022 | | | | | |
| | | More | Turbine not designed to output the same pressure under different turbulent rates | Pressure not enough to power through Reverse | None | 3.004 | Review design requirements for variable power turbine ( e.g. variable number of stages of turbine) | C. J. Sun | Start May, 2022 | | | | | |
| | | Pressure Build-up unexpectedly | explosion | There is a surge fan TN-004 that can be used to pressure to the whole system | | | | | | | | | | |
| | Concentration | Less | Low HCN concentrations leakeage of low enough resistance lines | Low productivity | Equipments and pipelines designed to a reasonable margin of error | | | | | | | | | |
| | Fire & Explosion | Other than | Ignition source | Fire & Explosion | Equipments and pipelines designed to appropriates standard for the prevention of mechanical spark and electrical spark | | | | | | | | | |
| | Mechanical Integrity | No | Inability to Maintenance | All the way up to Freak explosion | Clearly defined maintenance procedures and schedules and responsibilities | | | | | | | | | |
| | | Less/Lack Maintenance | Lack of Maintenance | All the way up to Freak explosion | Clearly defined maintenance procedures and schedules and responsibilities | | | | | | | | | |
| | | Rate of | corrosion/abrasion | All the way up to Freak explosion | Clearly defined maintenance procedures and schedules as well as corrosion allowance for equipments and pipelines | | | | | | | | | |
| | | Reverse | Leakage | All the way up to Freak explosion | Clearly defined maintenance procedures and schedules and responsibilities | | | | | | | | | |
| | Human factors | Rate of | Mistakes when doing maintenance work | Freak explosion and poisoning | None | 3.005 | Review safety checklist design requirements for equipments and pipelines containing HCN or flammable gases or other hazardous materials present on the plant | C. H. Chui | Start May, 2022 | | | | | |
| | | | | | | | | | | | | | | |
| | Level | No | FDA-004 fail-close | Increased HCN gas, numbness, Toxic substance | None | 3.006 | Shake LCV-004 fail-open | H. H. Sun | Start May, 2022 | | | | | |
| | | Less | Pump A Kn-n failure | Increased HCN gas, numbness, Toxic substance | Backup pump is installed in parallel | | | | | | | | | |
| | | | Pump B Kn-n failure | Increased HCN gas, numbness, Toxic substance | Backup pump is installed in parallel | | | | | | | | | |
| | | | Level Loops LCV-004 failure | Increased HCN gas, numbness, Toxic substance | Backup pump is installed in parallel | | | | | | | | | |
| | | More | Pump A Kn-n failure | Increased HCN gas, numbness, Toxic substance | Backup pump is installed in parallel | | | | | | | | | |
| | Pressure | Less | N/A | | | | | | | | | | | |
| | | More | Pump A Kn-n failure | Increased HCN gas, numbness, Toxic substance | Backup pump is installed in parallel | | | | | | | | | |
| | Temperature | Less | Near temperature of cooled product gas | Gives HCN to existence, might lead to high concentration of HCN to ammonium sulphate | Inlet water is always pretreated with steam in the deaerator to many boiling point | | | | | | | | | |
| | | More | Higher temperatures of cooled product gas because of varying water turbulent rates | High temperatures in ammonia absorber, low concentration in HCN absorber, Low productivity | Water is a current cooling stage after the vastes heat Under WV-002 to resistance H2O in the gas mixture | | | | | | | | | |
| | Pressure | Less | Turbine not designed to output the same pressure under different turbulent rates | Pressure not enough to power through Reverse | None | 5.001 | Review design requirements for variable power turbine ( e.g. variable number of stages of turbine) | S. S. Wei | Start May, 2022 | | | | | |
| | | More | Turbine not designed to output the same pressure under different turbulent rates | Pressure not enough to power through Reverse | None | 5.002 | Review design requirements for variable power turbine ( e.g. variable number of stages of turbine) | C. J. Sun | Start May, 2022 | | | | | |
| | | Pressure Build-up unexpectedly | explosion | There is a surge fan TN-004 that can be used to pressure to the whole system | | | | | | | | | | |
| | Fire & Explosion | Other than | Ignition source | Fire & Explosion | Equipments and pipelines designed to appropriates standard for the prevention of mechanical spark and electrical spark | | | | | | | | | |
| | Mechanical Integrity | No | Inability to Maintenance | All the way up to Freak explosion | Clearly defined maintenance procedures and schedules and responsibilities | | | | | | | | | |
| | | Less/Lack Maintenance | Lack of Maintenance | All the way up to Freak explosion | Clearly defined maintenance procedures and schedules and responsibilities | | | | | | | | | |
| | | Rate of | corrosion/abrasion | All the way up to Freak explosion | Clearly defined maintenance procedures and schedules as well as corrosion allowance for equipments and pipelines | | | | | | | | | |
| | | Reverse | Leakage | Boiled water burned | Clearly defined maintenance procedures and schedules and responsibilities | | | | | | | | | |
| | Human factors | Rate of | Mistakes when doing maintenance work | Freak explosion and poisoning | None | 5.003 | Review safety checklist design requirements for equipments and pipelines containing HCN or flammable gases or other hazardous materials present on the plant | C. J. Sun | Start May, 2022 | | | | | |
| | | | | | | | | | | | | | | |
| | Level | No | FDA-004 fail-close | Increased HCN gas, numbness, Toxic substance | None | 6.001 | Shake LCV-004 fail-open | H. H. Sun | Start May, 2022 | | | | | |
| | | Less | Pump A Kn-n failure | Increased HCN gas, numbness, Toxic substance | Backup pump is installed in parallel | | | | | | | | | |
| | | | Pump B Kn-n failure | Increased HCN gas, numbness, Toxic substance | Backup pump is installed in parallel | | | | | | | | | |
| | | | Level Loops LCV-004 failure | Increased HCN gas, numbness, Toxic substance | Backup pump is installed in parallel | | | | | | | | | |
| | | More | Pump A Kn-n failure | Increased HCN gas, numbness, Toxic substance | Backup pump is installed in parallel | | | | | | | | | |
| | Pressure | Less | N/A | | | | | | | | | | | |
| | | More | Pump A Kn-n failure | Increased HCN gas, numbness, Toxic substance | Backup pump is installed in parallel | | | | | | | | | |
| | Temperature | Less | Near temperatures of cooled product gas | Gives HCN to existence, might lead to high concentration of HCN to ammonium sulphate | Inlet water is always pretreated with steam in the deaerator to many boiling point | | | | | | | | | |
| | | More | Higher temperatures of cooled product gas | High temperatures in ammonia absorber, low concentration in HCN absorber, Low productivity | Water is a current cooling stage after the vastes heat Under WV-002 to resistance H2O in the gas mixture | | | | | | | | | |
| | Mechanical Integrity | No | corrosion/abrasion | Boiled water burned | Clearly defined maintenance procedures and schedules and responsibilities as well as corrosion allowance for equipments and pipelines | | | | | | | | | |
| | | Reverse | Leakage | Boiled water burned | Clearly defined maintenance procedures and schedules and responsibilities | | | | | | | | | |
| | Pressure | Less | Control valve PCV-005 fail | Steam not produced to DA but Lower is cooled | Pumps maintenance this is in place to enable replacement | | | | | | | | | |
| | Other | Other | HC-005 will pass turbines | Natural gas to run electricity needs | Backup | | | | | | | | | |
| | Human factors | More | Very few people there | Human error | Clearly defined maintenance procedures and schedules | | | | | | | | | |
| | Mechanical Integrity | Rate of | corrosion/abrasion | Boiled water burned | Clearly defined maintenance procedures as well as corrosion allowance for equipments and pipelines | | | | | | | | | |
| | | Reverse | Leakage | Boiled water burned | Clearly defined maintenance procedures and schedules and responsibilities | | | | | | | | | |
| | Flow | No | No flow in index n, or -n | Use ceased for node n-0.5 | | | | | | | | | | |
| | | Less | Less flow in either of index n or -n | Use ceased for node n-0.6 | | | | | | | | | | |
| | | More | More flow in either of index n or -n | Use ceased for node n-0.7 | | | | | | | | | | |
| | Temperature | Less | Near temperatures of gas entering absorber | Gives HCN to existence, might lead to high concentration of HCN to ammonium sulphate | Inlet water is always pretreated with steam in the deaerator to many boiling point | | | | | | | | | |
| | | More | Higher temperatures of gas entering absorber | High temperatures in ammonia absorber, Low concentration in HCN absorber, Low productivity | Water is a current cooling stage after the vastes heat Under WV-002 to resistance H2O in the gas mixture | 8.001 | There is a lack of a control rep to control temperature of the cooling gas from the ammonia absorber to DA using cooling water Rosmes. Add temperature control and water mapping of H2O to withdrawal and control of flow to ammonia absorber | C. J. Sun | Start May, 2022 | | | | | |
| | Pressure | Less | Turbine not designed to output the same pressure under different turbulent rates | Pressure not enough to power through Reverse | None | 8.002 | Review design requirements for variable power turbine ( e.g. variable number of stages of turbine) | C. H. Sun | Start May, 2022 | | | | | |
| | | More | Turbine not designed to output the same pressure under different turbulent rates | Pressure not enough to power through Reverse | None | 8.003 | Review design requirements for variable power turbine ( e.g. variable number of stages of turbine) | C. Y. Chui | Start May, 2022 | | | | | |
| | | Pressure Build-up unexpectedly | explosion | There is a surge fan TN-004 that can be used to pressure to the whole system | | | | | | | | | | |
| | Fire & Explosion | No well as | Mixing with air | Fire & Explosion | Pipelines and equipments designed to appropriates standard for sealing | | | | | | | | | |
| | | Other than | Ignition source | Fire & Explosion | Equipments and pipelines designed to appropriates standard for the prevention of mechanical spark and electrical spark | | | | | | | | | |
| | Mechanical Integrity | No | Inability to Maintenance | All the way up to Freak explosion | Clearly defined maintenance procedures and schedules and responsibilities | | | | | | | | | |
| | | Less/Lack Maintenance | Lack of Maintenance | All the way up to Freak explosion | Clearly defined maintenance procedures and schedules and responsibilities | | | | | | | | | |
| | | Rate of | corrosion/abrasion | All the way up to Freak explosion | Clearly defined maintenance procedures as well as corrosion allowance for equipments and pipelines | | | | | | | | | |
| | | Reverse | Leakage | All the way up to Freak explosion | Clearly defined maintenance procedures and schedules and responsibilities | | | | | | | | | |
| | Human factors | Rate of | Mistakes when doing maintenance work | Freak explosion and poisoning | None | 8.004 | Review safety checklist design requirements for equipments and pipelines containing HCN or flammable gases or other hazardous materials present on the plant | C. Y. Chui | Start May, 2022 | | | | | |

# Appendix 4 : HAZID Worksheet

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|---|---|---|---|---|
| **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 | 1 | 3 | 3 | 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 training of personnel on safety issues, managemenet conducted to acceptable standards | 1 | 3 | 3 | 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 | 1 | 3 | 3 | 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 will 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, crosion allowance. | 2 | 3 | 6 | 3.1 | Review Safety-interlock design standards and code, 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, crosion allowance. | 3 | 4 | 9 | 3.2 | Review Safety-interlock design standards and code, 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 appropriate 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 appropriate 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 | 3 | 3 | | | | | | |

| | | | | |
|---|---|---|---|---|
| **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 the 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 personnel 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 , crosoion 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 designed 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 | | | | | | |

The University of Nottingham

UNITED KINGDOM · CHINA · MALAYSIA

# UoN HAZID WORKBOOK

| | |
|---|---|
| **PROJECT TITLE:** | Hydrogen Cyanide and AMS Plant Replacement-Andrussow process |

| | |
|---|---|
| **PROJECT GROUP No.** | 6 |

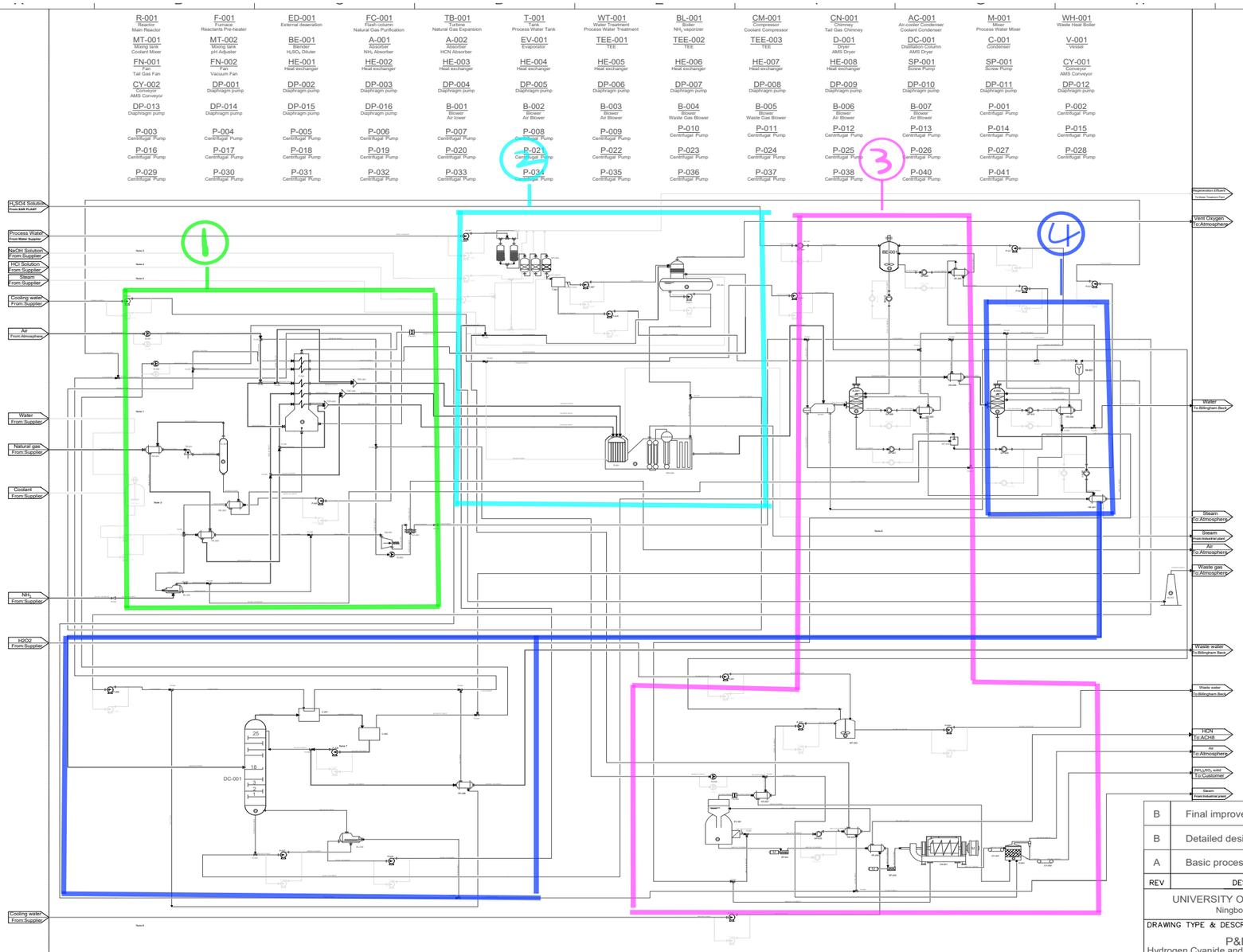
| | |
|---|---|
| **PROCESS OPTION DESCRIPTION:** | Hydrogen Cyanide and AMS Plant Replacement-Andrussow process |

| | |
|---|---|
| **PROJECT TEAM MEMBERS** | Zhi yu CHAI |
| | Yukun WANF |
| | Lisha WEI |
| | Yu ang GUO |
| | Jiajie SUN |
| | Huanyu CHEN |
| | Jiaxu LYU |
| | |
| | |

| | |
|---|---|
| **REVISION** | 5 |
| **DATE** | 26/04/2022 |

**Reference:** **CEEDG101 UoN CEE HAZID Procedure**

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| R-001 Reactor Main Reactor | F-001 Furnace Reactants Pre-heater | ED-001 External deaeration | FC-001 Flash column Natural Gas Purification | TB-001 Turbine Natural Gas Expansion | T-001 Tank Process Water Tank | WT-001 Water Treatment Process Water Treatment | BL-001 Boiler $NH_3$ vaporizer | CM-001 Compressor Coolant Compressor | CN-001 Chimney Tail Gas Chimney | AC-001 Air-cooler Condenser Coolant Condenser | M-001 Mixer Process Water Mixer | WH-001 Waste Heat Boiler |
| MT-001 Mixing tank Coolant Mixer | MT-002 Mixing tank pH Adjuster | BE-001 Blender $H_2SO_4$ Diluter | A-001 Absorber $NH_3$ Absorber | A-002 Absorber HCN Absorber | EV-001 Evaporator | TEE-001 TEE | TEE-002 TEE | TEE-003 TEE | D-001 Dryer AMS Dryer | DC-001 Distillation Column AMS Dryer | C-001 Condenser | V-001 Vessel |
| FN-001 Fan Tail Gas Fan | FN-002 Fan Vacuum Fan | HE-001 Heat exchanger | HE-002 Heat exchanger | HE-003 Heat exchanger | HE-004 Heat exchanger | HE-005 Heat exchanger | HE-006 Heat exchanger | HE-007 Heat exchanger | HE-008 Heat exchanger | SP-001 Screw Pump | SP-001 Screw Pump | CY-001 Conveyor AMS Conveyor |
| CY-002 Conveyor AMS Conveyor | DP-001 Diaphragm pump | DP-002 Diaphragm pump | DP-003 Diaphragm pump | DP-004 Diaphragm pump | DP-005 Diaphragm pump | DP-006 Diaphragm pump | DP-007 Diaphragm pump | DP-008 Diaphragm pump | DP-009 Diaphragm pump | DP-010 Diaphragm pump | DP-011 Diaphragm pump | DP-012 Diaphragm pump |
| DP-013 Diaphragm pump | DP-014 Diaphragm pump | DP-015 Diaphragm pump | DP-016 Diaphragm pump | B-001 Blower Air lower | B-002 Blower Air Blower | B-003 Blower Air Blower | B-004 Blower Waste Gas Blower | B-005 Blower Waste Gas Blower | B-006 Blower Air Blower | B-007 Blower Air Blower | P-001 Centrifugal Pump | P-002 Centrifugal Pump |
| P-003 Centrifugal Pump | P-004 Centrifugal Pump | P-005 Centrifugal Pump | P-006 Centrifugal Pump | P-007 Centrifugal Pump | P-008 Centrifugal Pump | P-009 Centrifugal Pump | P-010 Centrifugal Pump | P-011 Centrifugal Pump | P-012 Centrifugal Pump | P-013 Centrifugal Pump | P-014 Centrifugal Pump | P-015 Centrifugal Pump |
| P-016 Centrifugal Pump | P-017 Centrifugal Pump | P-018 Centrifugal Pump | P-019 Centrifugal Pump | P-020 Centrifugal Pump | P-021 Centrifugal Pump | P-022 Centrifugal Pump | P-023 Centrifugal Pump | P-024 Centrifugal Pump | P-025 Centrifugal Pump | P-026 Centrifugal Pump | P-027 Centrifugal Pump | P-028 Centrifugal Pump |
| P-029 Centrifugal Pump | P-030 Centrifugal Pump | P-031 Centrifugal Pump | P-032 Centrifugal Pump | P-033 Centrifugal Pump | P-034 Centrifugal Pump | P-035 Centrifugal Pump | P-036 Centrifugal Pump | P-037 Centrifugal Pump | P-038 Centrifugal Pump | P-040 Centrifugal Pump | P-041 Centrifugal Pump | |




## NOTES

### LEGEND

INSTRUMENT SUPPLY OR CONNECTION TO PROCESS

NORMAL NO FLOW

PNEUMATIC SIGNAL

ELECTRIC SIGNAL

MAN HOLE

Note 1:WATER FOR START UP
Note 2:COOLANT FOR START UP
Note 3:NAOH FOR BACK WASHING
Note 4:HCL FOR BACK WASHING
Note 5:STEAM FOR START UP
Note 6:LINE FOR STEAM RELEASING
Note 7:GLANDLESS PUMP
Note 8:COOLING WATER WITHE HIGHER PRESSURE
Note 9:HCL AND NAOH FOR BACK WASHING RESPECTIVELY

| REV | DESCRIPTION | DRAWN BY | DATE | APPROVED | DATE |
|---|---|---|---|---|---|
| B | Final improvement | ZY | 3/30/22 | ZY | 3/30/22 |
| B | Detailed design and labeled | HY | 3/15/22 | HY | 3/15/22 |
| A | Basic process design | ZY | 3/12/22 | ZY | 3/12/22 |

UNIVERSITY OF NOTTINGHAM
Ningbo,CHINA

DRAWING TYPE & DESCRIPTION.
P&ID
Hydrogen Cyanide and AMS Plant Replacement
Andrussow

PROJECT TITLE
Hydrogen cyanide plant



| | INITIALS: | DATE: |
|---|---|---|
| DRAWN BY: | ZY | 3/02/22 |
| CHECKED BY: | YA | 3/19/22 |
| APPROVED BY: | HY | 3/30/22 |
| DRAWING No: | PID-Overview | |
| GROUP No: | 06 | REV A |
| DRAWING SCALE: | NTS | |

# MATERIALS ASSESSMENT DATA SHEET

| PROJECT/OPTION: Hydrogen Cyanide and AMS Plant Replacement 1 Andrussow process | | | Regulation (EC) No 1272/2008 - Classification, Labelling and Packaging of Substances and Mixtures Symbol(s) | | | | | | | | | DATE: 26/04/2022 | | COMPILED BY:Jiajie SUN Lisha WEI | | PROJECT GROUP 6 | | REVISION No. 05 | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | Material | MSDS Available? | Phase? (Gas, Liq, Solid etc.) | GHS 01: Unstable/Explosive | GHS 02: Flammable | GHS 03: Oxidising | GHS 04:Compressed Gas | GHS 05: Corrosive | GHS 06: Toxic | GHS 07: Irritant/Toxic | GHS 08: Systemic Health Issues | GHS 09: Environment | NOTABLE HAZARD STATEMENTS | | | | NOTABLE PRECAUTIONARY STATEMENTS | | | | | | | |
| 1 | Ammonia | Yes | Gas | | × | | | | | | | | | | | | | | | | | | | |
| 2 | Ammonia | Yes | Liquid | | × | | | | | | | | | | | | | | | | | | | |
| 3 | Nitrogen | Yes | Gas | | | | × | | | | | | H280 Contains gas under | | | | P410 Protect from sunlight. | | | | | | | |
| 4 | Carbon dioxide | Yes | Gas | | | | × | | | | | | H280 Contains gas under | | | | P410 Protect from sunlight. | P403 Store in a well-ventilated | | | | | | |
| 5 | Methane | Yes | Gas | | × | | × | | | | | | H220 Extremely flammable gas. | H280 Contains gas under pressure; | | | P210 Keep away from heat, hot | P377 Leaking gas fire: Do not | P381 Eliminate all ignition sources if | P410 Protect from sunlight. | P403 Store in a well-ventilated place. | | | | |
| 6 | Ethane | Yes | Gas | | × | | × | | | | | | H220 Extremely flammable gas. | H280 Contains gas under pressure; | | | P210 Keep away from heat, hot | P377 Leaking gas fire: Do not | P381 Eliminate all ignition sources if | P410 Protect from sunlight. | P403 Store in a well-ventilated place. | | | | |
| 7 | Ethane | Yes | Liquid | | × | | | | | | | | H224 Extremely flammable liquid | | | | P210 Keep away from heat, hot | P377 Leaking gas fire: Do not | P381 Eliminate all ignition sources if | | | | | | |
| 8 | Propane | Yes | Gas | | × | | × | | | | | | H220 Extremely flammable gas. | H280 Contains gas under pressure; | | | P210 Keep away from heat, hot | P377 Leaking gas fire: Do not | P381 Eliminate all ignition sources if | P410 Protect from sunlight. | P403 Store in a well-ventilated place. | | | | |
| 9 | Propane | Yes | Liquid | | × | | | | | | | | H224 Extremely flammable liquid | | | | P210 Keep away from heat, hot | P377 Leaking gas fire: Do not | P381 Eliminate all ignition sources if | | | | | | |
| 10 | Butane | Yes | Gas | | × | | × | | | | | | H220 Extremely flammable gas. | H280 Contains gas under pressure; | | | P210 Keep away from heat, hot | P377 Leaking gas fire: Do not | P381 Eliminate all ignition sources if | P410 Protect from sunlight. | P403 Store in a well-ventilated place. | | | | |
| 11 | Butane | Yes | Liquid | × | × | | | | | | | | H224 Extremely flammable liquid | | | | P210 Keep away from heat, hot | P377 Leaking gas fire: Do not | P381 Eliminate all ignition sources if | | | | | | |
| 12 | Hydrogen cynide | Yes | Gas | × | × | | | | × | × | × | × | H220 Extremely flammable gas. | H300+H310+H330 Fatal if swallowed, | H370 Causes damage to organs. | | P210 Keep away from heat, hot | P233 Keep container tightly | P240+P241+P242 +P243 Ground / | P260+P264+P270 Do not breathe | P271 Use only outdoors or in a well-ventilated | P280 Wear protective gloves / protective | P284 Wear respiratory | P403+P233+P23 5 Store in a well- | P501 Dispose of contents/container |
| 13 | Hydrogen cynide | Yes | Liquid | | × | | | | × | × | × | × | H224 Extremely flammable liquid | H300+H310+H330 Fatal if swallowed, | H370 Causes damage to organs. | | P210 Keep away from heat, hot | P233 Keep container tightly | P240+P241+P242 +P243 Ground / | P260+P264+P270 Do not breathe | P271 Use only outdoors or in a well-ventilated | P280 Wear protective gloves / protective | P284 Wear respiratory | P403+P233+P23 5 Store in a well- | P501 Dispose of contents/container |
| 14 | Sulfuric acid | Yes | Liquid | | | × | | × | | × | | | H290 May be corrosive to | H303 May be harmful if | H314 Causes severe skin burns | | P234 Keep only in original | P264 Wash skin thoroughly after | P280 Wear protective gloves/ | P301 + P330 + P331 IF | P303 + P361 + P353 IF ON SKIN (or hair): Take | P304 + P340 + P310 IF INHALED: Remove person | P305 + P351 + P338 + | P405+P406 Store locked up. | P501 Dispose of contents/ container |
| 15 | Water | Yes | Liquid | | | | | | | | | | | | | | | | | | | | | |
| 16 | Steam | Yes | Gas | | | | × | | | | | | H280 Contains gas under | H314 Causes severe skin burns | | | P261 Avoid breathing vapors | P280 Wear eye protection, face | P304+P340 If inhaled: Remove | P308+P313 If exposed or | | | | | |
| 17 | Ammonium sulphate | Yes | Liquid | | | | | | | X | | X | H402 Harmful to aquatic life | H302 harmful if swallowed | | | P273 Avoid release to the | P501 dispose of contents/contain | | | | | | | |
| 18 | Oxygen | Yes | Gas | | | × | × | | | | | | H270 May cause or intensify fire; | H280 Contains gas under pressure; | | | P220 Keep/Store away from | P244 Keep valves and fittings free | P370 + P376 In case of fire: Stop | P410 + P403 Protect from | | | | | |
| 19 | Hydrogen | Yes | Gas | | × | | × | | | | | | H220 Extremely flammable gas. | H280 Contains gas under pressure; | | | P210 Keep away from heat, hot | P377 Leaking gas fire: Do not | P381 Eliminate all ignition sources if | P403 Store in a well-ventilated | | | | | |
| 20 | Carbon monoxide | Yes | Gas | | × | | × | | × | | × | | H220 Extremely flammable gas. | H280 Contains gas under pressure; | H331 Toxic if inhaled | H360 May damage fertility or the | H372 Causes damage to organs | P210 Keep away from heat, hot | P260+P270 Do not breathe gas. | P264 Wash exposed skin | P271+P403+P405 Use and store only | P280 Wear protective clothing, protective | P377 LEAKING GAS FIRE: Do not extinguish, unless | P381 Eliminate all ignition | P381 Eliminate all ignition | P501 Dispose of contents/container |
| 21 | hydrogen peroxide | Yes | liquid | | | × | | × | | × | | | H318 Causes serious eye damage | H302 Harmful if swallowed | H272 may intensify | | | P264 Wash face, hands and any | P280 Wear protective gloves/ | P210 Keep away from | P220 - Keep/Store away from | P221 - Take any precaution to avoid | | | | |
| 22 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 23 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 24 | | | | | | | | | | | | | | | | | | | | | | | | | | |
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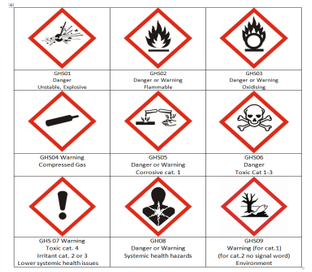
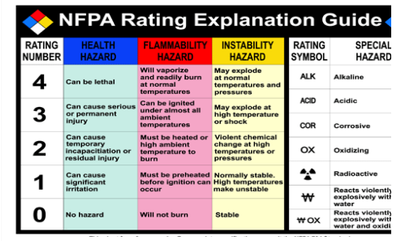
| 29 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 30 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 31 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 32 | | | | | | | | | | | | | | | | | | | | | | | | | | |



# HAZARDS INVENTORY

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | PROJECT: Hydrogen Cyanide and AMS Plant Replacement- Andrussow process | | | | | | DATE: 26/04/2022 |
| | PFD Drawing No: 001 | | | | | | REVISION No: 5 |
| | GROUP No. 6 | SECTIONS PRESENT | | | | | COMPILIED BY: Li sha WEI , Yukun WANG |
| | SPECIFIC HAZARDS | Section 1: | Section 2: | Section 3: | Section 4: | Section 5: | COMMENTS |
| Material | Flammable Materials | × | × | × | × | | |
| | Toxic Substances | × | × | × | × | | |
| | Gases under High Pressure | × | × | | | | |
| | Liquids under High Pressure | × | × | | | | |
| | Hot Fluids | × | × | | × | | |
| | Cryogenic Fluids | × | | | | | |
| | Oxidising Materials | | | | | | |
| | Reactive/Unstable Materials | | × | × | × | | |
| | Explosive Substances | × | × | × | × | | |
| | Corrosive Materials | | | × | × | | |
| | Poisonous Materials | | × | × | × | | |
| | Biological Hazardous Materials | | | | | | |
| | Ecotoxic Materials | | | | | | |
| | Combustible Dusts | | | | | | |
| | | | | | | | |
| | | | | | | | |
| Equipment | High Speed Rotational Equipment | × | | × | | | |
| | Equipment Under Pressure | × | | | | | |
| | Equipment at High Temperature | × | × | | × | | |
| | Equipment at Low Temperature | × | | | | | |
| | Lifting Equipment | | | | | | |
| | Ionising Radiation Present | | | | | | |
| | General Non-Ionised Radiation Present | | | | | | |
| | | | | | | | |
| | | | | | | | |
| Process | Exothermic Reaction | | × | | | | |
| | Endothermic Reaction | | | | | | |
| | Runaway Reaction | | × | × | × | | |
| | Catalyst Poisoning | | × | | | | |
| | Explosive Reaction | | × | | × | | |
| | High Pressure | × | × | | | | |
| | Low Pressure/Vacuum | | | × | | | |
| | Pressure Cycling | | | | | | |
| | High Temperature | × | × | | | | |
| | Low Temperature | × | | | | | |
| | Temperature Cycling | | | | | | |
| | | | | | | | |
| | | | | | | | |
| Other | Ground Conditions | | | | | | |
| | Transport/Traffic | | | | | | |
| | Natural Hazards | × | × | × | × | | |
| | Manual Operations | | | | | | |
| | Sampling | | | | | | |
| | Maintenance | × | × | × | × | | |
| | Working At Height | | | | | | |
| | Noise | × | | × | | | |
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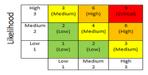
| **PROJECT:** | Hydrogen Cyanide and AMS Plant Replacement-Andrussow process | **HAZID DATE:** | 26/04/2022 |
| **PFD DRAWING No.** | 1 | **PROJECT GROUP No.:** | 6. |
| **PARTICIPANTS:** | | ZYC YAG YKW JJS HYC LSW JXL | |
| **FACILITY SECTION No.:** | 1 | **PARTICIPANTS SIGNATURES:** | ZYC YAG YKW JJS HYC LSW JXL |
| **FACILITY SECTION DESCRIPTION** | Pre-treatment of natural gas | **REVISION:** | **5** |

HAZID RISK MATRIX




1 OPEN

2 CLOSED

3 N/A

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|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | **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 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 deisgnd 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 | | | | | | |
| 14 | | | | | | | | | | | | | |
| 15 | | | | | | | | | | | | | |

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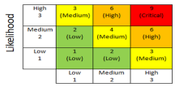
|---|---|---|---|
| **PROJECT:** | Hydrogen Cyanide and AMS Plant Replacement-Andrussow process | **HAZID DATE:** | 26/04/2022 |
| **PFD DRAWING No.** | 1 | **PROJECT GROUP No.: PARTICIPANTS:** | 6. ZYC YAG YKW JJS HYC LSW JXL |
| **FACILITY SECTION No.:** | 2 | **PARTICIPANTS SIGNATURES:** | ZYC YAG YKW JJS HYC LSW JXL |
| **FACILITY SECTION DESCRIPTION** | Main reaction & Pre-treatment of process | **REVISION:** | **5** |

HAZID RISK MATRIX




| | | | | | 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 | 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 | | | | | | |
| 15 | | | | | | | | | | | | | |
| 16 | | | | | | | | | | | | | |

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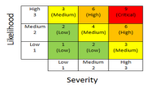
|---|---|---|---|
| **PROJECT:** | Hydrogen Cyanide and AMS Plant Replacement-Andrussow process | **HAZID DATE:** | 26/04/2022 |
| **PFD DRAWING No.** | 1 | **PROJECT GROUP No.:** | 6. |
| **FACILITY SECTION No.:** | 3 | **PARTICIPANTS:** | ZYC YAG YKW JJS HYC LSW JXL |
| **FACILITY SECTION DESCRIPTION** | AMS treatment | **PARTICIPANTS SIGNATURES:** | ZYC YAG YKW JJS HYC LSW JXL |
| | | **REVISION:** | **5** |

HAZID RISK MATRIX




| | |
|---|---|
| 1 | OPEN |
| 2 | CLOSED |
| 3 | N/A |

| | | | | 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 desigend 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 | | | | | | |
| 10 | | | | | | | | | | | | | |
| 11 | | | | | | | | | | | | | |
| 12 | | | | | | | | | | | | | |
| 13 | | | | | | | | | | | | | |
| 14 | | | | | | | | | | | | | |

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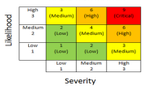
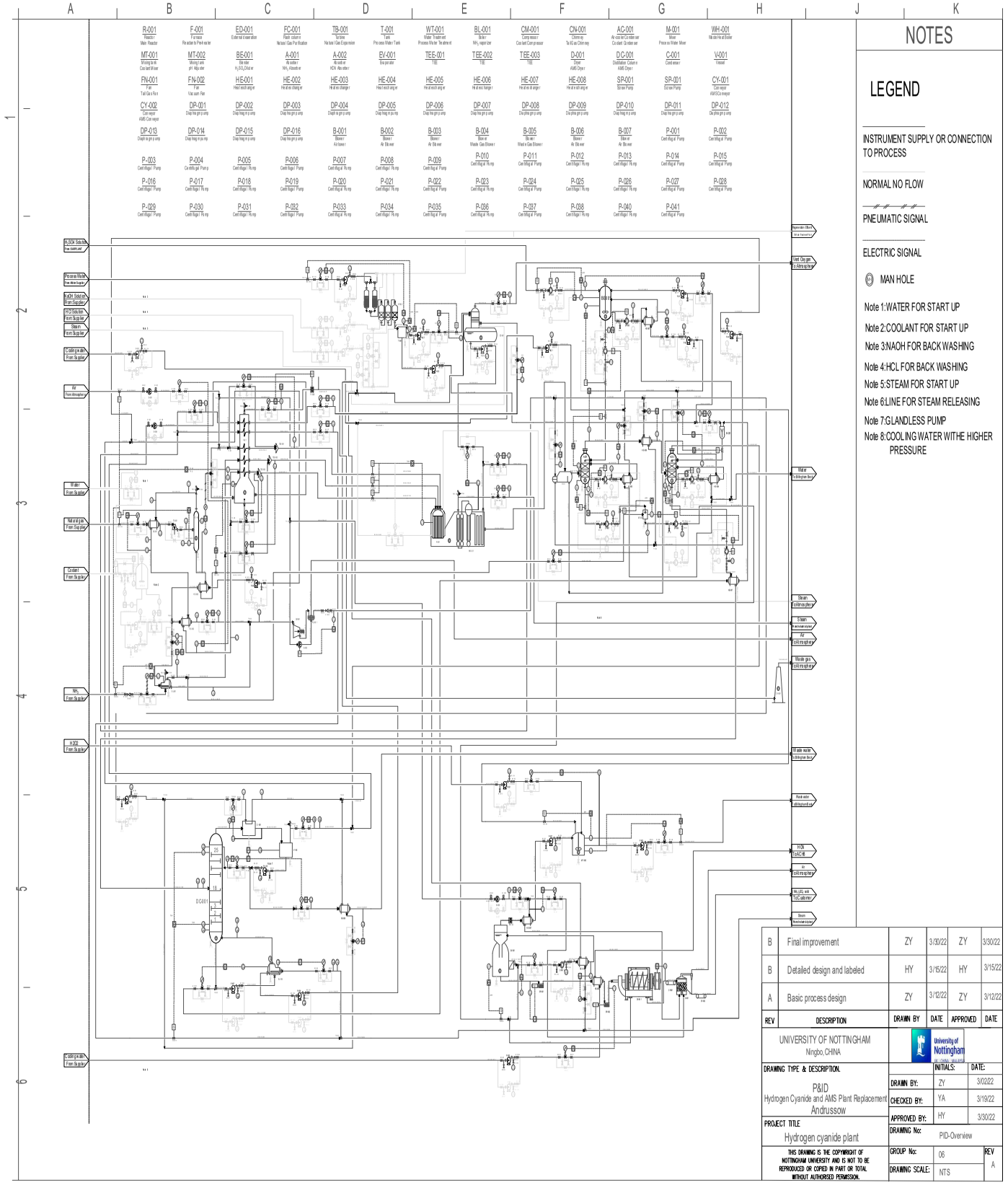
| **PROJECT:** | Hydrogen Cyanide and AMS Plant Replacement-Andrussow process | **HAZID DATE:** | 26/04/2022 |
| **PFD DRAWING No.** | | **PROJECT GROUP No.:** | 6. ZYC YAG YKW JJS HYC LSW JXL |
| | | **PARTICIPANTS:** | |
| **FACILITY SECTION No.:** | 4 | **PARTICIPANTS SIGNATURES:** | ZYC YAG YKW JJS HYC LSW JXL |
| **FACILITY SECTION DESCRIPTION** | HCN Absorber | **REVISION:** | **5** |

HAZID RISK MATRIX




| | |
|---|---|
| 1 | OPEN |
| 2 | CLOSED |
| 3 | N/A |

| | | | | | 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 | | | | | | |
| 14 | | | | | | | | | | | | | |


A
B
C
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E
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1
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6
R-001 Reactor Water Reactor
F-001 Furnace Pre-water for Pre-heat for
ED-001 External evaporation
FC-001 Flash column for Nylon Clay Pot Solution
TB-001 Turbine for Hot Acid Crack Expansion
T-001 Tank Pre-mass Water's Tank
WT-001 Water Treatment Process Water Treatment
BL-001 Boiler Mix, vapor per
CM-001 Compressor Coal and Carry-on-sour
CN-001 Column to Tail Gas Chim-ney
AC-001 Air-cool for Coal-Acid Coolant Cyclone-sour
M-001 Mixer Pre-ox for Water Mixer
WH-001 Waste Heat Boiler
MT-001 Mixing tank Coal and Mixer
MT-002 Mixing Lamp pH Alky-zer
BE-001 Blender H2SO4 Mixer
A-001 Air-cooler Mix, Absorb-er
A-002 Air-cooler HCN - Abs-orber
EV-001 Evaporator Evaporator
TEE-001 TEE
TEE-002 TEE
TEE-003 TEE
D-001 Dryer AMS Dryer
D-C-001 Distillation Column AMS Dryer
C-001 Condenser
V-001 Vessel
FN-001 Fan Fuel Gas Flue
FN-002 Fan Vacuum Flue
HE-001 Heat exchanger
HE-002 Heat exchanger
HE-003 Heat exchanger
HE-004 Heat exchanger
HE-005 Heat exchanger
HE-006 Heat exchanger
HE-007 Heat exchanger
HE-008 Heat exchanger
SP-001 Screw Pump
SP-001 Screw Pump
CY-101 Cyclone AMS Cyclone
CY-002 Cyclone AMS Cyclone
DP-001 Drag flow pump
DP-002 Drag flow pump
DP-003 Drag flow pump
DP-004 Drag flow pump
DP-005 Drag flow pump
DP-006 Drag flow pump
DP-007 Drag flow pump
DP-008 Drag flow pump
DP-009 Drag flow pump
DP-010 Drag flow pump
DP-011 Drag flow pump
DP-012 Drag flow pump
DP-013 Drag flow pump
DP-014 Drag flow pump
DP-015 Drag flow pump
DP-016 Drag flow pump
B-001 Blower Air Blower
B-002 Blower Air Blower
B-003 Blower Air Blower
B-004 Blower Waste Gas Blower
B-005 Blower Waste Gas Blower
B-006 Blower Air Blower
B-007 Water Air Blower
P-001 Centrifugal Pump
P-002 Centrifugal Pump
P-003 Centrifugal Pump
P-004 Centrifugal Pump
P-005 Centrifugal Pump
P-006 Centrifugal Pump
P-007 Centrifugal Pump
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P-036 Centrifugal Pump
P-037 Centrifugal Pump
P-038 Centrifugal Pump
P-040 Centrifugal Pump
P-041 Centrifugal Pump
NOTES
LEGEND
INSTRUMENT SUPPLY OR CONNECTION TO PROCESS
NORMAL NO FLOW
PNEUMATIC SIGNAL
ELECTRIC SIGNAL
MAN HOLE
Note 1:WATER FOR START UP
Note 2:COOLANT FOR START UP
Note 3:NAOH FOR BACK WASHING
Note 4:HCL FOR BACK WASHING
Note 5:STEAM FOR START UP
Note 6:LINE FOR STEAM RELEASING
Note 7:GLANDLESS PUMP
Note 8:COOLING WATER WITHE HIGHER PRESSURE
B Final improvement ZY 3/30/22 ZY 3/30/22
B Detailed design and labeled HY 3/15/22 HY 3/15/22
A Basic process design ZY 3/12/22 ZY 3/12/22
REV DESCRIPTION DRAWN BY DATE APPROVED DATE
UNIVERSITY OF NOTTINGHAM
Ningbo, CHINA
University of Nottingham
DRAWING TYPE & DESCRIPTION.
P&ID
Hydrogen Cyanide and AMS Plant Replacement
Andrussow
PROJECT TITLE
Hydrogen cyanide plant
INITIALS: DATE:
DRAWN BY: ZY 3/2022
CHECKED BY: YA 3/19/22
APPROVED BY: HY 3/30/22
DRAWING No: P&D-Overview
GROUP No: 06
REV A
DRAWING SCALE: NTS
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| Project Title: | HCN Plant replacement at the Cassel Works Site | | P&ID Title/Description | Andrussow process P&ID | P&ID No. Rev No.: | 1 |
|---|---|---|---|---|---|---|
| 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 | 26/4/2022 |
| 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 mixed 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 mixed 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 mixed 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 mixed 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 mixed 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 appropriate 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, leading 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 equipments 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 responsibilities | | | | | | |
| | | Less/Lack Maintenance | Lack of Maintenance | All the way up to Fire& explosion | Clearly defined maintenance procedures and schedules and responsibilities | | | | | | |
| | | 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 responsibilities | | | | | | |
| | 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 | |
| | Flow | No | the cascade control loop involving FCV-004 & LCV-002 fail close, 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 passing | Disruption of production | Bypass maintenance line is in place to enable replacement | | | | | | |
| | | | | | 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 fail close | Disruption of production | Bypass maintenance line is in place to enable replacement | | | | | | |
| | | More | the cascade control loop involving FCV-004 & LCV-002 fail | 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 | |

| Project Title: | HCN Plant replacement at the Cassel Works Site | P&ID Title/Description | Andrussow process P&ID | P&ID No. Rev No.: | 1 |
|---|---|---|---|---|---|
| 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 | 26/4/2022 |
| 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 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | 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 responsibilities | | | | | | |
| | | Less/Lack Maintenance | Lack of Maintenance | All the way up to Fire& explosion | Clearly defined maintenance procedures and schedules and responsibilities | | | | | | |
| | | 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 responsibilities | | | | | | |
| | 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 annonsiate values | | | | | | |
| | Mechanical integrity | No | Inability to Maintenance | Congested pipe line | Clearly defined maintenance procedures and schedules and responsibilities | | | | | | |
| | | Less/Lack Maintenance | Lack of Maintenance | Congested pipe line | Clearly defined maintenance procedures and schedules and responsibilities | | | | | | |
| | | Reverse | Leakage | decreased efficiency | Clearly defined maintenance procedures and schedules and responsibilities | | | | | | |
| | 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 hinh 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 pipe | | | | | | |
| | | 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 | | | | | | |

| Project Title: | HCN Plant replacement at the Cassel Works Site | | P&ID Title/Description | Andrussow process P&ID | | P&ID No. Rev No.: | 1 |
|---|---|---|---|---|---|---|---|
| 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 | 26/4/2022 |
| 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 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 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 | | | | | | |
| | Pressure | Less | Control valve PCV-006 fail | Steam not produced to 20 bar standard | Bypass maintenance line is in place to enable replacement | | | | | | |

| Project Title: | | HCN Plant replacement at the Cassel Works Site | | | P&ID Title/Description | | | P&ID No. Rev No.: | 1 |
|---|---|---|---|---|---|---|---|---|---|
| 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 | 26/4/2022 |
| 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 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 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 | | | | | | | |
| 7 | 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 | | | | | | |
| | 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 | |
| 8 | | | 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 | | | | | | |
| | Human factors | Part of | Mistakes when doing maintenance work | Fire& explosion and poisoning | None | 8.03 | 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 | |
| | Level | No | During plant startup | Damage to pump DP-007 | Safety interlock that only allow starting the pump when there is enough level | | | | | | |
| | | | Unsteady operation | Decreased product quality | Optimised Functional design | | | | | | |
| | | Less | Not enough sulphuric acid solution from BE-001 | Unabsorbed NH3 leads to HCN polymerisation | Flowrate is controlled with respect to a composition analyzer on the top product line | | | | | | |
| | | | Unsteady operation | Decreased product quality | Optimised Functional design | | | | | | |
| | | More | Too much sulphuric acid solution from BE-001 | Increased cost of processing waste H2SO4 | Flowrate is controlled with respect to a composition analyzer on the top product line | | | | | | |
| | Temperature | Less | inlet gas mixture temperature too low | High entrainment of HCN along ammonium sulphate stream | None | 9.01 | Add a control mechanism that controls the inlert gas temperature by regulating cooling water using FCV-014 | Z. Y. Chai | 31st May, 2022 | OPEN | |
| | | | Too much sulphuric acid solution from BE-001 | Increased cost of processing waste H2SO4 | Flowrate is controlled with respect to a composition analyzer on the top product line | | | | | | |
| | | More | inlet gas mixture temperature too high | Increased temperature of absorber top product gas, that entrains more water, as well as more energy consumption | None | 9.01 | Add a control mechanism that controls the inlert gas temperature by regulating cooling water using FCV-014 | H. Y. Chen | 31st May, 2022 | OPEN | |
| | | | Not enough sulphuric acid solution from BE-001 | Unabsorbed NH3 leads to HCN polymerisation | Flowrate is controlled with respect to a composition analyzer on the top product line | | | | | | |
| | Pressure | Less | Turbine not designed to output the same pressure under different turndown ratios | Pressure not enough to power enough flowrate | None | 9.02 | 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 | 9.03 | Review design requirements for variable power turbine ( e.g. variable number of stages of turbine) | J. J. Sun | 31st May, 2022 | OPEN | |
| 9 | | | 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 | HCN polymirisation | Fire & Explosion | Residence time and PH designed according to appropriate standard to prevent HCN polymerisation | | | | | | |
| | | Other than | Ignition source | Fire & Explosion | Equipments and pipelines designed to appropriate standard for prevention of mechanical spark and electrical spark | | | | | | |
| | | No | Inability to Maintenance | All the way up to Fire& explosion | Clearly defined maintenance procedures and schedules and resonsibilities | | | | | | |

| Project Title: | | HCN Plant replacement at the Cassel Works Site | | | P&ID Title/Description | | | | | P&ID No. Rev No.: | 1 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 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 | 26/4/2022 |
| 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 |
| | Mechanical integrity | 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 | 9.04 | Review safety interlock design requirments for equipments and pipelines containing HCN or flammable gases or other hazardous materials present on the plant | Y. A. Guo | 31st May, 2022 | OPEN | |
| | Flow | No | Pump DP-003 failure | Unabsorbed NH3 leads to HCN polymerisation | Backup pump is installed in parallel | | | | | | |
| | | | Level in BE-001 too low leads to shutdown | Unabsorbed NH3 leads to HCN polymerisation | Level in BE-001 is controlled by regulating supply of H2O and H2SO4 | 10.01 | Investigate the stability of H2SO4 and H2O supply and decide if storage tank is needed to ensure stable supply | J. X. Lyu | 31st May, 2022 | OPEN | |
| | | Less | Pump DP-003 failure | Unabsorbed NH3 leads to HCN polymerisation | Backup pump is installed in parallel | | | | | | |
| | | More | Pump DP-003 failure | Increased cost of processing waste H2SO4 | Backup pump is installed in parallel | | | | | | |
| | Composition | No | Shortage of H2O supply | Overheating of absorber leads to HCN runnaway polymerisation | Continuous supply of H2O | 10.02 | Investigate the stability of H2O supply and decide if storage tank is needed to ensure stable supply | L. S. Wei | 31st May, 2022 | OPEN | |
| | | | Shortage of H2SO4 supply | Unabsorbed NH3 leads to HCN polymerisation | Continuous supply of H2SO4 | 10.03 | Investigate the stability of H2SO4 supply and decide if storage tank is needed to ensure stable supply | J. J. Sun | 31st May, 2022 | OPEN | |
| | | Less/More | Shortage of H2O supply | Overheating of absorber leads to HCN runnaway polymerisation | Continuous supply of H2O | 10.02 | Investigate the stability of H2O supply and decide if storage tank is needed to ensure stable supply | Y. A. Guo | 31st May, 2022 | OPEN | |
| | | | Shortage of H2SO4 supply | Unabsorbed NH3 leads to HCN polymerisation | Continuous supply of H2SO4 | 10.03 | Investigate the stability of H2SO4 supply and decide if storage tank is needed to ensure stable supply | Z. Y. Chai | 31st May, 2022 | OPEN | |
| 10 | Temperature | More | Shortage of H2O supply | Overheating of absorber leads to HCN runnaway polymerisation | Continuous supply of H2O | 10.02 | Investigate the stability of H2O supply and decide if storage tank is needed to ensure stable supply | J. X. Lyu | 31st May, 2022 | OPEN | |
| | | | P-017 failure | | Backup pump is installed in parallel | | | | | | |
| | | Less | Shortage of H2SO4 supply | Unabsorbed NH3 leads to HCN polymerisation | Continuous supply of H2SO4 | 10.03 | Investigate the stability of H2SO4 supply and decide if storage tank is needed to ensure stable supply | Y. K. Wang | 31st May, 2022 | OPEN | |
| | | | DP-001 failure | | Backup pump is installed in parallel | | | | | | |
| | Fire & Explosion | As well as | Dilution of Concentrated Sulphuric acid | Fire & Explosion | Dilution ratio and mixing properly designed to avoid overheating and 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 | cracks and pipeline aging | Clearly defined maintenance procedures and schedules and resonsibilities | | | | | | |
| | | Less/Lack Maintenance | Lack of Maintenance | cracks and pipeline aging | Clearly defined maintenance procedures and schedules and resonsibilities | | | | | | |
| | | Part of | corrosion/errosion | Pipeline leakafe and bursting hazard | Clearly defined maintenance procedures and schedules and resonsibilities as well as corrosion allowance for equipments and pipelines | | | | | | |
| | | Reverse | Leakage | Injury to personnel | Clearly defined maintenance procedures and schedules and resonsibilities | | | | | | |
| | Human factors | Part of | Mistakes when doing maintenance work | poisoning and injury to personnel | None | 10.4 | Review safety interlock design requirments for equipments and pipelines containing Sulphuric acid | L. S. Wei | 31st May, 2022 | OPEN | |
| | Flow | No | Level in A-001 is too low | Damage to pump DP-007 | Safety interlock that only allow starting the pump when there is enough level | | | | | | |
| | | Less | Level in A-001 is low | N/A | | | | | | | |
| | | More | Level in A-001 is High | N/A | | | | | | | |
| | Temperature | More | inlet gas mixture temperature too high | Increased temperature of absorber top product gas, that entrains more water, as well as more energy consumption | None | 11.01 | Add a control mechanism that controls the inlert gas temperature by regulating cooling water using FCV-014 | J. X. Lyu | 31st May, 2022 | OPEN | |
| | | | Inlet sulphuric acid flow too low | Unabsorbed NH3 leads to HCN polymerisation | Flowrate is controlled with respect to a composition analyzer on the top product line | | | | | | |
| | | Less | inlet gas mixture temperature too low | increased entrainment of HCN with ammonium sulphate flow from A-001 | None | 11.01 | Add a control mechanism that controls the inlert gas temperature by regulating cooling water using FCV-014 | Y. K. Wang | 31st May, 2022 | OPEN | |
| | | | Inlet sulphuric acid flow too high | See HAZOP for node 10 | | | | | | | |
| 11 | Pressure | Less | Turbine not designed to output the same pressure under different turndown ratios | Pressure not enough to power enough flowrate | None | 11.02 | Review design requirements for variable power turbine ( e.g. variable number of stages of | 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 | 11.03 | Review design requirements for variable power turbine ( e.g. variable number of stages of | Y. A. Guo | 31st May, 2022 | OPEN | |
| | | | Pressure build-up unexpectedly | explosion | There is a huge fan FN-001 that creates negative pressure in the whole system | | | | | | |
| | | No | Inability to Maintenance | cracks and pipeline aging | Clearly defined maintenance procedures and schedules and resonsibilities | | | | | | |

| Project Title: | | HCN Plant replacement at the Cassel Works Site | | | P&ID Title/Description | | Andrussow process P&ID | | | P&ID No. Rev No.: | 1 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 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 | 26/4/2022 |
| 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 |
| | Mechanical integrity | Less/Lack Maintenance | Lack of Maintenance | cracks and pipeline aging | Clearly defined maintenance procedures and schedules and resonsibilities | | | | | | |
| | | Part of | corrosion/errosion | Pipeline leakafe and bursting hazard | Clearly defined maintenance procedures and schedules and resonsibilities as well as corrosion allowance for equipments and pipelines | | | | | | |
| | | Reverse | Leakage | Injury to personnel | Clearly defined maintenance procedures and schedules and resonsibilities | | | | | | |
| | Human factors | Part of | Mistakes when doing maintenance work | poisoning and injury to personnel | None | 11.04 | 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 | |
| | Flow | Less | inlet gas mixture temperature too low leading to HCN condensation | increased entrainment of HCN with ammonium sulphate flow from A-001 | None | 12.01 | Add a control mechanism that controls the inlert gas temperature by regulating cooling water using FCV-014 | Y. A. Guo | 31st May, 2022 | OPEN | |
| | | | Inlet sulphuric acid flow too high | See HAZOP for node 10 | | | | | | | |
| | | More | inlet gas mixture temperature too High leading too much H2O entrainment | Increased energy consumption | | | | | | | |
| | Temperature | Less | inlet gas mixture temperature too low | increased entrainment of HCN with ammonium sulphate flow from A-001 | None | 12.01 | Add a control mechanism that controls the inlert gas temperature by regulating cooling water using FCV-014 | H. Y. Chen | 31st May, 2022 | OPEN | |
| | | | A-001 Top product gas overly cooled by HE-003 | Inlet gas temperature to A-002 is feedback-controlled by regulating coolant flowrate through TCV-007 | | | | | | | |
| | | More | inlet gas mixture temperature too High leading too much H2O entrainment | Increased energy consumption | | | | | | | |
| | | | A-001 Top product gas not adequately cooled by HE-003 | Inlet gas temperature to A-002 is controlled by regulating coolant flowrate through TCV-007 | | | | | | | |
| 12 | Fire & Explosion | As well as | HCN polymirisation | Fire & Explosion | Resilience line and PFI designed according to appropriate standard to prevent HCN | | | | | | |
| | | Other than | Ignition source | Fire & Explosion | Equipments and pipelines designed to appropriate standard for prevention of | | | | | | |
| | Mechanical integrity | No | Inability to Maintenance | cracks and pipeline aging | Clearly defined maintenance procedures and schedules and resonsibilities | | | | | | |
| | | Less/Lack Maintenance | Lack of Maintenance | cracks and pipeline aging | Clearly defined maintenance procedures and schedules and resonsibilities | | | | | | |
| | | Part of | corrosion/errosion | Pipeline leakafe and bursting hazard leading 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 | 12.02 | 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 | |
| Counting | 68 | 162 | 193 | 194 | 166 | | 49 | 49 | 49 | 49 | |

University of Nottingham
Department of Chemical and Environmental Engineering
HAZOP NODE LIST

| Project Title: | | HCN Plant replacement at the Cassel Works Site | | |
|---|---|---|---|---|
| P&ID Title/Rev/Description | | | | |
| Group No.: | | 6 | Study Leader/Date | 26/4/2022 |
| Node No | Description | To | From | Comments |
| 1 | Purified natural gas feed line | R-001 | FC-001&F-001 | |
| 2 | Vaporised ammonia feed line | R-001 | BL-0018F-001 | |
| 3 | Air feed line | R-001 | Atmosphere | |
| 4 | Reactor R-001 | Reactor R-001 integrated with waste heat boiler WH-001 | | |
| 5 | Waste heat boiler WH-001 | Waste heat boiler WH-001 integrated with Reactor R-001 | | |
| 6 | Steam water for WH-001 | WH-001 | ED-001 | |
| 7 | Steam produced by WH-001 | Steam users (plants neayby) | WH-001 | |
| 8 | Cooled reactor product gas mixture & the water condensed from the mixture leaving from HE-003 through line WW-141-2"-A1PR-PP to waste treatment | A-001&MT-003 | WH-001 | |
| 9 | Ammonia absorber A-001 | Ammonia absorber using Dilute sulphuric acid as absorbent | | |
| 10 | Dilute sulphuric acid | A-001 | BE-001 | |
| 11 | Product gas stripped of ammonia | A-002 | A-001 | |
| 12 | Ammonium sulphate | MT-002 | A-001 | |
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| 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 | Contaminatio n | | | 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 | | | Contaminatio n 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 | | | | | |