Base Load Power Hub (BLPH)

Failure modes, effects, and criticality analysis (FMECA) Report

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Table of contents

1 INTRODUCTION 5
1.1 PROJECT OVERVIEW 5
1.1.1 Project Location 5
1.1.2 Project Concept 6
1.2 DOCUMENT SCOPE 7
2 MAIN REFERENCES 8
3 DEFINITIONS AND ABBREVIATIONS 9
3.1.1 Definitions 9
3.1.2 Abbreviations 10
4 METHODOLOGY 11
4.1 GENERAL PRINCIPLE 11
4.2 fmeca DEVELOPMENT 11
4.2.1 Identification of the elements to be subjected to FMECA study 12
4.2.2 Analysis of the main failure modes of each selected element and identification of main causes 12
4.2.3 Evaluation of potential likelihood of the analyzed failure mode 13
4.2.4 Evaluation of the potential effects of the selected failure on the single element and on the entire system 14
4.2.5 Semi-quantitative assessment of the initial risk associated to each failure mode (not compensated by the mitigating measures) by combination of likelihood estimate and potential impact evaluation 15
4.2.6 Identification of the mitigating measures installed in the system to reduce the extent of the effects of the failure 17
4.2.7 Semi-quantitative assessment of the compensated risk which includes in the evaluation the effectiveness of the available mitigating measures 18
4.2.8 Identification of possible critical issues and eventual recommendation for improvement ... 18
5 FMECA STUDY RESULTS 19
5.1 BASIC ASSUMPTIONS 19
5.1.1 Analysed elements 19
5.1.2 Analysed failure modes 20
5.2 MAIN RESULTS – HYDROGEN CIRCUIT 21

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5.2.1 Calculated values 21
5.2.2 Final considerations on hydrogen circuit 22
5.3 MAIN RESULTS – Instrument air and Nitrogen 24
5.3.1 Calculated values 24
5.3.2 Final considerations on Instrument Air and Nitrogen circuit 25
5.4 MAIN RESULTS – F&G network 27
5.4.1 Calculated values 27
5.4.2 Final considerations on Instrument F&G network 28

List of Figures

Figure 1 HOLLANDSE KUST NOORD WIND PARK Location Map 5
Figure 2 - Wind Park Details 6
Figure 3 – BLPH Concept 6
Figure 4 Calculated risk for hydrogen circuit 21
Figure 5 Calculated risk for Instrument Air and Nitrogen circuit 24
Figure 6 Calculated risk for F&G network 27

List of tables

Table 1 - Reference Documents 8
Table 2 - Definitions 9
Table 3 - Abbreviations 10
Table 4 – General likelihood definition for failure modes 13
Table 5 – Detailed likelihood definition for failure modes 14
Table 6 – General consequence definition for failure modes 14
Table 7 – Detailed consequence definition for failure modes 15
Table 8 – Risk Matrix 15
Table 9 – Detailed mitigating for failure modes 17

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1 INTRODUCTION

1.1 PROJECT OVERVIEW

Crosswind, a Shell and Eneco joint venture, was awarded the tender to develop the offshore Hollandse Kust Noord (HKN) wind farm, located 18.5km off the coast of Netherlands near the town of Egmond aan Zee. The consortium plans to have HKN operational in 2023 with an installed capacity of 759MW generating at least 3.3TWh per year. This is sufficient renewable power to supply more than 1 million Dutch households with green electricity.

Offshore wind farms produce intermittent electricity and balancing these dips and peaks and integrating this electricity into the national energy system requires new technologies. For this reason, the offshore wind farm will include several new technologies that could be implemented at full-scale in the future. The new technologies being explored include a floating solar park, a short-duration battery storage as well as long-term storage via green hydrogen produced by water electrolysis and subsequently consumed in a fuel cell. The combination of these individual measures, herein referred to as the Base Load Power Hub (BLPH) will ensure a continuous power supply regardless of the wind situation.

1.1.1 Project Location

The Hollandse Kust Noord (HKN) wind farm is located 18.5km off the coast of the Netherlands near the town of Egmond aan Zee.

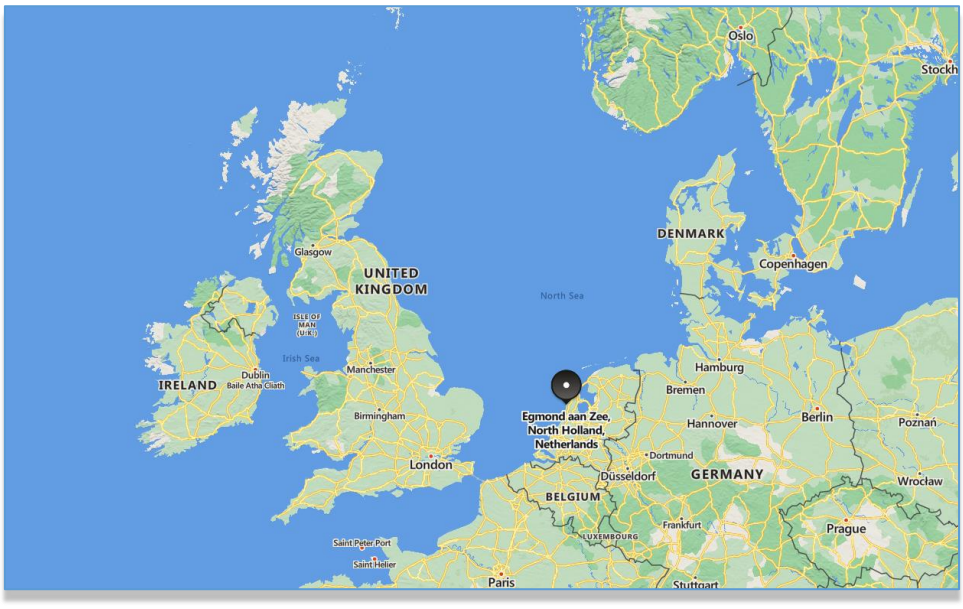


Figure 1 HOLLANDSE KUST NOORD WIND PARK Location Map

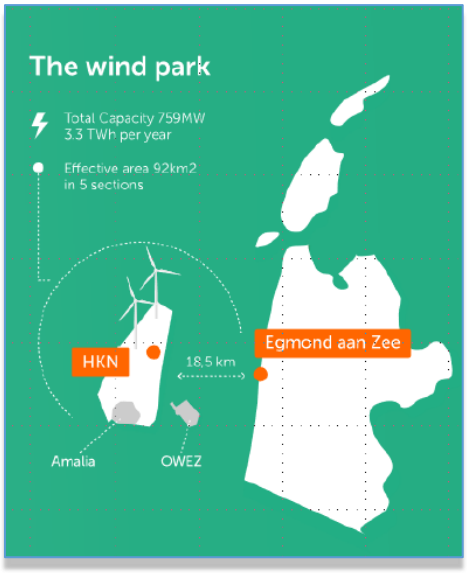


Figure 2 - Wind Park Details

The wind farm will consist of No. 69 x 11.5MW wind turbine generators each to be installed on a dedicated monopile structure. A 70th monopile located on coordinates E 590719.1, N 5841602.3 is reserved for installing the platform accommodating the BLPH. The monopile structure was designed and installed by Van Oord Offshore Wind (VooW) and therefore not part of the BLPH scope.

1.1.2 Project Concept

All components included in the BLPH will be integrated onshore on a topside and installed in an offshore location within the boundaries of the HKN wind farm. At its simplest, the BLPH will store energy during periods of high electricity generation from renewable sources (a wind turbine generator and the floating solar PV farm) and release it during periods of low generation. In practice. It is expected that the energy stored will supplement generation from renewable sources to ensure that at least 1.0MW of power is exported to the electrical grid regardless of wind/solar availability.

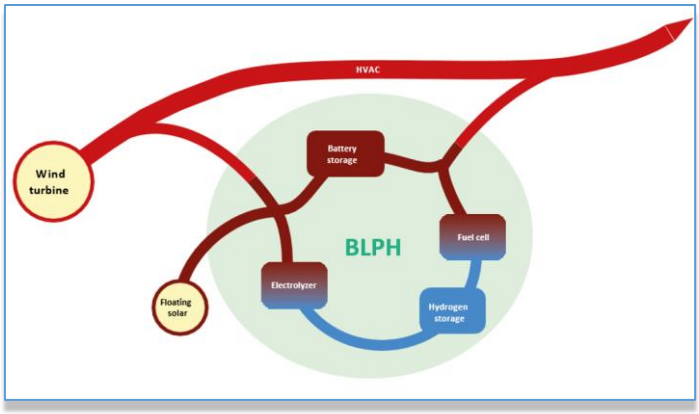


Figure 3 – BLPH Concept

Electricity in the BLPH will be stored in the form of electrons in a battery energy storage system (BESS) as well as converted into green hydrogen via water electrolysis. When the power output from the connecting wind turbine drops to below 1 MWe, the BLPH will return its stored energy to supplement the remaining power output. This will be by discharging the BESS, while stored hydrogen will be converted back into electricity using a fuel cell to extend the discharge duration.

The purpose of the BLPH s to function as a testbed for the integration of energy storage technologies with renewable generation. It is expected that equipment installed on the BLPH will operate as Normally Unmanned Installation for at least two (2) years with no or minimal maintenance and it will have its own independent control room with the ability to communicate with Crosswind's control room.

1.2 DOCUMENT SCOPE

Present Report illustrates the FMECA study for BLPH, focused on the hydrogen circuit which is under the scope of supply of Rosetti Marino.

The main objective of the report is to provide details on following elements:

- Description of the PROJECT and the Battery Limits of the FMECA study.
- Project documents with all the information required to develop the FMECA study:
- Procedure and methodology of the FMECA study, based on this document.
- Results of the FMECA study.

The report includes the complete worksheet for the application of FMECA study to the selected circuit.

2 MAIN REFERENCES

Ref.	Description
[1]	ISO 17776 - Petroleum and natural gas industries – Offshore production installations – Major accident hazard management during the design of new installations
[2]	IEC 60812 "Analysis technique for system reliability – Procedure for failure mode and effects analysis"
[3]	123A90-DDL-PR-PID-80009-80027 – BLPH Piping and Instrumentation Diagrams
[4]	1724000437-PR-PID-00018 – Nitrogen Generation Package Piping and Instrumentation Diagram
[5]	1724000437-PR-PID-00018 – Instrument air Package Piping and Instrumentation Diagram
[6]	123A90-DDL-PP-DL-70070-70072 – BLPH Plot plans
[7]	123A90-DDL-SAF-RE-30006 – HAZOP Report
[8]	123A90-DDL-SAF-RE-30009 – HAZID Report
[9]	123A90-DDL-SAF-DL-30028 – F&G Detectors lay out
[10]	BLPH 3D Model
[11]	1723001756-MAC-MAN-00019 – Instruction and operating manual H2 Storage vessel V-25001 A-F
[12]	OREDA Offshore Reliability Data Hanndbook (5th edition)
[13]	123A90-DDL-MAT-RE-60011 - Materials Selection Report

Table 1 - Reference Documents

3 DEFINITIONS AND ABBREVIATIONS

3.1.1 Definitions

COMPANY or Client (CPY)	Crosswind.
EFFECTS ANALYSIS	The outcome of an identified failure mode. For the purpose of this project, the outcome is identified in terms capability to harm people or environment and to impact on the asset.
EPC CONTRACTOR (CTR)	ROSETTI MARINO S.p.A.
EVENT	Occurrence or change of a particular set of circumstances.
FAILURE MODE	Refers to any specific ways in which a system, component, or process can fail to perform its intended function. For example, in a mechanical system, a failure mode could be something like a component breaking, seizing, or leaking
FMECA	Acronym of "Failure Mode and Effects Criticality Analysis". It's a structured process aimed at identification of potential failure modes of a system, evaluate the consequences or effects of those failures, and assess their criticality or impact on the system's performance.
FREQUENCY	The estimated number of events per defined unit of time (normally refereed to one-year time).
PROJECT	HOLLANDSE KUST NOORD WIND PARK Project

Table 2 - Definitions

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3.1.2 Abbreviations

BESS	Battery Energy Storage System
BLPH	Base Load Power Hub
CPI	Company Provided Items
DNV	Det Norske Veritas
FMECA	Failure Mode and Effects Criticality Analysis
H&MB	Heat and Material Balance
HKN	Hollandse Kust Noord
HSE	Health, Safety and Environment
RM	Rosetti Marino
SCE	Safety Critical Element
TOR	Terms of Reference

Table 3 - Abbreviations

4 METHODOLOGY

4.1 GENERAL PRINCIPLE

FMECA (Failure Mode and Effect Critical Analysis) is a systematic procedure, applied to a specific system, aimed at identifying potential failure modes, their causes, and their criticality or impact on the system's performance.

FMECA is applied to industrial processes in order to identify:

- the effects resulting from the systematic identification of possible different failure modes of each subsystem/component, which could impact the operability and safety of the overall unit;
- the criticalities and weaknesses of the process as results of possible failure modes of components, establishing a priority scale for potential improvement actions.

FMECA study has been developed by using a specific worksheet which were prepopulated by expert analyst and then reviewed and completed by support of a multidisciplinary team represented the project functions (safety, technology, operations, maintenance), ensuring the analysis is comprehensive and effective.

4.2 FMECA DEVELOPMENT

FMECA study on the Crosswind module has been performed according to following main steps:

1. Identification of the elements to be subjected to FMECA study.
2. Analysis of the main failure modes of each selected element and identification of main causes.
3. Evaluation of potential likelihood of the analyzed failure mode.
4. Evaluation of the potential effects of the selected failure on the single element and on the entire system.
5. Identification of the mitigating measures installed in the system to reduce the extent of the effects of the failure.
6. Semi-quantitative assessment of the initial risk associated to each failure mode (not compensated by the mitigating measures) by combination of likelihood estimate and potential impact evaluation.
7. Semi-quantitative assessment of the compensated risk which includes in the evaluation the effectiveness of the available mitigating measures.
8. Identification of possible critical issues and eventual recommendation for improvement.

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4.2.1 Identification of the elements to be subjected to FMECA study

FMECA study will be carried out with reference to the systems included into Rosetti Marino's scope of delivery, which includes:

- BLPH Topside structures.
- Hydrogen production and storage circuit, including all process equipment, piping, instrumentation and control and emergency systems but excluding CPI package (electrolyzers, fuel cells, BESS system).
- Instrument air, nitrogen production circuit and water treatment package.
- Fire and gas detection system.

The failure mode analysis will be applied to the identified SECEs, as reported in:

- Document Number: 123A90-DDL-SAF-RE-30003 "Safety Critical Elements (SCE) and Performance Standard"

This selection is aimed at including the already identified critical elements for the module.

Additional elements included in the control systems which might have a significant impact in case of failure, will be specifically included in the FMECA analysis.

4.2.2 Analysis of the main failure modes of each selected element and identification of main causes

For each element a detailed analysis will be made for the definition of the possible failure modes. These typically include (among others):

- Failure modes leading to loss of capability to perform its design intent;
- Failure modes leading to degradation/loss of mechanical integrity.

4.2.3 Evaluation of potential likelihood of the analyzed failure mode

The likelihood evaluation is performed by application of a simplified approach as detailed in following table.

Likelihood Level	Likelihood Definition
Low (0.1)	The threat-source lacks capability, or controls are in place to prevent, or at least significantly impede, the vulnerability from being determined.
Medium (0.5)	The threat-source is significantly capable, but controls are in place that may impede successful determination of the vulnerability.
High (1.0)	The threat-source is significantly capable and controls to prevent the vulnerability from being determined are ineffective.

Table 4 – General likelihood definition for failure modes

The selected values for the identified failure modes are detailed in following table, on basis of the applied failure likelihood factor.

Likelihood Level	Event
0.1	Corrosion in Stainless Steel piping
	Corrosion in H_2 storage vessel. (refer to note1)
0.2	Manual LO left closed due to misoperation
	Manual LC left open due to misoperation
	ESD activation (fails on demand)
0.3	Valve in stuck position
	Inadequate installation
	External leakage from a gasket/valve seat
	Instrument failure (incorrect reading) as part of a SIF
	Internal leakage (on off valve)
	Manual left closed due to misoperation (fixed at start up)
	Manual left open due to misoperation (fixed at start up)
	Incorrect calibration of PSV set
0.4	Control system (erratic output)
	Loss of instrument air
	Loss of power supply
0.5	Instrument failure (incorrect reading) as part of control loop

Likelihood Level	Event
0.6	No event with such likelihood has been identified in the present analysis
0.7	Internal leakage (control valve)
0.8	No event with such likelihood has been identified in the present analysis
0.9	No event with such likelihood has been identified in the present analysis
1.0	No event with such likelihood has been identified in the present analysis

Table 5 – Detailed likelihood definition for failure modes

Note 1: The storage vessels (made of carbon steel) are externally protected against atmospheric corrosion by a suitable coating system. Since UV radiation can degrade polymer coatings, a UV-resistant paint system has been selected. Possible environmental effects on materials during transport to the site are considered and managed through proper handling, transportation, storage procedures, and appropriate painting. Furthermore, an adequate corrosion allowance has been included in the design. Therefore, considering these protective measures, the fact that the design complies with international standards for the use of carbon steel in hydrogen service, and that corrosion is expected only over a long period compared to the mission time, a corrosion factor value of 0.1 is considered representative also for the storage vessel.

4.2.4 Evaluation of the potential effects of the selected failure on the single element and on the entire system

The evaluation of magnitude of the potential effects is performed by application of a simplified approach as detailed in following table.

Magnitude of Effects	Impact Definition
High (100)	Exercise of the vulnerability: 1) may result in the very costly loss of major tangible assets or resources; 2) may significantly violate, harm, or impede an organization's function, reputation, or interest; 3) may result in human death or serious injury.
Medium (50-90)	Exercise of the vulnerability: 1) may result in the costly loss of tangible assets or resources; 2) may violate, harm, or impede an organization's function, reputation, or interest; 3) may result in human injury.
Low (10-40)	Exercise of the vulnerability: 1) may result in the loss of some tangible assets or resources 2) may noticeably affect an organization's function, reputation, or interest.

Table 6 – General consequence definition for failure modes

The selected values for the identified Impacts are detailed in following table, on basis of the applied failure likelihood factor.

Magnitude of Effects	Impact Definition
10	Not measurable consequences
20	No event with such magnitude effect has been identified in the present analysis
30	Process upset (generic)
40	Total Stop of BLPH production
50	Fire with very limited possibility to escalate (ignition from vent line)
	Total stop of production (depressurized)
	Missed intervention due to alarm failure
60	No event with such magnitude effect has been identified in the present analysis
70	Fire with limited possibility to escalate (ignition from low pressure circuit)
	Loss of positive isolation of the circuit due to valve internal leakage
80	No event with such magnitude effect has been identified in the present analysis
90	No event with such magnitude effect has been identified in the present analysis
100	Fire with significant possibility of escalation

Table 7 – Detailed consequence definition for failure modes

4.2.5 Semi-quantitative assessment of the initial risk associated to each failure mode (not compensated by the mitigating measures) by combination of likelihood estimate and potential impact evaluation

Initial risk (not compensated by the mitigating measures) was performed by application of the following matrix.

Threat	Impact		
Likelihood	Low (10-40)	Medium (50-90)	High 100
High (1.0)	10 x 1.0 = 10	50 x 1.0 = 50	100 x 1.0 = 100
Medium (0.5)	10 x 0.5 = 5	50 x 0.5 = 25	100 x 0.5 = 50
Low (0.1)	10 x 0.1 = 1	50 x 0.1 = 5	100 x 0.1 = 10

Table 8 – Risk Matrix

Classification of the risk is as follows:

- High Risk (red region): action is required for the risk reduction;
- Medium Risk (yellow region): risk is tolerable but further mitigating measure shall be evaluated also on basis of cost-benefit analysis;
- Low Risk (green region): risk is tolerable; continuous improvement area.

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4.2.6 Identification of the mitigating measures installed in the system to reduce the extent of the effects of the failure

The analysis is dedicated to identification of available mitigating measures, specifically designed to mitigate the effects previously identified as consequences of the failure mode.

Measures have been selected as indicated in following table.

Likelihood Level	Mitigating measure
0.1	No mitigation measures with such likelihood level has been identified in the present analysis
0.2	PSV as ultimate safeguard against overpressurization
	SIF to trip the BLPH
	Mechanical device designed for the extent of the impact
0.3	Activation of F&G system
	Design specification
	Pressure test before commissioning
	Process control system capable to regulate the upset
	Procedures for activities with positive isolation with DB manual valves
0.4	No mitigation measures with such likelihood level has been identified in the present analysis
0.5	Periodic inspection of BLPH
	Missed alarm activation

Table 9 – Detailed mitigating for failure modes

Notes to the table:

1) Each mitigation measure shall be designed for the effects under analysis (e.g.: to properly apply mitigation associated to a PSV in case of fire, it is required that the PSV is designed for this scenario).
2) It is suggested to apply a maximum number of two distinct independent mitigation measures as maximum (e.g.: one mechanical plus one procedural measure).
3) Range of variability for mitigating measures based on human intervention to be applied as follows:
   - 0.2 in presence of rigorous procedure, with evidence of training activities and signed records of each activity;
   - 0.5 in presence of less rigorous procedural system.

4.2.7 Semi-quantitative assessment of the compensated risk which includes in the evaluation the effectiveness of the available mitigating measures

After application of mitigating factors, the semi-quantitative risk evaluation has been performed again in order to determine the updated risk level associated to the analysed failure mode.

Risk matrix has been applied again to re-evaluate the classification of the final risk.

4.2.8 Identification of possible critical issues and eventual recommendation for improvement

The failure modes that are classified as High Risk determine a critical case and therefore it is required to determine specific recommendations aimed at risk reduction.

The additional measures shall be selected in same approach of the existing mitigating measures, taking into account following considerations:

- Select, if possible, an additional measure which is of different typology of the existing mitigating measures (if the existing measure is an alarm, it is suggested to recommend a mechanical type of measure and vice versa).
- When possible, select a measure to reduce the likelihood of the failure (thus preventing the occurrence of the scenario) rather than mitigation of the effects of the failure scenario

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5 FMECA STUDY RESULTS

5.1 BASIC ASSUMPTIONS

5.1.1 Analysed elements

FMECA study has been performed on following systems:

- Hydrogen circuit, limited to the section under the responsibility of supply by Rosetti Marino (excluding the Electrolyzer and the Fuel Cell packages) for a total number of analyzed failure modes equal to 96;
- Instrument air and nitrogen circuit (excluding the production packages), for a total number of analyzed failure modes equal to 35;
- Fire and Gas network, for a total number of analyzed failure modes equal to 15.

Specific items have been evaluated as a group, in consideration of the fact that the modalities of failures and the extent of consequences are very similar.

With reference to process equipment, following groups have been analysed:

- Hydrogen storage vessels (V-25001A_F);
- Hydrogen vent KO Drum (V-43001);
- Hydrogen vent (Q-43001).

With reference to process piping element, following groups have been analysed:

- Hydrogen process lines;
- Hydrogen vent lines;
- Hydrogen lines to PSV/BDV;
- Nitrogen connecting line to hydrogen storage vessels;
- Instrument air process lines;
- Nitrogen production and distribution lines;
- Nitrogen production and distribution to vent header;
- Nitrogen line to PSV

With reference to other process systems, following groups have been analysed:

- PSVs;
- BDVs;
- ESD circuit (including sensors, logic solvers and actuators);

- ON-off operating valves;
- Control systems (including sensors, DCS and actuators);
- Alarms;
- Specific systems (e.g.: liquid guard in hydrogen vent Q-43001).

With reference to F&G network, following groups have been analysed:

- Gas detectors (including ultrasonic and point source);
- Fire detectors (including UV-IR).

The detailed worksheet is reported in Attachment 1 of present document.

5.1.2 Analysed failure modes

The typology of failure mode for each element have been selected from international reference [12], selecting the most appropriated for the typology of platform (unmanned and offshore).

Each element has been analysed with reference to following main failure modes:

- Mechanical integrity;
- Internal leakage;
- Fault;
- Blockage/plugged;
- Deteriorated;
- Incorrect position (for valves);
- Stuck (for valves).

Other typologies of failure modes have been applied for specific cases, as indicated in the worksheets.

5.2 MAIN RESULTS – HYDROGEN CIRCUIT

Following paragraphs illustrate the synthetic results of Risk Matrix application on the several failure calculated failure modes associated with hydrogen circuit.

5.2.1 Calculated values

The representation of calculated results is reported in following picture or the figure. The horizontal axis reports the number associated to each "failure mode" as reported in the FMECA worksheet.

The graph area is divided into three regions, representing the different risk levels.

The blue curve represents the initial risk while the green curve represents the compensated risk for each failure mode.

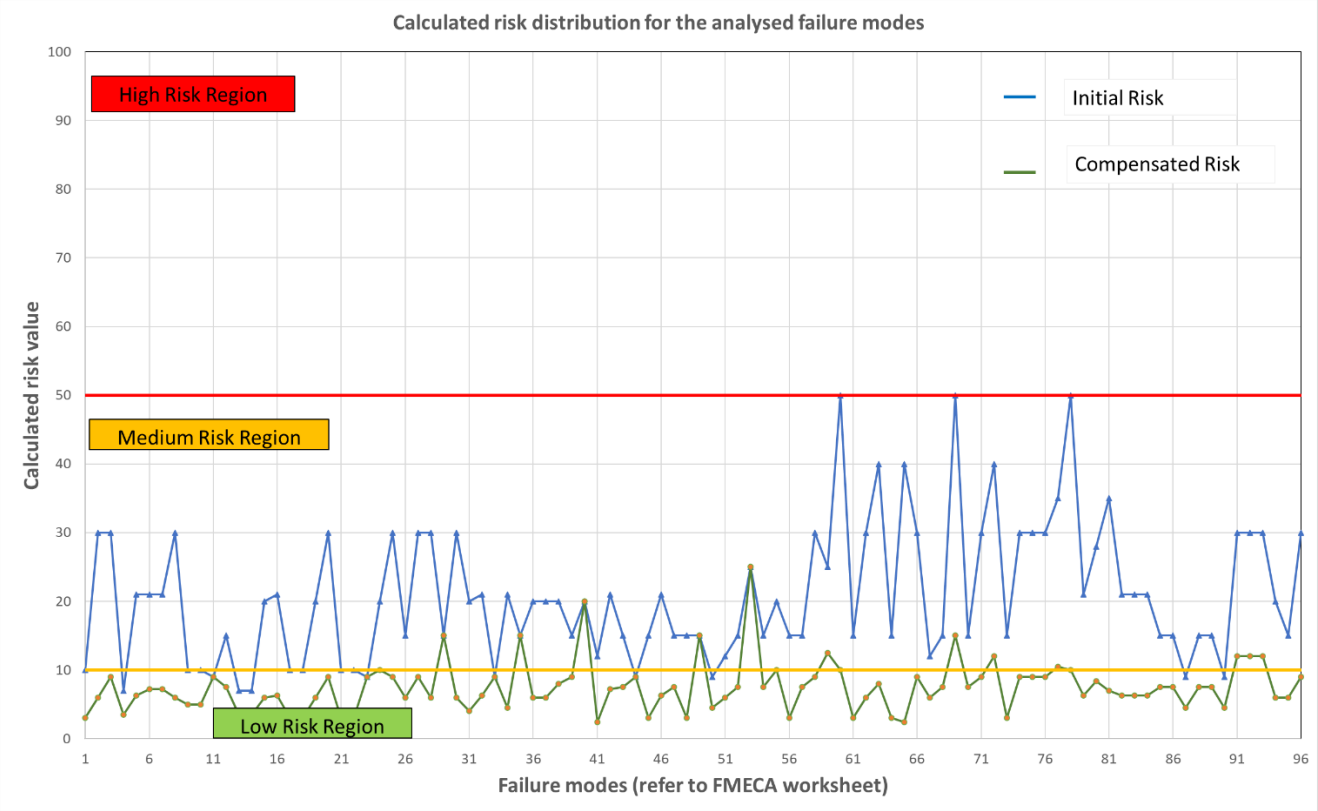


Figure 4 Calculated risk for hydrogen circuit

On the basis of the represented results, following considerations apply:

- the calculated initial risk is mainly located in the "medium risk" region, in consideration of the presence of several scenarios which can determine severe impact on the platform (above 70) and which lead to a medium initial risk;
- the calculated compensated risk is mainly located in the "low risk" region, in consideration of the fact that the installed mitigating measures can provide suitable support to manage the risk in the less dangerous region;
- there are some cases (16 overall, including 6 cases in which the value is exactly 10, located on the border line) in which the green curve of compensated risk is inside the "medium risk" region; this result leads to the consideration that for such identified failure modes, it is possible to identify further actions aimed at reducing the calculated risk to the "low risk" region.

5.2.2 Final considerations on hydrogen circuit

The analysis of hydrogen circuit has mainly identified failure mode scenarios classified into the Low Risk Region in terms of compensated risk. This result can confirm that the design of the platform is suitable to manage the potential failures that could happen in the process circuit containing hydrogen.

Main elements that can support the calculated results are the following:

- Use of stainless steel for the whole hydrogen circuit which can guarantee an effective barrier against risks of internal or external corrosion (which might be initial cause of potential loss of containment of hydrogen);
- Availability of ESD systems associated with selected process parameter deviations;
- Availability of extensive network of F&G detection which can provide immediate interaction to shut down the plant in safe way in case of revealed gas or fire detection;
- Availability of hydrogen vent system which can provide dispersion of hydrogen (also in case of plant depressurization) at high point and with minor impact in terms of radiation to the platform in case of vented gas ignition.

There are some failure modes scenarios which might lead to a compensated risk classified as medium inside the "medium risk" region. On these scenarios, specific considerations apply, as detailed in following paragraphs.

1. HAZOP Recommendations cases

For most identified case of "medium risk", the classification is due to process risks which have already been analysed with HAZOP technique and for which specific HAZOP recommendations have already been set. Therefore, follow up on these HAZOP actions can guarantee the risk reduction also in the FMECA study.

2. Initiators for hydrogen circuit depressurization

BLPH depressurization can be achieved by following failure mode:

- Spurious activation of 25-PT-002, 25-PT-004, 25-PT-006, 25-PT-008, 25-PT-009, 25-PT-011, 25-PT-012 to activate ESD1D due to high high pressure in each hydrogen storage vessel 25-V-25001A/F (total hydrogen circuit depressurization)
- Spurious opening of 25-BDV-003, 25-BDV-005, 25-BDV-007, 25-BDV-010, 25-BDV-013, 25-BDV-016, 25-BDV-019, 25-BDV-022 on the hydrogen circuit (single hydrogen section depressurization).

BLPH hydrogen circuit depressurization (partial or total) can cause significant impact on operation due to complete stop of production and loss of product. Moreover, the depressurization could determine the formation of a jet fire over the hydrogen vent, in case of ignition of released gas from hydrogen circuit. It is important to specify the following elements:

- the hydrogen vent is designed in such a way to minimize the impact in terms of radiation level to process equipment and shall not have particular concern on the personnel since the platform is unmanned;
- in case of spurious trip, the hydrogen circuit is already in ESD1 and ESD1, therefore the circuit shall be isolated and stopped leading to a limited release of flammable gas from the vent.

In any case, for sake of completeness, it was decided to classify the event as potentially significant for the platform.

Missing a possible redundancy in the circuit (e.g.: depressurization is activated by single PT on single hydrogen vessel) the final calculated result is in the "medium risk".

However, as final consideration, being the platform unmanned and being the potential consequences in case of missed depressurization potentially catastrophic (fire, escalation, explosion), the final evaluation is to keep the design as is and accept the residual risk on the failure mode of spurious depressurization.

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5.3 MAIN RESULTS – Instrument air and Nitrogen

Following paragraphs illustrate the synthetic results of Risk Matrix application on the several failure calculated failure modes associated with Instrument Air and Nitrogen distribution circuit.

5.3.1 Calculated values

The representation of calculated results is reported in following picture or the figure. The horizontal axis reports the number associated to each "failure mode" as reported in the FMECA worksheet.

The graph area is divided into three regions, representing the different risk levels.

The blue curve represents the initial risk while the green curve represents the compensated risk for each failure mode.

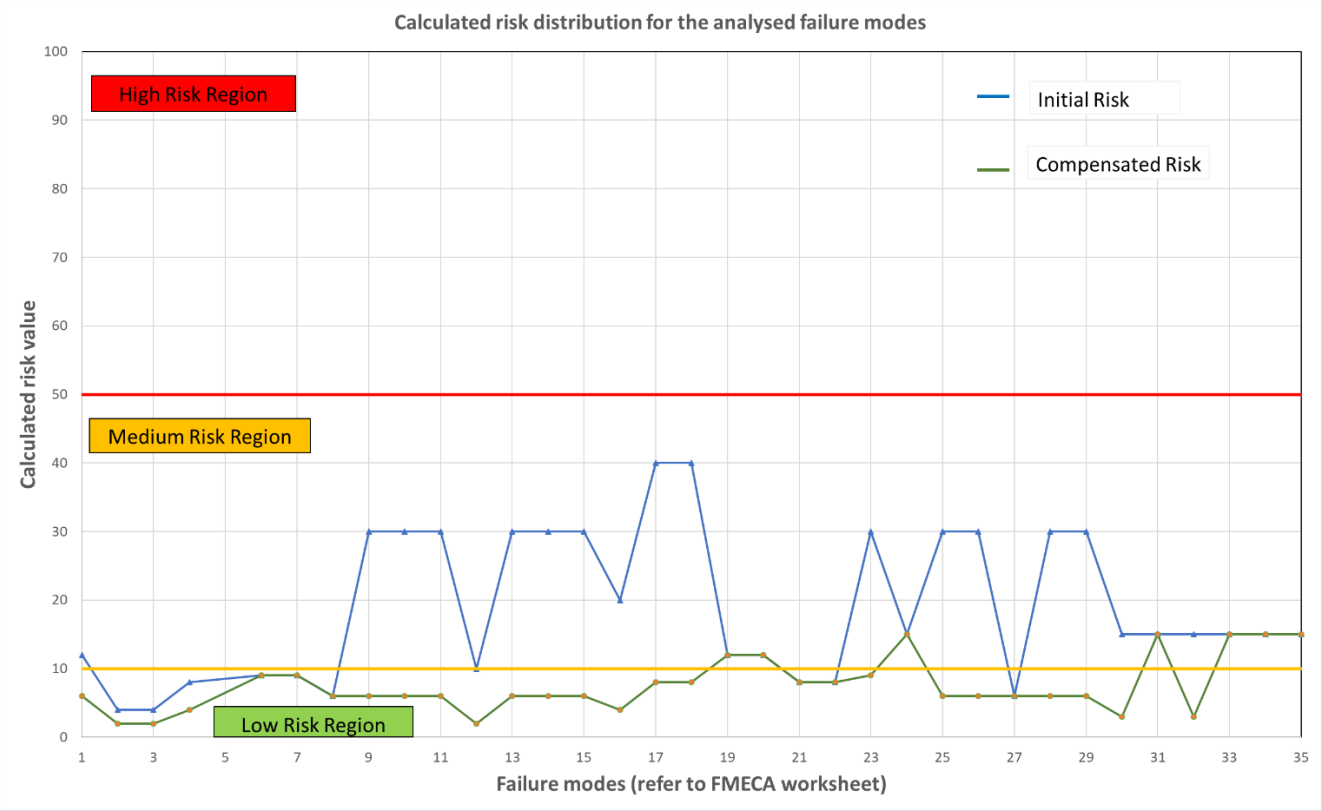


Figure 5 Calculated risk for Instrument Air and Nitrogen circuit

On the basis of the represented results, following considerations apply:

- the calculated initial risk is mainly located in the "medium risk" region, in consideration of the presence of a not negligible number of scenarios which can determine severe impact on the platform (above 70) and which lead to a medium initial risk;
- the calculated compensated risk is mainly located in the "low risk" region, in consideration of the fact that the installed mitigating measures can provide suitable support to manage the risk in the less dangerous region;
- there are some cases (7 overall, with maximum value equal to 15, very close to border with low risk region) in which the green curve of compensated risk is inside the "medium risk" region; this result leads to the consideration that for such identified failure modes, it is possible to identify further actions aimed at reducing the calculated risk to the "low risk" region.

5.3.2 Final considerations on Instrument Air and Nitrogen circuit

The analysis of Instrument Air and Nitrogen circuit has mainly identified failure mode scenarios classified into the Low Risk Region in terms of compensated risk. This result can confirm that the design of the platform is suitable to manage the potential failures that could occur in these vital utilities circuit.

Main elements that can support the calculated results are the following:

- Availability of ESD systems associated with selected process parameter deviations which can guarantee to lead the plant in safe conditions.

There are some failure modes scenarios which might lead to a compensated risk classified as medium inside the "medium risk" region. On these scenarios, specific considerations apply, as detailed in following paragraphs.

1. Initiators determining process upset or process shut down

In six out of the seven identified failure modes for "medium risk", the consequences are mainly associated to process upset or to complete hydrogen circuit shut down. In these cases, there are no direct safety consequences, therefore the calculated "medium risk" is relevant to economic/operability concerns.

2. Initiators for hydrogen circuit depressurization

BLPH depressurization can be achieved by a failure mode linked to spurious activation of 64-PT-002 to activate ESD1D due to low low pressure in nitrogen production header (total hydrogen circuit depressurization).

BLPH hydrogen circuit depressurization can cause significant impact on operation due to complete stop of production and loss of product. Moreover, the depressurization could determine the formation of a jet fire over the hydrogen vent, in case of ignition of released gas from hydrogen circuit.

It is important to specify the following elements:

- the hydrogen vent is designed in such a way to minimize the impact in terms of radiation level to process equipment and shall not have particular concern on the personnel since the platform is unmanned;
- in case of spurious trip, the hydrogen circuit is already in ESD1 and ESD1D, therefore the circuit shall be isolated and stopped leading to a limited release of flammable gas from the vent.

In any case, for sake of completeness, it was decided to classify the event as potentially significant for the platform.

Missing a possible redundancy in the circuit (e.g.: depressurization is activated by single PT on nitrogen production header) the final calculated result is in the "medium risk".

However, as final consideration, being the platform unmanned and being the potential consequences in case of missed depressurization potentially catastrophic (fire, escalation, explosion), the final evaluation is to keep the design as is and accept the residual risk on the failure mode of spurious depressurization.

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5.4 MAIN RESULTS – F&G network

Following paragraphs illustrate the synthetic results of Risk Matrix application on the several failure calculated failure modes associated with F&G network.

5.4.1 Calculated values

The representation of calculated results is reported in following picture or the figure. The horizontal axis reports the number associated to each "failure mode" as reported in the FMECA worksheet.

The graph area is divided into three regions, representing the different risk levels.

The blue curve represents the initial risk while the green curve represents the compensated risk for each failure mode.

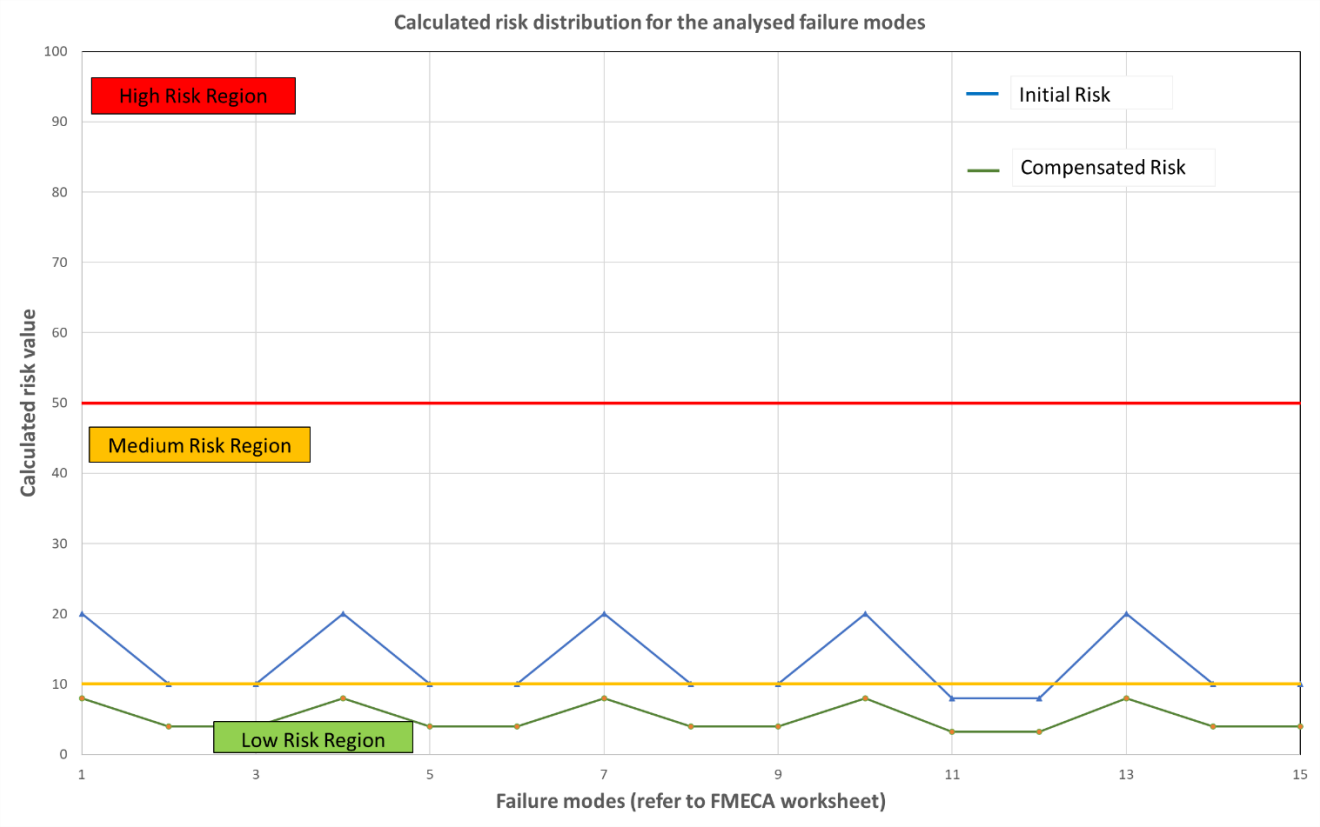


Figure 6 Calculated risk for F&G network

On the basis of the represented results, following considerations apply:

- the calculated initial risk is mainly located in the "medium risk" region, in consideration of the presence of a not negligible number of scenarios which can determine severe impact on the platform (above 70) and which lead to a medium initial risk;
- the calculated compensated risk is fully located in the "low risk" region, in consideration of the fact that the installed mitigating measures can provide suitable support to manage the risk in the less dangerous region;
- in particular, the mitigating action is provided by the following elements:
    - availability of redundant configuration of the F&G network, covering different areas, all with redundant detectors;
    - availability of ultrasonic gas detection systems which can provide a wide capability to detect high pressure and highly directional gas jets;
    - the design philosophy aimed at selection of SIL 2 certified Fire and gas detection which provide an important level of reliability of the network.

5.4.2 Final considerations on Instrument F&G network

From the calculated results, it is possible to conclude that the design of F&G network for the unmanned BPLH represent a robust and reliable system to protect the BLPH in case of unexpected gas release or fire occurrence in the platform.

No additional considerations are derived from present study, unless the issue to properly perform the required tests and maintenance activities on the sensor to guarantee the respect of the designed level of integrity for the F&G network.

id	System	Element	Typology	Failure mode	Effects analysis	Original Threat Likelihood	Original Impact	Result	Risk Rating	Mitigating Measures	Mitigating Measures likelihood	Threat Likelihood	Impact	Mitigated Result	Mitigated Risk Rating	Recommendations	Notes
1	Hydrogen storage vessels	Pressure vessel V-25001A-F	Mechanical Integrity	Corrosion issue on the shell of the vessel (low expected likelihood due to vessel desing and mission time).	Possible, in long term, loss of mechanical integrity and consequent loss of containment with release of hydrogen and fire with release of hydrogen and jet fire in case of ignition, with potential escalation and extensive damage to the structure	0.1	100	10	Medium	1. F&G system with automatic isolation of the hydrogen circuit	0.3	0.03	100	3	Low		
2	Hydrogen storage vessels	Pressure vessel V-25001A-F	Mechanical Integrity	Leak from a gasket on flanged joint	Loss of containment with release of hydrogen and fire with release of hydrogen and jet fire in case of ignition, with potential escalation and extensive damage to the structure	0.3	100	30	Medium	1. Design specification and installation procedure 2. Pressure test during pre-commissioning 3. F&G system with automatic isolation of the hydrogen circuit	0.2	0.06	100	6	Low		
3	Hydrogen storage vessels	Pressure vessel V-25001A-F	Mechanical Integrity	Loss of mechanical integrity of the vessel due to incorrect design or incorrect installation	Loss of containment with release of hydrogen and fire with release of hydrogen and jet fire in case of ignition, with potential escalation and extensive damage to the structure	0.3	100	30	Medium	1. Pressure test during pre-commissioning 2. F&G system with automatic isolation of the hydrogen circuit	0.3	0.09	100	9	Low		
4	Hydrogen storage vessels	Hydrogen vent KO Drum V-43001	Mechanical Integrity	Corrosion issue on the shell of the vessel (low expected likelihood due to use of stainless steel)	Possible, in long term, loss of mechanical integrity and consequent loss of containment with release of hydrogen and fire in case of ignition, with limited possibility of escalation and extensive damage to the structure, due to low pressure system	0.1	70	7	Low	1. Periodic Inspection 2. F&G system with automatic isolation of the hydrogen circuit	0.5	0.05	70	3.5	Low		
5	Hydrogen storage vessels	Hydrogen vent KO Drum V-43001	Mechanical Integrity	Leak from a gasket on flanged joint	Loss of containment with release of hydrogen and fire with release of hydrogen and fire in case of ignition, with limited possibility of escalation and extensive damage to the structure, due to low pressure system	0.3	70	21	Medium	1. Design specification and installation procedure 2. Pressure test during pre-commissioning 3. F&G system with automatic isolation of the hydrogen circuit	0.3	0.09	70	6.3	Low		
6	Hydrogen storage vessels	Hydrogen vent KO Drum V-43001	Mechanical Integrity	Loss of mechanical integrity of the vessel due to incorrect design or incorrect installation	Loss of containment with release of hydrogen and fire with release of hydrogen and fire in case of ignition, with limited possibility of escalation and extensive damage to the structure, due to low pressure system	0.3	70	21	Medium	1. Pressure test during pre-commissioning 2. F&G system with automatic isolation of the hydrogen circuit	0.3	0.09	80	7.2	Low		
7	Hydrogen storage vessels	Hydrogen vent Q-43001	Mechanical Integrity	Loss of mechanical integrity of the vessel due to incorrect design or incorrect installation	Loss of containment with release of hydrogen and fire with release of hydrogen and fire in case of ignition, with limited possibility of escalation and extensive damage to the structure, due to low pressure system	0.3	70	21	Medium	1. Pressure test during pre-commissioning 2. F&G system with automatic isolation of the hydrogen circuit	0.3	0.09	80	7.2	Low		
8	Piping system	**Hydrogen process line** (1"-HY-007-03HSS-N, 1"-HY-015-03HSS-N, 1"-HY-016-03HSS-N, 1"-HY-017-03HSS-N, 1"-HY-018-03HSS-N, 1"-HY-019-03HSS-N, 1"-HY-020-03HSS-N, 1"-HY-143-03HSS-N, 1"-HY-026-03HSS-N, 1"-HY-132-03HSS-N, 1"-HY-133-03HSS-N, 1"-HY-134-03HSS-N, 1"-HY-135-03HSS-N, 1"-HY-136-03HSS-N, 1 1/2"-HY-148-03HSS-N, 2"-HY-023-03HSS-N)	Mechanical Integrity	Leak from a gasket on flanged joint	Loss of containment with release of hydrogen and fire with release of hydrogen and jet fire in case of ignition, with potential escalation and extensive damage to the structure	0.3	100	30	Medium	1. Design specification and installation procedure 2. Pressure test during pre-commissioning 3. F&G system with automatic isolation of the hydrogen circuit	0.2	0.06	100	6	Low		
9	Piping system	**Hydrogen process line** (1"-HY-007-03HSS-N, 1"-HY-015-03HSS-N, 1"-HY-016-03HSS-N, 1"-HY-017-03HSS-N, 1"-HY-018-03HSS-N, 1"-HY-019-03HSS-N, 1"-HY-020-03HSS-N, 1"-HY-143-03HSS-N, 1"-HY-026-03HSS-N, 1"-HY-132-03HSS-N, 1"-HY-133-03HSS-N, 1"-HY-134-03HSS-N, 1"-HY-135-03HSS-N, 1"-HY-136-03HSS-N, 1 1/2"-HY-148-03HSS-N, 2"-HY-023-03HSS-N)	Mechanical Integrity	External corrosion issue on the piping (low expected likelihood due to use of stainless steel)	Possible, in long term, loss of containment with release of hydrogen and jet fire in case of ignition, with potential escalation and extensive damage to the structure	0.1	100	10	Medium	1. Pressure test during pre-commissioning 2. F&G system with automatic isolation of the hydrogen circuit	0.5	0.05	100	5	Low		
10	Piping system	**Hydrogen process line** (1"-HY-007-03HSS-N, 1"-HY-015-03HSS-N, 1"-HY-016-03HSS-N, 1"-HY-017-03HSS-N, 1"-HY-018-03HSS-N, 1"-HY-019-03HSS-N, 1"-HY-020-03HSS-N, 1"-HY-143-03HSS-N, 1"-HY-026-03HSS-N, 1"-HY-132-03HSS-N, 1"-HY-133-03HSS-N, 1"-HY-134-03HSS-N, 1"-HY-135-03HSS-N, 1"-HY-136-03HSS-N, 1 1/2"-HY-148-03HSS-N, 2"-HY-023-03HSS-N)	Mechanical Integrity	Internal corrosion issue on the piping (low expected likelihood due to use of stainless steel)	Possible, in long term, loss of containment with release of hydrogen and jet fire in case of ignition, with potential escalation and extensive damage to the structure	0.1	100	10	Medium	1. Pressure test during pre-commissioning 2. F&G system with automatic isolation of the hydrogen circuit	0.5	0.05	100	5	Low		
11	Piping system	**Hydrogen process line** (1"-HY-007-03HSS-N, 1"-HY-015-03HSS-N, 1"-HY-016-03HSS-N, 1"-HY-017-03HSS-N, 1"-HY-018-03HSS-N, 1"-HY-019-03HSS-N, 1"-HY-020-03HSS-N, 1"-HY-143-03HSS-N, 1"-HY-026-03HSS-N, 1"-HY-132-03HSS-N, 1"-HY-133-03HSS-N, 1"-HY-134-03HSS-N, 1"-HY-135-03HSS-N, 1"-HY-136-03HSS-N, 1 1/2"-HY-148-03HSS-N, 2"-HY-023-03HSS-N)	Blockage/plugged	Manual valve in the hydrogen process line left closed due to misoperation (fixed at start up and then the position will be kept since the platform is unmanned)	Stop of hydrogen flow leading to stop of production and process upset	0.3	30	9	Low		1	0.3	30	9	Low		
12	Piping system	**Hydrogen vent line** (2"-VL-003-01HSS-N, 1"-VL-143-01HSS-N, 4"-VL-145-01HSS-N, 4"-VL-025-01HSS-N, 4"-VL-068-01HSS-N, 4"-VL-111-01HSS-N, 4"-VL-172-01HSS-N, 4"-VL-112-01HSS-N, 4"-VL-176-01HSS-N, 4"-VL-113-01HSS-N, 4"-VL-181-01HSS-N, 4"-VL-114-01HSS-N, 4"-VL-185-01HSS-N, 4"-VL-115-01HSS-N, 1"-VL-022-01HSS-N, 1"-VL-010-01HSS-N, 8"-VL-116-01HSS-N, 8"-VL-117-01HSS-N)	Mechanical Integrity	Leak from a gasket on flanged joint	Loss of containment only in case of hydrogen routed to vent line with potential fire but limited possibility of escalation due to low operating pressure in the circuit.	0.3	50	15	Medium	1. Design specification and installation procedure 2. Pressure test during pre-commissioning 3. F&G system with automatic isolation of the hydrogen circuit	0.5	0.15	50	7.5	Low		

id	System	Element	Typology	Failure mode	Effects analysis	Original Threat Likelihood	Original Impact	Result	Risk Rating	Mitigating Measures	Mitigating Measures likelihood	Threat Likelihood	Impact	Mitigated Result	Mitigated Risk Rating	Recommendations	Notes
13	Piping system	**Hydrogen vent line** (2"-VL-003-01HSS-N, 1"-VL-143-01HSS-N, 4"-VL-145-01HSS-N, 4"-VL-025-01HSS-N, 4"-VL-068-01HSS-N, 4"-VL-111-01HSS-N, 4"-VL-172-01HSS-N, 4"-VL-112-01HSS-N, 4"-VL-176-01HSS-N, 4"-VL-113-01HSS-N, 4"-VL-181-01HSS-N, 4"-VL-114-01HSS-N, 4"-VL-185-01HSS-N, 4"-VL-115-01HSS-N, 1"-VL-022-01HSS-N, 1"-VL-010-01HSS-N)	Mechanical Integrity	External corrosion issue on the piping (low expected likelihood due to use of stainless steel)	Loss of containment only in case of hydrogen routed to vent line with potential fire but limited possibility of escalation due to low operating pressure in the circuit.	0.1	70	7	Low	1. Design specification and installation procedure 2. Pressure test during pre-commissioning 3. F&G system with automatic isolation of the hydrogen circuit	0.5	0.05	70	3.5	Low		
14	Piping system	**Hydrogen vent line** (2"-VL-003-01HSS-N, 1"-VL-143-01HSS-N, 4"-VL-145-01HSS-N, 4"-VL-025-01HSS-N, 4"-VL-068-01HSS-N, 4"-VL-111-01HSS-N, 4"-VL-172-01HSS-N, 4"-VL-112-01HSS-N, 4"-VL-176-01HSS-N, 4"-VL-113-01HSS-N, 4"-VL-181-01HSS-N, 4"-VL-114-01HSS-N, 4"-VL-185-01HSS-N, 4"-VL-115-01HSS-N, 1"-VL-022-01HSS-N, 1"-VL-010-01HSS-N)	Mechanical Integrity	Internal corrosion issue on the piping (low expected likelihood due to use of stainless steel)	Loss of containment only in case of hydrogen routed to vent line with potential fire but limited possibility of escalation due to low operating pressure in the circuit.	0.1	70	7	Low	1. Design specification and installation procedure 2. Pressure test during pre-commissioning 3. F&G system with automatic isolation of the hydrogen circuit	0.5	0.05	70	3.5	Low		
15	Piping system	**Hydrogen vent line** (2"-VL-003-01HSS-N, 1"-VL-143-01HSS-N, 4"-VL-145-01HSS-N, 4"-VL-025-01HSS-N, 4"-VL-068-01HSS-N, 4"-VL-111-01HSS-N, 4"-VL-172-01HSS-N, 4"-VL-112-01HSS-N, 4"-VL-176-01HSS-N, 4"-VL-113-01HSS-N, 4"-VL-181-01HSS-N, 4"-VL-114-01HSS-N, 4"-VL-185-01HSS-N, 4"-VL-115-01HSS-N, 1"-VL-022-01HSS-N, 1"-VL-010-01HSS-N)	Blockage/plugged	Manual valve in the hydrogen process line left closed due to misoperation (LO)	Unavailability of vent line leading to possible overpressurization of the hydrogen circuit and potential jet fire and extensive escalation on the platform.	0.2	100	20	Medium	1. F&G system with automatic isolation of the hydrogen circuit	0.3	0.06	100	6	Low		
16	Piping system	**Hydrogen line to PSV/BDV** (1"-HY-024-01HSS-N, 3"-HY-142-01HSS-N, 1"-HY-166-01HSS-N, 3"-HY-167-01HSS-N, 1"-HY-170-01HSS-N, 3"-HY-171-01HSS-N, 1"-HY-174-01HSS-N, 3"-HY-175-01HSS-N, 1"-HY-179-01HSS-N, 3"-HY-180-01HSS-N, 1"-HY-183-01HSS-N, 3"-HY-184-01HSS-N, 1"-HY-144-01HSS-N, 1"-HY-152-01HSS-N, 1"-HY-163-01HSS-N)	Mechanical Integrity	Leak from a gasket on flanged joint	Loss of containment only in case of hydrogen routed to vent line with potential fire but limited possibility of escalation due to position of vent line.	0.3	70	21	Medium	1. Design specification and installation procedure 2. Pressure test during pre-commissioning 3. F&G system with automatic isolation of the hydrogen circuit	0.3	0.09	70	6.3	Low		
17	Piping system	**Hydrogen line to PSV/BDV** (1"-HY-024-01HSS-N, 3"-HY-142-01HSS-N, 1"-HY-166-01HSS-N, 3"-HY-167-01HSS-N, 1"-HY-170-01HSS-N, 3"-HY-171-01HSS-N, 1"-HY-174-01HSS-N, 3"-HY-175-01HSS-N, 1"-HY-179-01HSS-N, 3"-HY-180-01HSS-N, 1"-HY-183-01HSS-N, 3"-HY-184-01HSS-N, 1"-HY-144-01HSS-N, 1"-HY-152-01HSS-N, 1"-HY-163-01HSS-N)	Mechanical Integrity	External corrosion issue on the piping (low expected likelihood due to use of stainless steel)	Loss of containment and potential jet fire and extensive escalation on the platform.	0.1	100	10	Medium	1. Pressure test during pre-commissioning 2. F&G system with automatic isolation of the hydrogen circuit	0.3	0.03	100	3	Low		
18	Piping system	**Hydrogen line to PSV/BDV** (1"-HY-024-01HSS-N, 3"-HY-142-01HSS-N, 1"-HY-166-01HSS-N, 3"-HY-167-01HSS-N, 1"-HY-170-01HSS-N, 3"-HY-171-01HSS-N, 1"-HY-174-01HSS-N, 3"-HY-175-01HSS-N, 1"-HY-179-01HSS-N, 3"-HY-180-01HSS-N, 1"-HY-183-01HSS-N, 3"-HY-184-01HSS-N, 1"-HY-144-01HSS-N, 1"-HY-152-01HSS-N, 1"-HY-163-01HSS-N)	Mechanical Integrity	Internal corrosion issue on the piping (low expected likelihood due to use of stainless steel)	Loss of containment and potential jet fire and extensive escalation on the platform.	0.1	100	10	Medium	1. Pressure test during pre-commissioning 2. F&G system with automatic isolation of the hydrogen circuit	0.3	0.03	100	3	Low		
19	Piping system	**Hydrogen line to PSV/BDV** (1"-HY-024-01HSS-N, 3"-HY-142-01HSS-N, 1"-HY-166-01HSS-N, 3"-HY-167-01HSS-N, 1"-HY-170-01HSS-N, 3"-HY-171-01HSS-N, 1"-HY-174-01HSS-N, 3"-HY-175-01HSS-N, 1"-HY-179-01HSS-N, 3"-HY-180-01HSS-N, 1"-HY-183-01HSS-N, 3"-HY-184-01HSS-N, 1"-HY-144-01HSS-N, 1"-HY-152-01HSS-N, 1"-HY-163-01HSS-N)	Blockage/plugged	Manual valve in the hydrogen PSV/BDV lines left closed due to misoperation (LO)	Unavailability of vent line when needed leading to overpressurization and potential for mechanical damage, loss of containment, hydrogen release and fire with potential for escalation	0.2	100	20	Medium	1. F&G system with automatic isolation of the hydrogen circuit	0.3	0.06	100	6	Low		
20	Piping system	**N2 connecting line to hydrogen storage vessels** (1"-HY-153-01HSS-N, 1"-HY-186-01HSS-N, 1"-HY-187-01HSS-N, 1"-HY-188-01HSS-N, 1"-HY-189-01HSS-N, 1"-HY-190-01HSS-N)	Mechanical Integrity	Leak from a gasket on flanged joint connected to hydrogen circuit	Loss of containment and potential jet fire and extensive escalation on the platform.	0.3	100	30	Medium	1. Design specification and installation procedure 2. Pressure test during pre-commissioning 3. F&G system with automatic isolation of the hydrogen circuit	0.3	0.09	100	9	Low		
21	Piping system	**N2 connecting line to hydrogen storage vessels** (1"-HY-153-01HSS-N, 1"-HY-186-01HSS-N, 1"-HY-187-01HSS-N, 1"-HY-188-01HSS-N, 1"-HY-189-01HSS-N, 1"-HY-190-01HSS-N)	Mechanical Integrity	External corrosion issue on the piping low expected likelihood due to use of stainless steel)	Loss of containment and potential jet fire and extensive escalation on the platform.	0.1	100	10	Medium	1. Design specification and installation procedure 2. Pressure test during pre-commissioning 3. F&G system with automatic isolation of the hydrogen circuit	0.3	0.03	100	3	Low		
22	Piping system	**N2 connecting line to hydrogen storage vessels** (1"-HY-153-01HSS-N, 1"-HY-186-01HSS-N, 1"-HY-187-01HSS-N, 1"-HY-188-01HSS-N, 1"-HY-189-01HSS-N, 1"-HY-190-01HSS-N)	Mechanical Integrity	Internal corrosion issue on the piping (low expected likelihood due to use of stainless steel)	Loss of containment and potential jet fire and extensive escalation on the platform.	0.1	100	10	Medium	1. Design specification and installation procedure 2. Pressure test during pre-commissioning 3. F&G system with automatic isolation of the hydrogen circuit	0.3	0.03	100	3	Low		
23	Piping system	**N2 connecting line to hydrogen storage vessels** (1"-HY-153-01HSS-N, 1"-HY-186-01HSS-N, 1"-HY-187-01HSS-N, 1"-HY-188-01HSS-N, 1"-HY-189-01HSS-N, 1"-HY-190-01HSS-N)	Blockage/plugged	Manual valve in the nitrogen blanketing line left closed due to misoperation (fixed at start up and consequently the BLPH is unmanned)	Unavailability of nitrogen line when needed with delay in operations and process upset	0.3	30	9	Low		1	0.3	30	9	Low		

id	System	Element	Typology	Failure mode	Effects analysis	Original Threat Likelihood	Original Impact	Result	Risk Rating	Mitigating Measures	Mitigating Measures likelihood	Threat Likelihood	Impact	Mitigated Result	Mitigated Risk Rating	Recommendations	Notes
24	Pressure Safety Valves	25-PSV-001A/F (on hydrogen storage vessels V-25001A/F)	Internal Leakage	Incorrect calibration of Pressure Safety Valve	Leaking of process hydrogen to vent line leading to hydrogen release to atmosphere. Possible jet fire in case of ignition. The extent of damage is very limited since the hydrogen circuit vent line is located in safe position in terms of radiation levels to process equipment and the platform is normally unmanned.	0.4	50	20	Medium	1. Design specification and installation procedure 2. High flow alarm FAH001 on hydrogen vent line to stack	0.5	0.2	50	10	Medium		
25	Pressure Safety Valves	25-PSV-001A/F (on hydrogen storage vessels V-25001A/F)	Unavailability at correct set point	Incorrect calibration of Pressure Safety Valve	Possible overpressurization in the process circuit due to unavailability of PSV at the required set pressure, leading to overpressurizazion of hydrogen circuit, potential mechanical damage and with release of hydrogen and fire with potential escalation and extensive damage to the structure	0.3	100	30	Medium	1. Design specification and installation procedure 3. Availability of 25-PIC-005/007/010/013/016/019 on hydrogen storage vessels V-25001A/F to regulate pressure within design values	0.3	0.09	100	9	Low		
26	Pressure Safety Valves	80-PSV-001 (on hydrogen storage vessels V-25001A/F)	Internal Leakage	Incorrect calibration of Pressure Safety Valve	Leaking of process hydrogen to vent line leading to hydrogen release to atmosphere. Possible jet fire in case of ignition. The extent of damage is minimum since the hydrogen circuit vent line is located in safe position in terms of radiation levels to process equipment and the platform is normally unmanned.	0.3	50	15	Medium	1. Design specification and installation procedure 2. PSV calibration before installation. 3. High flow alarm FAH001 on hydrogen vent line to stack	0.2	0.06	100	6	Low		
27	Pressure Safety Valves	80-PSV-001 (on hydrogen storage vessels on outlet line of V-25001A/F)	Unavailability at correct set point	Incorrect calibration of Pressure Safety Valve	Possible overpressurization in the process circuit due to unavailability of PSV at the required set pressure, leading to overpressurizazion of hydrogen circuit, potential mechanical damage and with release of hydrogen and fire with potential escalation and extensive damage to the structure	0.3	100	30	Medium	1. Design specification and installation procedure 2. F&G system with automatic isolation of the hydrogen circuit	0.3	0.09	100	9	Low		
28	Emergency Shut Down Systems	**Pressure Transmitter for V-25001A/F high high pressure** (25-PT-002, 25-PT-004, 25-PT-006, 25-PT-008, 25-PT-009, 25-PT-011, 25-PT-012)	Fault	Instrument Failure (reading lower value than real)	Fault pressure measure leading to unavailability of trip for high high pressure which could result (in case of demand) to potential mechanical damage and with release of hydrogen and fire with potential escalation and extensive damage to the structure	0.3	100	30	Medium	1. Availability of 25-PSV-001A/F (on hydrogen storage vessels V-25001A/F) for ultimate protection against high pressure	0.2	0.06	100	6	Low		
29	Emergency Shut Down Systems	**Pressure Transmitter for V-25001A/F high high pressure** (25-PT-002, 25-PT-004, 25-PT-006, 25-PT-008, 25-PT-009, 25-PT-011, 25-PT-012)	Fault	Instrument Failure (reading higher value than real)	Fault pressure measure leading to spurious depressurization of the hydrogen vessels and release of hydrogen from vent line and jet fire in case of ignition. The extent of damage is very limited since the hydrogen circuit vent line is located in safe position in terms of radiation levels to process equipment and the platform is normally unmanned.	0.3	50	15	Medium	1. High flow alarm FAH001 on hydrogen vent line to stack (not useful to prevent depressurization	1	0.3	50	15	Medium		
30	Emergency Shut Down Systems	**Pressure Transmitter for V-25001A/F high high pressure** (25-PT-002, 25-PT-004, 25-PT-006, 25-PT-008, 25-PT-009, 25-PT-011, 25-PT-012)	Blockage/plugged	Manual valve in the pressure transmitter nozzle left closed due to misoperation (fixed after start up)	Fault pressure measure leading to unavailability of trip for high high pressure which could result (in case of demand) to potential mechanical damage and with release of hydrogen and fire with potential escalation and extensive damage to the structure	0.3	100	30	Medium	1. Availability of 25-PSV-001A/F (on hydrogen storage vessels V-25001A/F) for ultimate protection against high pressure	0.2	0.06	100	6	Low		
31	Emergency Shut Down Systems	**Pressure Transmitter for V-25001A/F high high pressure** (25-PT-002, 25-PT-004, 25-PT-006, 25-PT-008, 25-PT-009, 25-PT-011, 25-PT-012)	Pressure measure	Fail to function on demand	Unavailability of trip for high high pressure leading to to overpressurizazion of hydrogen circuit, potential mechanical damage and with release of hydrogen and fire with potential escalation and extensive damage to the structure	0.2	100	20	Medium	1. Availability of 25-PSV-001A/F (on hydrogen storage vessels V-25001A/F) for ultimate protection against high pressure	0.2	0.04	100	4	Low		
32	Emergency Shut Down Systems	**Level Transmitter for V-43001 high high level** (43-LT-002)	Fault	Instrument Failure (reading lower value than real)	Fault pressure measure leading to unavailability of trip for high high level which could result (in case of demand) increase of back pressure in vent line leading to possibile overpressurization and mechanical damage, release of hydrogen and fire in case of ignition, with limited possibility of escalation and extensive damage to the structure, due to low pressure system	0.3	70	21	Medium	1. F&G system with automatic isolation of the hydrogen circuit	0.3	0.09	70	6.3	Low		
33	Emergency Shut Down Systems	**Level Transmitter for V-43001 high high level** (43-LT-002)	Fault	Instrument Failure (reading higher value than real)	Fault pressure measure leading to spurious ESD1 activation on BLPH (pressurized shut down) stop of production and delay in operations	0.3	30	9	Low		1	0.3	30	9	Low		
34	Emergency Shut Down Systems	**Level Transmitter for V-43001 high high level** (43-LT-002)	Blockage/plugged	Manual valve in the pressure transmitter nozzle left closed due to misoperation (fixed after start up)	Fault pressure measure leading to unavailability of trip for high high level which could result (in case of demand) increase of back pressure in vent line leading to possibile overpressurization and mechanical damage, release of hydrogen and fire in case of ignition, with limited possibility of escalation and extensive damage to the structure, due to low pressure system	0.3	70	21	Medium	1. F&G system with automatic isolation of the hydrogen circuit	0.3	0.09	50	4.5	Low		

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35	Emergency Shut Down Systems	**Level Transmitter for V-43001 high high level** (43-LT-002)	Level measure	Fail to function on demand	Fault pressure measure leading to unavailability of trip for high high level which could result (in case of demand) increase of back pressure in vent line leading to possibile overpressurization and mechanical damage, release of hydrogen and fire in case of ignition, with limited possibility of escalation and extensive damage to the structure, due to low pressure system	0.3	50	15	Medium	1. F&G system with automatic isolation of the hydrogen circuit	1	0.3	50	15	Medium		
36	Emergency Shut Down Systems	**Emergency push buttons** (950ESD-01101, 950ESDD-01101, 950ESD-03101, 950ESDD-03101, 950ESD-04101, 950ESDD-04101, 950ESD-06101, 950ESDD-06101, 950ESD-07101, 950ESDD-07101)	Damaged	Fail to function on demand	Unavailability of ESD manual action for Hydrogen circuit leading to potential escalation and extensive damage to the structure	0.2	100	20	Medium	1. ESD can be independently activated by F&G network	0.3	0.06	100	6	Low		
37	Blow Down Valves	**Blow Down valves for hydrogen circuit** (25-BDV-003, 25-BDV-005, 25-BDV-007, 25-BDV-010, 25-BDV-013, 25-BDV-016, 25-BDV-019, 25-BDV-022)	Blockage/plugged	Manual valves upstream BDV left closed due to misoperation (LO)	Blockage of vent line leading to impossibility to depressurize the hydrogen circuit with potential escalation and extensive damage to the structure	0.2	100	20	Medium	1. ESD can be independently activated by F&G network	0.3	0.06	100	6	Low		
38	Blow Down Valves	**Blow Down valves for hydrogen circuit** (25-BDV-003, 25-BDV-005, 25-BDV-007, 25-BDV-010, 25-BDV-013, 25-BDV-016, 25-BDV-019, 25-BDV-022)	Open position	Loss of instrument air	Unexpected depressurization of the hydrogen circuit with hydrogen routed to vent to atmosphere and consequent jet fire in case of ignition. The extent of damage is very limited since the hydrogen circuit vent line is located in safe position in terms of radiation levels to process equipment and the platform is normally unmanned.	0.4	50	20	Medium	1. High flow alarm FAH001 on hydrogen vent line to stack. 2. Low low pressure in instrument air header activates ESD1	0.2	0.08	100	8	Low		
39	Blow Down Valves	**Blow Down valves for hydrogen circuit** (25-BDV-003, 25-BDV-005, 25-BDV-007, 25-BDV-010, 25-BDV-013, 25-BDV-016, 25-BDV-019, 25-BDV-022)	Mechanical Integrity	Internal leakage from closed BDV	Unexpected progressive depressurization of the hydrogen circuit to vent to atmosphere and consequenct fire in case of ignition. The extent of damage is minimum since the hydrogen circuit vent line is located in safe position in terms of radiation levels to process equipment and the platform is normally unmanned.	0.3	50	15	Medium	1. Pressure test during pre-commissioning 2. High flow alarm FAH001 on hydrogen vent line to stack	0.3	0.09	100	9	Low		
40	Blow Down Valves	**Blow Down Solenoid valves for hydrogen circuit** (25-BDY-003, 25-BDY-005, 25-BDY-007, 25-BDY-010, 25-BDY-013, 25-BDY-016, 25-BDY-019, 25-BDY-022)	Fault	Loss of electrical energy	Unexpected depressurization of the hydrogen circuit with hydrogen routed to vent to atmosphere and consequenct fire in case of ignition. The extent of damage is minimum since the hydrogen circuit vent line is located in safe position in terms of radiation levels to process equipment and the platform is normally unmanned.	0.4	50	20	Medium	1. High flow alarm FAH001 on hydrogen vent line to stack	0.5	0.2	100	20	Medium		
41	Emergency Shut Down Valves	**Emergency Shut Down valve for hydrogen circuit** (25-SDV-001, 25-SDV-023)	Incorrect position	Loss of instrument air	Blockage of process line leading to isolation of hydrogen circuit and consequent process upset upset and stop of production (no hazardous situations identified)	0.4	30	12	Medium	1. Limit switches on SDV providing alarm of incorrect position. 2. Low low pressure in instrument air header activates ESD1	0.2	0.08	30	2.4	Low		
42	Emergency Shut Down Valves	**Emergency Shut Down valve for hydrogen circuit** (25-SDV-001, 25-SDV-023)	Mechanical Integrity	Internal leakage from closed SDV	Leakage of gas in isolated hydrogen circuit leading to potential hazardous conditions for the operators in case of subsequent activity on the plant (checks, maintenance).	0.3	70	21	Medium	1. Dedicated procedures for activity of checks or maintenance (positive isolation with DB manual valves)	0.3	0.09	80	7.2	Low		
43	Emergency Shut Down Valves	**Emergency Shut Down Solenoid valve for hydrogen circuit** (25-SDY-001, 25-SDY-023)	Fault	Loss of electrical energy	Blockage of process line leading to isolation of hydrogen circuit and consequent process upset upset and stop of production (no hazardous situations identified)	0.5	30	15	Medium	1. Limit switches on SDV providing alarm of incorrect position	0.5	0.25	30	7.5	Low		
44	On-Off operating valves	**On-Off operating valves in hydrogen circuit** (25-XV-001, 25-XV-002, 25-XV-024, 25-XV-004, 25-XV-006, 25-XV-008, 25-XV-009, 25-XV-011, 25-XV-012, 25-XV-014, 25-XV-015, 25-XV-017, 25-XV-018, 25-XV-020, 25-XV-021)	Blockage/plugged	Manual valves upstream XV left closed due to misoperation (fixed at start up)	Blockage of process line leading to isolation of sections of hydrogen circuit and consequent process upset upset and stop of production (no hazardous situations identified)	0.3	30	9	Low		1	0.3	30	9	Low		
45	On-Off operating valves	**On-Off operating valves in hydrogen circuit** (25-XV-001, 25-XV-002, 25-XV-024, 25-XV-004, 25-XV-006, 25-XV-008, 25-XV-009, 25-XV-011, 25-XV-012, 25-XV-014, 25-XV-015, 25-XV-017, 25-XV-018, 25-XV-020, 25-XV-021)	Closed position	Loss of instrument air	Blockage of process line leading to isolation of sections of hydrogen circuit and consequent process upset upset and stop of production (no hazardous situations identified)	0.5	30	15	Medium	1. Limit switches on XV providing alarm of incorrect position 2. Low low pressure in instrument air header activates ESD1	0.2	0.1	30	3	Low		
46	On-Off operating valves	**On-Off operating valves in hydrogen circuit** (25-XV-001, 25-XV-002, 25-XV-024, 25-XV-004, 25-XV-006, 25-XV-008, 25-XV-009, 25-XV-011, 25-XV-012, 25-XV-014, 25-XV-015, 25-XV-017, 25-XV-018, 25-XV-020, 25-XV-021)	Mechanical Integrity	Internal leakage from closed XV	Leakage of gas in isolated hydrogen circuit leading to potential hazardous conditions for the operators in case of subsequent activity on the plant (checks, maintenance).	0.3	70	21	Medium	1. Dedicated procedures for activity of checks or maintenance (positive isolation with DB manual valves) 2. Availability of SDVs for proper isolation of hydrogen circuit in case of emergency	0.3	0.09	70	6.3	Low		

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47	On-Off operating valves	**On-Off operating Solenoid valves in hydrogen circuit** (25-XY-001, 25-XY-002, 25-XY-024, 25-XY-004, 25-XY-006, 25-XY-008, 25-XY-009, 25-XY-011, 25-XY-012, 25-XY-014, 25-XY-015, 25-XY-017, 25-XY-018, 25-XY-020, 25-XY-021)	Fault	Loss of electrical energy	Blockage of process line leading to isolation of sections of hydrogen circuit and consequent process upset (no hazardous situations identified)	0.5	30	15	Medium	1. Limit switches on SDV providing alarm of incorrect position	0.5	0.25	30	7.5	Low		
48	Control system	**Pressure measuring element on Electrolyzer package outlet line** (25-PT-001)	Fault	Instrument Failure (reading lower value than real)	Increase of pressure in the hydrogen storage circuit leading to process upset with no hazardous consequences, since DP of Hydrogen circuit is consistent with DP of Electrolyzer package.	0.5	30	15	Medium	1. 25-PAHH-004, 25-PAHH-006, 25-PAHH-008, 25-PAHH-009, 25-PAHH-011, 25-PAHH-012 to isolate the hydrogen storage vessels (protecting from the source of high pressure)	0.2	0.1	30	3	Low		
49	Control system	**Pressure measuring element on Electrolyzer package outlet line** (25-PT-001)	Fault	Instrument Failure (reading higher value than real)	Decrease of pressure in the hydrogen storage circuit leading to process upset with no hazardous consequences.	0.5	30	15	Medium		1	0.5	30	15	Medium		
50	Control system	**Pressure measuring element on Electrolyzer package outlet line** (25-PT-001)	Blockage/plugged	Manual valve in the pressure transmitter nozzle left closed due to misoperation (fixed at start up)	Fault pressure measure leading to incorrect pressure control system and finally possible increase of pressure in the hydrogen storage circuit leading to process upset with no hazardous consequences, since DP of Hydrogen circuit is consistent with DP of Electrolyzer package.	0.3	30	9	Low	1. 25-PAHH-004, 25-PAHH-006, 25-PAHH-008, 25-PAHH-009, 25-PAHH-011, 25-PAHH-012 to isolate the hydrogen storage vessels (protecting from the source of high pressure)	0.5	0.15	30	4.5	Low		
51	Control system	**Pressure control system on Electrolyzer package outlet line** (25-PIC-001)	Fault	Erratic Output	Increase of pressure in the hydrogen storage circuit leading to process upset with no hazardous consequences, since DP of Hydrogen circuit is consistent with DP of Electrolyzer package.	0.4	30	12	Medium	1. 25-PAHH-004, 25-PAHH-006, 25-PAHH-008, 25-PAHH-009, 25-PAHH-011, 25-PAHH-012 to isolate the hydrogen storage vessels (protecting from the source of high pressure)	0.5	0.2	30	6	Low		
52	Control system	**Pressure measuring element on hydrogen storage vessels** (25-PT-005, 25-PT-007, 25-PT-010, 25-PT-013, 25-PT-016, 25-PT-019)	Fault	Instrument Failure (reading lower value than real)	Increase of pressure in the hydrogen storage vessels leading to process upset with no hazardous consequences, since DP of Hydrogen circuit is consistent with DP of Electrolyzer package.	0.5	30	15	Medium	1. 25-PAHH-004, 25-PAHH-006, 25-PAHH-008, 25-PAHH-009, 25-PAHH-011, 25-PAHH-012 to isolate the hydrogen storage vessels (protecting from the source of high pressure)	0.5	0.25	30	7.5	Low		
53	Control system	**Pressure measuring element on hydrogen storage vessels** (25-PT-005, 25-PT-007, 25-PT-010, 25-PT-013, 25-PT-016, 25-PT-019)	Fault	Instrument Failure (reading higher value than real)	Unexpected depressurization of the hydrogen circuit with hydrogen routed to vent to atmosphere and consequenct fire in case of ignition. The extent of damage is minimum since the hydrogen circuit vent line is located in safe position in terms of radiation levels to process equipment and the platform is normally unmanned.	0.5	50	25	Medium	1. High flow alarm FAH001 on hydrogen vent line to stack	0.5	0.25	100	25	Medium		
54	Control system	**Pressure measuring element on hydrogen storage vessels** (25-PT-005, 25-PT-007, 25-PT-010, 25-PT-013, 25-PT-016, 25-PT-019)	Blockage/plugged	Manual valve in the pressure transmitter nozzle left closed due to misoperation (fixed at start up)	Unexpected depressurization of the hydrogen circuit with hydrogen routed to vent to atmosphere and consequenct fire in case of ignition. The extent of damage is minimum since the hydrogen circuit vent line is located in safe position in terms of radiation levels to process equipment and the platform is normally unmanned.	0.3	50	15	Medium	1. High flow alarm FAH001 on hydrogen vent line to stack	0.5	0.15	50	7.5	Low		
55	Control system	**Pressure control system on hydrogen storage vessels** (25-PIC-005, 25-PIC-007, 25-PIC-010, 25-PIC-013, 25-PIC-016, 25-PIC-019)	Fault	Erratic Output	Unexpected depressurization of the hydrogen circuit with hydrogen routed to vent to atmosphere and consequenct fire in case of ignition. The extent of damage is minimum since the hydrogen circuit vent line is located in safe position in terms of radiation levels to process equipment and the platform is normally unmanned.	0.4	50	20	Medium	1. High flow alarm FAH001 on hydrogen vent line to stack	0.5	0.2	50	10	Medium		
56	Control system	**Pressure control valve on hydrogen storage vessels** (25-PV-005, 25-PV-007, 25-PV-010, 25-PV-013, 25-PV-016, 25-PV-019)	Fault	Loss of instrument air	Sudden closure of control valve leading to increase of pressure in the hydrogen vessel circuit with process upset and no hazardous consequences, since DP of Hydrogen circuit is consistent with DP of Electrolyzer package	0.5	30	15	Medium	1. Low Low pressure on Instruiment air header will activate BLPH shut down	0.2	0.1	30	3	Low		
57	Control system	**Pressure control valve on hydrogen storage vessels** (25-PV-005, 25-PV-007, 25-PV-010, 25-PV-013, 25-PV-016, 25-PV-019)	Stuck	Structural deficiency	Valve stuck in open position leading to unexpected depressurization of the hydrogen circuit towards the vent to atmosphere and consequenct fire in case of ignition. The extent of damage is minimum since the hydrogen circuit vent line is located in safe position in terms of radiation levels to process equipment and the platform is normally unmanned.	0.3	50	15	Medium	1. Design specification and installation procedure	0.5	0.15	50	7.5	Low		
58	Control system	**Pressure control valve on hydrogen storage vessels** (25-PV-005, 25-PV-007, 25-PV-010, 25-PV-013, 25-PV-016, 25-PV-019)	Mechanical Integrity	External leakage from valve seal or from flanged joint	Release of hydrogen and jet fire in case of ignition, with potential escalation and extensive damage to the structure	0.3	100	30	Medium	1. Design specification and installation procedure 2. F&G system with automatic isolation of the hydrogen circuit	0.3	0.09	100	9	Low		

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59	Control system	**Pressure control valve on hydrogen storage vessels** (25-PV-005, 25-PV-007, 25-PV-010, 25-PV-013, 25-PV-016, 25-PV-019)	Mechanical Integrity	Internal leakage from closed control valve	Pregressive depressurization of the hydrogen circuit towards the vent to atmosphere and consequenct fire in case of ignition. The extent of damage is minimum since the hydrogen circuit vent line is located in safe position in terms of radiation levels to process equipment and the platform is normally unmanned.	0.5	50	25	Medium	1. Design specification and installation procedure 2. High flow alarm FAH001 on hydrogen vent line to stack	0.5	0.25	50	12.5	Medium		
60	Control system	**Pressure measuring element on inlet of Fuel cell** (25-PT-025A/B)	Fault	Instrument Failure (reading lower value than real)	Wide opening of PV-025A/B and increase of pressure downstream hydrogen storage circuit with possible overpressurization, mechanical damage, release of hydrogen with jet fire in case of ignition. Potential escalation and extensive damage to the structure.	0.5	100	50	High	1. 25-PSV-001 in the line downstream PV-025A/B 2. F&G system with automatic isolation of the hydrogen circuit	0.2	0.1	100	10	Medium		
61	Control system	**Pressure measuring element on inlet line of Fuel cell** (25-PT-025A/B)	Fault	Instrument Failure (reading higher value than real)	Closure of 25-PV-025A/B with consequent stop of feed line to Fuel cell leading to delay in operation with process upset and no hazardous consequences.	0.5	30	15	Medium	1. 25-PAHH-004, 25-PAHH-006, 25-PAHH-008, 25-PAHH-009, 25-PAHH-011, 25-PAHH-012 to isolate the hydrogen storage vessels (protecting from the source of high pressure)	0.2	0.1	30	3	Low		
62	Control system	**Pressure element on inlet line of Fuel cell** (25-PT-025A/B)	Blockage/plugged	Manual valve in the pressure transmitter nozzle left closed due to misoperation (fixed at start up)	Wide opening of PV-025A/B and increase of pressure downstream hydrogen storage circuit with possible overpressurization, mechanical damage, release of hydrogen with jet fire in case of ignition. Potential escalation and extensive damage to the structure.	0.3	100	30	Medium	1. 25-PSV-001 in the line downstream PV-025A/B 2. F&G system with automatic isolation of the hydrogen circuit	0.2	0.06	100	6	Low		
63	Control system	**Pressure control system element on inlet line of Fuel cell** (25-PIC-025A/B)	Fault	Erratic Output	Wide opening of PV-025A/B and increase of pressure downstream hydrogen storage circuit with possible overpressurization, mechanical damage, release of hydrogen with jet fire in case of ignition. Potential	0.4	100	40	Medium	1. 25-PSV-001 in the line downstream PV-025A/B 2. F&G system with automatic isolation of the hydrogen circuit	0.2	0.08	100	8	Low		
64	Control system	**Pressure control valve element on inlet line of Fuel cell** (25-PV-025A/B)	Fail	Loss of instrument air	Closure of 25-PV-025A/B with consequent stop of feed line to Fuel cell leading to delay in operation with process upset and no hazardous consequences.	0.5	30	15	Medium	1. Low Low pressure on Instruiment air header will activate BLPH shut down	0.2	0.1	30	3	Low		
65	Control system	**Pressure control valve on inlet line of Fuel cell** (25-PV-025A/B)	Stuck	Structural deficiency	25-PV-025A/B stuck in open position leading to increase of pressure downstream hydrogen storage circuit with possible overpressurization, mechanical damage, release of hydrogen with jet fire in case of	0.4	100	40	Medium	1. F&G system with automatic isolation of the hydrogen circuit	0.2	0.08	30	2.4	Low		
66	Control system	**Pressure control valve on inlet line of Fuel cell** (25-PV-025A/B)	Mechanical Integrity	External leakage from valve seal or from flanged joint	Release of hydrogen and jet fire in case of ignition, with potential escalation and extensive damage to the structure	0.3	100	30	Medium	1. Design specification and installation procedure 2. F&G system with automatic isolation of the hydrogen circuit	0.3	0.09	100	9	Low		
67	Control system	**Pressure control valve on inlet line of Fuel cell** (25-PV-025A/B)	Mechanical Integrity	Internal leakage from closed control valve	Incorrect isolation of the hydrogen storage circuit leading to gas leakage to downstream circuit of the fuel cell with potential for process upset and unsafe operation	0.4	30	12	Medium	1. Design specification and installation procedure	0.5	0.2	30	6	Low		
68	Control system	**Flow measuring element on inlet of Nitrogen to hydrogen storage vessels** (25-FT-001, 25-FT-002, 25-FT-003, 25-FT-014, 25-FT-005, 25-FT-006)	Fault	Instrument Failure (reading lower value than real)	During filling operation, wide opening of 25-FV-001, 25-FV-001, 25-FV-001, 25-FV-001, 25-FV-001, 25-FV-001 leading to increase of flow of nitrogen to V-25001A/F and consequent off spec hydrogen (containing nitrogen) to Fuel Cell and process upset.	0.5	30	15	Medium	1. Dedicated procedure for process start up	0.5	0.25	30	7.5	Low		
69	Control system	**Flow measuring element on inlet of Nitrogen to hydrogen storage vessels** (25-FT-001, 25-FT-002, 25-FT-003, 25-FT-014, 25-FT-005, 25-FT-006)	Fault	Instrument Failure (reading lower value than real)	During normal operation, wide opening of 25-FV-001, 25-FV-001, 25-FV-001, 25-FV-001, 25-FV-001, 25-FV-001 leading to hydrogen backflow to nitrogen system leading to overpressurization and mechanical damage. Release of hydrogen with jet fire in case of ignition. Potential escalation and extensive damage to the structure.	0.5	100	50	High	1. Check valve in the nitrogen inlet line 2. F&G system with automatic isolation of the hydrogen circuit	0.3	0.15	100	15	Medium		
70	Control system	**Flow measuring element on inlet of Nitrogen to hydrogen storage vessels** (25-FT-001, 25-FT-002, 25-FT-003, 25-FT-014, 25-FT-005, 25-FT-006)	Fault	Instrument Failure (reading higher value than real)	Closure 25-FV-001, 25-FV-001, 25-FV-001, 25-FV-001, 25-FV-001, 25-FV-001 of feed line of nitrogen to V-25001A/F leading to delay in operations and process upset.	0.5	30	15	Medium	1. Dedicated procedure for process start up	0.5	0.25	30	7.5	Low		
71	Control system	**Flow measuring element on inlet of Nitrogen to hydrogen storage vessels** (25-FT-001, 25-FT-002, 25-FT-003, 25-FT-014, 25-FT-005, 25-FT-006)	Blockage/plugged	Manual valve in the pressure transmitter nozzle left closed due to misoperation (fixed at start up)	During normal operation, wide opening of 25-FV-001, 25-FV-001, 25-FV-001, 25-FV-001, 25-FV-001, 25-FV-001 leading to hydrogen backflow to nitrogen system leading to overpressurization and mechanical damage. Release of hydrogen with jet fire in case of ignition. Potential escalation and extensive damage to the structure.	0.3	100	30	Medium	1. Check valve in the nitrogen inlet line 2. F&G system with automatic isolation of the hydrogen circuit	0.3	0.09	100	9	Low		

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72	Control system	**Pressure control system element on inlet of Nitrogen to hydrogen storage vessels** (25-FIC-001, 25-FIC-002, 25-FIC-003, 25-FIC-014, 25-FIC-005, 25-FIC-006)	Fault	Erratic Output	During normal operation, wide opening of 25-FV-001, 25-FV-001, 25-FV-001, 25-FV-001, 25-FV-001, 25-FV-001 leading to hydrogen backflow to nitrogen system leading to overpressurization and mechanical damage. Release of hydrogen with jet fire in case of ignition. Potential escalation and extensive damage to the structure.	0.4	100	40	Medium	1. Check valve in the nitrogen inlet line 2. F&G system with automatic isolation of the hydrogen circuit	0.3	0.12	100	12	Medium		
73	Control system	**Pressure control valve on inlet line of Nitrogen to hydrogen storage vessels** (25-FV-001, 25-FV-002, 25-FV-003, 25-FV-014, 25-FV-005, 25-FV-006)	Fault	Loss of instrument air	Closure of 25-FV-001, 25-FV-002, 25-FV-003, 25-FV-014, 25-FV-005, 25-FV-006 in feed line nitrogen to V-25001A/F leading to delay in operation.	0.5	30	15	Medium	1. Low Low pressure on Instruiment air header will activate BLPH shut down	0.2	0.1	30	3	Low		
74	Control system	**Pressure control valve on inlet line of Nitrogen to hydrogen storage vessels** (25-FV-001, 25-FV-002, 25-FV-003, 25-FV-014, 25-FV-005, 25-FV-006)	Stuck	Structural deficiency	Valve stuck in open position leading, in normal operation, wide opening of 25-FV-001, 25-FV-001, 25-FV-001, 25-FV-001, 25-FV-001, 25-FV-001 leading to hydrogen backflow to nitrogen system leading to overpressurization and mechanical damage. Release of hydrogen with jet fire in case of ignition. Potential escalation and extensive damage to the structure.	0.3	100	30	Medium	1. Check valve in the nitrogen inlet line 2. F&G system with automatic isolation of the hydrogen circuit	0.3	0.09	100	9	Low		
75	Control system	**Pressure control valve on inlet line of Nitrogen to hydrogen storage vessels** (25-FV-001, 25-FV-002, 25-FV-003, 25-FV-014, 25-FV-005, 25-FV-006)	Mechanical Integrity	External leakage from valve seal or from flanged joint	Release of hydrogen and jet fire in case of ignition, with potential escalation and extensive damage to the structure	0.3	100	30	Medium	1. Design specification and installation procedure 2. F&G system with automatic isolation of the hydrogen circuit	0.3	0.09	100	9	Low		
76	Control system	**Pressure control valve on inlet line of Nitrogen to hydrogen storage vessels** (25-FV-001, 25-FV-002, 25-FV-003, 25-FV-014, 25-FV-005, 25-FV-006)	Mechanical Integrity	Internal leakage from closed control valve	Leaking from 25-FV-001, 25-FV-001, 25-FV-001, 25-FV-001, 25-FV-001, 25-FV-001 leading to hydrogen backflow to nitrogen system leading to overpressurization and mechanical damage. Release of hydrogen with jet fire in case of ignition. Potential escalation and extensive damage to the structure.	0.3	100	30	Medium	1. Design specification and installation procedure. 2. Check valve in the nitrogen inlet line 3. F&G system with automatic isolation of the hydrogen circuit	0.3	0.09	100	9	Low		
77	Control system	**Level measuring element in V-43001** (43-LT-001)	Fault	Instrument Failure (reading lower value than real)	Wide opening of LV-001 and gas blow by to brine discharge caisson and potential for hydrogen release and fire in case of ignition with limited possibility of escalation and extensive damage to the structure, due to low pressure system	0.5	70	35	Medium	1. F&G system with automatic isolation of the hydrogen circuit	0.3	0.15	70	10.5	Medium		
78	Control system	**Level measuring element in V-43001** (43-LT-001)	Fault	Instrument Failure (reading higher value than real)	Closure of 25-LV-001 with consequent increase of level in V-43001 and increase of back pressure in vent line leading to possibile overpressurization and mechanical damage, release of hydrogen and fire in case of ignition, with limited possibility of escalation and extensive damage to the structure, due to low pressure system	0.5	100	50	High	1. High high level 43-LAHH-002 with interlock to trip the BLPH	0.2	0.1	100	10	Medium		
79	Control system	**Level measuring element in V-43001** (43-LT-001)	Blockage/plugged	Manual valve in the pressure transmitter nozzle left closed due to misoperation (fixed at start up)	Wide opening of LV-001 and gas blow by to brine discharge caisson and potential for hydrogen release and fire in case of ignition with limited possibility of escalation and extensive damage to the structure, due to low pressure system	0.3	70	21	Medium	1. F&G system with automatic isolation of the hydrogen circuit	0.3	0.09	70	6.3	Low		
80	Control system	**Level control system element in V-43001** (43-LIC-001)	Fault	Erratic Output	Wide opening of LV-001 and gas blow by to brine discharge caisson and potential for hydrogen release and fire in case of ignition with limited possibility of escalation and extensive damage to the structure, due to low pressure system	0.4	70	28	Medium	1. F&G system with automatic isolation of the hydrogen circuit	0.3	0.12	70	8.4	Low		
81	Control system	**Level control in V-43001** (43-LV-001)	Fail	Loss of instrument air	Wide opening of LV-001 and gas blow by to brine discharge caisson and potential for hydrogen release and fire in case of ignition with limited possibility of escalation and extensive damage to the structure, due to low pressure system	0.5	70	35	Medium	1. Low Low pressure on Instruiment air header will activate BLPH shut down	0.2	0.1	70	7	Low		
82	Control system	**Level control in V-43001** (43-LV-001)	Stuck	Structural deficiency	Wide opening of LV-001 and gas blow by to brine discharge caisson and potential for hydrogen release and fire in case of ignition with limited possibility of escalation and extensive damage to the structure, due to low pressure system	0.3	70	21	Medium	1. F&G system with automatic isolation of the hydrogen circuit	0.3	0.09	70	6.3	Low		
83	Control system	**Level control in V-43001** (43-LV-001)	Mechanical Integrity	External leakage from valve seal or from flanged joint	Release of hydrogen and fire in case of ignition, with limited possibility of escalation and extensive damage to the structure, due to low pressure system	0.3	70	21	Medium	1. Design specification and installation procedure 2. F&G system with automatic isolation of the hydrogen circuit	0.3	0.09	70	6.3	Low		

id	System	Element	Typology	Failure mode	Effects analysis	Original Threat Likelihood	Original Impact	Result	Risk Rating	Mitigating Measures	Mitigating Measures likelihood	Threat Likelihood	Impact	Mitigated Result	Mitigated Risk Rating	Recommendations	Notes
84	Control system	**Level control in V-43001** (43-LV-001)	Mechanical Integrity	Internal leakage from closed control valve	Incorrect isolation of the hydrogen vent KO drum leading to gas blow by to brine discharge caisson and potential for hydrogen release and fire in case of ignition with limited possibility of escalation and extensive damage to the structure, due to low pressure system	0.3	70	21	Medium	1. Design specification and installation procedure 2. F&G system with automatic isolation of the hydrogen circuit	0.3	0.09	70	6.3	Low		
85	Alarm systems	Pressure measuring element in V-43001 (43-PT-001)	Fault	Instrument Failure (reading lower value than real)	Missed alarm activation with delay in intervention by operator with potential evolution to a more critical process condition	0.5	30	15	Medium	1. High flow alarm FAH001 on hydrogen vent line to stack	0.5	0.25	30	7.5	Low		
86	Alarm systems	Pressure measuring element in V-43001 (43-PT-001)	Fault	Instrument Failure (reading higher value than real)	Spurious alarm activation with operational upset	0.5	30	15	Medium	1. High flow alarm FAH001 on hydrogen vent line to stack	0.5	0.25	30	7.5	Low		
87	Alarm systems	Pressure measuring element in V-43001 (43-PT-001)	Blockage/plugged	Manual valve in the pressure transmitter nozzle left closed due to misoperation	Missed alarm activation with delay in intervention by operator with potential evolution to a more critical process condition	0.3	30	9	Low	1. High flow alarm FAH001 on hydrogen vent line to stack	0.5	0.15	30	4.5	Low		
88	Alarm systems	Flow measuring element in vent line downstream V-43001 (43-FT-001)	Fault	Instrument Failure (reading lower value than real)	Missed alarm activation with delay in intervention by operator with potential evolution to a more critical process condition	0.5	30	15	Medium	1. High pressure alarm PAH001 in V-43001	0.5	0.25	30	7.5	Low		
89	Alarm systems	Flow measuring element in vent line downstream V-43001 (43-FT-001)	Fault	Instrument Failure (reading higher value than real)	Spurious alarm activation with operational upset	0.5	30	15	Medium	1. High pressure alarm PAH001 in V-43002	0.5	0.25	30	7.5	Low		
90	Alarm systems	Flow measuring element in vent line downstream V-43001 (43-FT-001)	Blockage/plugged	Manual valve in the pressure transmitter nozzle left closed due to misoperation	Missed alarm activation with delay in intervention by operator with potential evolution to a more critical process condition	0.3	30	9	Low	1. High pressure alarm PAH001 in V-43003	0.5	0.15	30	4.5	Low		
91	Other	Liquid seal in Q-43004	Loss of liquid	Liquid seal evaporation (high boiling point liquid)	Loss of liquid seal in Q-43004 leading to loss of seal against air ingress in hydrogen vent line with potential formation of flammable mixture and localized explosion in case of ignition.	0.3	100	30	Medium	1. Continuous nitrgoen flow to flush the hydrogen vent line to prevent air ingress.	0.4	0.12	100	12	Medium		
92	Other	Liquid seal in Q-43005	Loss of liquid	Liquid droplets entrainment in gas flow	Loss of liquid seal in Q-43004 leading to loss of seal against air ingress in hydrogen vent line with potential formation of flammable mixture and localized explosion in case of ignition.	0.3	100	30	Medium	1. Continuous nitrgoen flow to flush the hydrogen vent line to prevent air ingress.	0.4	0.12	100	12	Medium		
93	Other	Liquid seal in Q-43006	Loss of liquid	Flange leak in drain line	Loss of liquid seal in Q-43004 leading to loss of seal against air ingress in hydrogen vent line with potential formation of flammable mixture and localized explosion in case of ignition.	0.3	100	30	Medium	1. Continuous nitrgoen flow to flush the hydrogen vent line to prevent air ingress.	0.4	0.12	100	12	Medium		
94	Other	Liquid seal in Q-43007	Loss of liquid	Freezing during winter season (mixture of warter and glycol suitable for minimum ambient temperature)	Blockage of ven line leading to possible overpressurization of hydrogen vent circuit, in case of demand, with consequent mechanical damage and release of hydrogen in the atmosphere, with jet fire in case of ignition and extensive damage to the platform.	0.2	100	20	Medium	1. Bottom side of hydrogen vent line is insulated and heat traced. 2. PAH-001 in V-43001 Hydrogen vent KO Drum	0.3	0.06	100	6	Low		
95	Other	Flame arrestor in Q-43007	Failure	Mechanical degradation due to exposure to environment	Loss of capacity of flame arrestor with potential propagation of flames inside the hydrogen vent leading to mechanical damage of the circuit and need for BLPH shut down and loss of production	0.3	50	15	Medium	1. Continuous nitrgoen flow to flush the hydrogen vent line to prevent air ingress.	0.4	0.12	50	6	Low		
96	Other	Flame arrestor in Q-43007	Blockage/plugged	Blockage of flame arrester vent due to bird activity (guano), including the bird screen on top of flame arrestor	Blockage of ven line leading to possible overpressurization of hydrogen vent circuit, in case of demand, with consequent mechanical damage and release of hydrogen in the atmosphere, with jet fire in case of ignition and extensive damage to the platform.	0.3	100	30	Medium	1. periodical checks of the efficiency of hydrogen vent flame arrester. 2. PAH-001 in V-43001 Hydrogen vent KO Drum	0.3	0.09	100	9	Low		

id	System	Element	Typology	Failure mode	Effects analysis	Original Threat Likelihood	Original Impact	Result	Risk Rating	Mitigating Measures	Mitigating Measures likelihood	Threat Likelihood	Impact	Mitigated Result	Mitigated Risk Rating	Recommendations	Notes
1	Piping system	**Instrument air process line** (1-1/2"-IA-108-01HSS-N, 1-1/2"-IA-204-01HSS-N)	Mechanical Integrity	Leak from a gasket on flanged joint	Loss of containment with release of instrument air and depressurization of the instrument air circuit with BLPH process shut down. Process upset due to uncontrolled shud down. No safety consequences expected since the desing of BLPH is based on "fail safe" concept. Total stop of production.	0.3	40	12	Medium	1. 63-PALL-004 activating ESD to pressurized shut down.	0.5	0.15	40	6	Low		
2	Piping system	**Instrument air process line** (1-1/2"-IA-108-01HSS-N, 1-1/2"-IA-204-01HSS-N)	Mechanical Integrity	External corrosion issue on the piping (low expected likelihood due to use of stainless steel)	Loss of containment with release of instrument air and depressurization of the instrument air circuit with BLPH process shut down. Process upset due to uncontrolled shud down. No safety consequences expected since the desing of BLPH is based on "fail safe" concept. Total stop of production.	0.1	40	4	Low	1. 63-PALL-004 activating ESD to pressurized shut down.	0.5	0.05	40	2	Low		
3	Piping system	**Instrument air process line** (1-1/2"-IA-108-01HSS-N, 1-1/2"-IA-204-01HSS-N)	Mechanical Integrity	Internal corrosion issue on the piping (low expected likelihood due to use of stainless steel)	Loss of containment with release of instrument air and depressurization of the instrument air circuit with BLPH process shut down. Process upset due to uncontrolled shud down. No safety consequences expected since the desing of BLPH is based on "fail safe" concept. Total stop of production.	0.1	40	4	Low	1. 63-PALL-004 activating ESD to pressurized shut down.	0.5	0.05	40	2	Low		
4	Piping system	**Instrument air process line** (1-1/2"-IA-108-01HSS-N, 1-1/2"-IA-204-01HSS-N)	Blockage/plugged	Manual valve in the instrument air production line line left closed due to misoperation (LO)	Unavailability of the instrument air circuit with BLPH process shut down. Process upset due to uncontrolled shud down. No safety consequences expected since the desing of BLPH is based on "fail safe" concept. Total stop of production.	0.2	40	8	Low	1. 63-PALL-004 activating ESD to pressurized shut down.	0.5	0.1	40	4	Low		
6	Piping system	**N2 production and distribution lines** (1"-N-158-01CS-N, 1"-N-100-01CS-N, 1"-N-028-01CS-N, 1"-N-124-01CS-N, 1"-N-125-01CS-N, 1"-N-126-01CS-N, 1"-N-127-01CS-N, 1"-N-128-01CS-N, 1"-N-151-01CS-N)	Mechanical Integrity	External corrosion issue on the piping	Loss of containment with release of nitrogen and depressurization of the nitrogen circuit. Process upset during start up and shut down phases. No safety consequences expected.	0.3	30	9	Low		1	0.3	30	9	Low		
7	Piping system	**N2 production and distribution lines** (1"-N-158-01CS-N, 1"-N-100-01CS-N, 1"-N-028-01CS-N, 1"-N-124-01CS-N, 1"-N-125-01CS-N, 1"-N-126-01CS-N, 1"-N-127-01CS-N, 1"-N-128-01CS-N, 1"-N-151-01CS-N)	Mechanical Integrity	Internal corrosion issue on the piping	Loss of containment with release of nitrogen and depressurization of the nitrogen circuit. Process upset during start up and shut down phases. No safety consequences expected.	0.3	30	9	Low		1	0.3	30	9	Low		
8	Piping system	**N2 production and distribution lines** (1"-N-158-01CS-N, 1"-N-100-01CS-N, 1"-N-028-01CS-N, 1"-N-124-01CS-N, 1"-N-125-01CS-N, 1"-N-126-01CS-N, 1"-N-127-01CS-N, 1"-N-128-01CS-N, 1"-N-151-01CS-N)	Blockage/plugged	Manual valve in the nitrogen blanketing line left closed due to misoperation (LO)	Unavailability of nitrogen line when needed with delay in operations and process upset	0.2	30	6	Low		1	0.2	30	6	Low		
9	Piping system	**N2 production and distribution line to vent header** (1"-N-158-01CS-N, 1"-N-100-01CS-N, 1"-N-101-01CS-N)	Mechanical Integrity	Leak from a gasket on flanged joint	Loss of containment with release of nitrogen and depressurization of the nitrogen circuit with unavailability of hydrogen vent line flushing with potential for formation of flammable mixture in the vent circuit with risk of localized ignition and explosion.	0.3	100	30	Medium	1. 64-PALL-002 on nitrogen production line to activate ESD1 (depressurized shut down of hydrogen circuit) 2. Hydrogen vent is equipped with liquid seal to prevent air ingress in the vent circuit and prevent potential formation of flammable mixture.	0.2	0.06	100	6	Low		
10	Piping system	**N2 production and distribution line to vent header** (1"-N-158-01CS-N, 1"-N-100-01CS-N, 1"-N-101-01CS-N)	Mechanical Integrity	External corrosion issue on the piping	Loss of containment with release of nitrogen and depressurization of the nitrogen circuit with unavailability of hydrogen vent line flushing with potential for formation of flammable mixture in the vent circuit with risk of localized ignition and explosion.	0.3	100	30	Medium	1. 64-PALL-002 on nitrogen production line to activate ESD1 (depressurized shut down of hydrogen circuit) 2. Hydrogen vent is equipped with liquid seal to prevent air ingress in the vent circuit and prevent potential formation of flammable mixture.	0.2	0.06	100	6	Low		
11	Piping system	**N2 production and distribution line to vent header** (1"-N-158-01CS-N, 1"-N-100-01CS-N, 1"-N-101-01CS-N)	Mechanical Integrity	Internal corrosion issue on the piping	Loss of containment with release of nitrogen and depressurization of the nitrogen circuit with unavailability of hydrogen vent line flushing with potential for formation of flammable mixture in the vent circuit with risk of localized ignition and explosion.	0.3	100	30	Medium	1. 64-PALL-002 on nitrogen production line to activate ESD1 (depressurized shut down of hydrogen circuit) 2. Hydrogen vent is equipped with liquid seal to prevent air ingress in the vent circuit and prevent potential formation of flammable mixture.	0.2	0.06	100	6	Low		
12	Piping system	**N2 production and distribution line to vent header** (1"-N-158-01CS-N, 1"-N-100-01CS-N, 1"-N-101-01CS-N)	Blockage/plugged	Manual valve in the nitrogen blanketing line left closed due to misoperation (LO)	Unavailability of hydrogen vent line flushing with potential for formation of flammable mixture in the vent circuit with risk of localized ignition and explosion.	0.1	100	10	Medium	1. 64-PALL-002 on nitrogen production line to activate ESD1 (depressurized shut down of hydrogen circuit) 2. Hydrogen vent is equipped with liquid seal to prevent air ingress in the vent circuit and prevent potential formation of flammable mixture.	0.2	0.02	100	2	Low		

id	System	Element	Typology	Failure mode	Effects analysis	Original Threat Likelihood	Original Impact	Result	Risk Rating	Mitigating Measures	Mitigating Measures likelihood	Threat Likelihood	Impact	Mitigated Result	Mitigated Risk Rating	Recommendations	Notes
13	Piping system	**N2 line to 64-PSV-001** (HOLD-N-167-01CS-N)	Mechanical Integrity	Leak from a gasket on flanged joint	Loss of containment with release of nitrogen and depressurization of the nitrogen circuit with unavailability of hydrogen vent line flushing with potential for formation of flammable mixture in the vent circuit with risk of localized ignition and explosion.	0.3	100	30	Medium	1. Pressure test during pre-commissioning. 2. 64-PALL-002 on nitrogen production line to activate ESD1 (depressurized shut down of hydrogen circuit) 3. Hydrogen vent is equipped with liquid seal to prevent air ingress in the vent circuit and prevent potential formation of flammable mixture.	0.2	0.06	100	6	Low		
14	Piping system	**N2 line to 64-PSV-001** (HOLD-N-167-01CS-N)	Mechanical Integrity	External corrosion issue on the piping	Loss of containment with release of nitrogen and depressurization of the nitrogen circuit with unavailability of hydrogen vent line flushing with potential for formation of flammable mixture in the vent circuit with risk of localized ignition and explosion.	0.3	100	30	Medium	1. Pressure test during pre-commissioning. 2. 64-PALL-002 on nitrogen production line to activate ESD1 (depressurized shut down of hydrogen circuit) 3. Hydrogen vent is equipped with liquid seal to prevent air ingress in the vent circuit and prevent potential formation of flammable mixture.	0.2	0.06	100	6	Low		
15	Piping system	**N2 line to 64-PSV-001** (HOLD-N-167-01CS-N)	Mechanical Integrity	Internal corrosion issue on the piping	Loss of containment with release of nitrogen and depressurization of the nitrogen circuit with unavailability of hydrogen vent line flushing with potential for formation of flammable mixture in the vent circuit with risk of localized ignition and explosion.	0.3	100	30	Medium	1. Pressure test during pre-commissioning. 2. 64-PALL-002 on nitrogen production line to activate ESD1 (depressurized shut down of hydrogen circuit) 3. Hydrogen vent is equipped with liquid seal to prevent air ingress in the vent circuit and prevent potential formation of flammable mixture.	0.2	0.06	100	6	Low		
16	Piping system	**N2 line to 64-PSV-001** (HOLD-N-167-01CS-N)	Blockage/plugged	Manual valve in the nitrogen PSV line left closed due to misoperation (LO)	Unavailability of vent line when needed leading to overpressurization and potential for mechanical damage, loss of containment, nitrogen release and and depressurization of the nitrogen circuit with unavailability of hydrogen vent line flushing with potential for formation of flammable mixture in the vent circuit with risk of localized ignition and explosion.	0.2	100	20	Medium	1. 64-PALL-002 on nitrogen production line to activate ESD1 (depressurized shut down of hydrogen circuit) 2. Hydrogen vent is equipped with liquid seal to prevent air ingress in the vent circuit and prevent potential formation of flammable mixture.	0.2	0.04	100	4	Low		
17	Pressure Safety Valves	**64-PSV-001** (on nitrogen production line)	Internal Leakage	Incorrect calibration of Pressure Safety Valve	Leaking of nitrogen to atmosphere. In long time, depressurization of the nitrogen circuit with unavailability of hydrogen vent line flushing with potential for formation of flammable mixture in the vent circuit with risk of localized ignition and explosion	0.4	100	40	Medium	1. 64-PALL-002 on nitrogen production line to activate ESD1 (depressurized shut down of hydrogen circuit) 2. Hydrogen vent is equipped with liquid seal to prevent air ingress in the vent circuit and prevent potential formation of flammable mixture.	0.2	0.08	100	8	Low		
18	Pressure Safety Valves	**64-PSV-001** (on nitrogen production line)	Unavailability at correct set point	Incorrect calibration of Pressure Safety Valve	Possible overpressurization in the process circuit due to unavailability of PSV at the required set pressure, leading to overpressurization of nitrogen circuit, potential mechanical damage and with nitrogen release and depressurization of the nitrogen circuit with unavailability of hydrogen vent line flushing with potential for formation of flammable mixture in the vent circuit with risk of localized ignition and explosion	0.4	100	40	Medium	1. 64-PALL-002 on nitrogen production line to activate ESD1 (depressurized shut down of hydrogen circuit) 2. Hydrogen vent is equipped with liquid seal to prevent air ingress in the vent circuit and prevent potential formation of flammable mixture.	0.2	0.08	100	8	Low		
19	Emergency Shut Down Systems	**Pressure Transmitter for instrument air low low pressure** (63-PT-004)	Fault	Instrument Failure (reading higher value than real)	Fault pressure measure leading to unavailability of trip for low low pressure which could result (in case of demand) to unavailability of the instrument air circuit with BLPH process shut down. Process upset due to uncontrolled shud down. No safety consequences expected since the desing of BLPH is based on "fail safe" concept. Total stop of production.	0.3	40	12	Medium		1	0.3	40	12	Medium		

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20	Emergency Shut Down Systems	**Pressure Transmitter for instrument air low low pressure** (63-PT-004)	Fault	Instrument Failure (reading lower value than real)	Fault pressure measure leading to spurious shut down of BLPH. No safety consequences expected since the desing of BLPH is based on "fail safe" concept. Total stop of production.	0.3	40	12	Medium		1	0.3	40	12	Medium		
21	Emergency Shut Down Systems	**Pressure Transmitter for instrument air low low pressure** (63-PT-004)	Blockage/plugged	Manual valve in the pressure transmitter nozzle left closed due to misoperation (fixed after start up)	Fault pressure measure leading to unavailability of trip for low low pressure which could result (in case of demand) to unavailability of the instrument air circuit with BLPH process shut down. Process upset due to uncontrolled shud down. No safety consequences expected since the desing of BLPH is based on "fail safe" concept. Total stop of production.	0.2	40	8	Low		1	0.2	40	8	Low		
22	Emergency Shut Down Systems	**Pressure Transmitter for instrument air low low pressure** (63-PT-004)	Pressure measure	Fail to function on demand	Unavailability of trip for low low pressure which could result (in case of demand) to unavailability of the instrument air circuit with BLPH process shut down. Process upset due to uncontrolled shud down. No safety consequences expected since the desing of BLPH is based on "fail safe" concept. Total stop of production.	0.2	40	8	Low		1	0.2	40	8	Low		
23	Emergency Shut Down Systems	**Pressure Transmitter for nitrogen low low pressure** (64-PT-002)	Fault	Instrument Failure (reading higher value than real)	Fault pressure measure leading to unavailability of trip for low low pressure which could result (in case of demand) to unavailability of hydrogen vent line flushing with potential for formation of flammable mixture in the vent circuit with risk of localized ignition and explosion.	0.3	100	30	Medium	1. 64-PAL-001A/B on nitrogen production line. 2. Hydrogen vent is equipped with liquid seal to prevent air ingress in the vent circuit and prevent potential formation of flammable mixture.	0.3	0.09	100	9	Low		
24	Emergency Shut Down Systems	**Pressure Transmitter for nitrogen low low pressure** (64-PT-002)	Fault	Instrument Failure (reading lower value than real)	Fault pressure measure leading to spurious depressurized shut down of BLPH, with hydrogen routed to vent to atmosphere and consequenct fire in case of ignition. The extent of damage is minimum since the hydrogen circuit vent line is located in safe position in terms of radiation levels to process equipment and the platform is normally unmanned.	0.3	50	15	Medium		1	0.3	50	15	Medium		
25	Emergency Shut Down Systems	**Pressure Transmitter for nitrogen low low pressure** (64-PT-002)	Blockage/plugged	Manual valve in the pressure transmitter nozzle left closed due to misoperation (fixed after start up)	Fault pressure measure leading to unavailability of trip for low low pressure which could result (in case of demand) to unavailability of hydrogen vent line flushing with potential for formation of flammable mixture in the vent circuit with risk of localized ignition and explosion.	0.3	100	30	Medium	1. 64-PALL-002 on nitrogen production line to activate ESD1 (depressurized shut down of hydrogen circuit) 2. Hydrogen vent is equipped with liquid seal to prevent air ingress in the vent circuit and prevent potential formation of flammable mixture.	0.2	0.06	100	6	Low		
26	Emergency Shut Down Systems	**Pressure Transmitter for nitrogen low low pressure** (64-PT-002)	Pressure measure	Fail to function on demand	Fault pressure measure leading to unavailability of trip for low low pressure which could result (in case of demand) to unavailability of hydrogen vent line flushing with potential for formation of flammable mixture in the vent circuit with risk of localized ignition and explosion.	0.3	100	30	Medium		0.2	0.06	100	6	Low		
27	Control system	**Pressure measuring element on nitrogen production line** (64-PT-001A/B)	Fault	Instrument Failure (reading lower value than real, lower failure rate since two valves in parallel)	Increase of pressure in the nitrogen circuit leading to process upset with no hazardous consequences, since DP of Hydrogen circuit is consistent with DP of N2 production package.	0.3	20	6	Low		1	0.3	20	6	Low		
28	Control system	**Pressure measuring element on nitrogen production line** (64-PT-001A/B)	Fault	Instrument Failure (reading higher value than real, lower failure rate since two valves in parallel)	Decrease of pressure in the nitrogen circuit with unavailability of hydrogen vent line flushing with potential for formation of flammable mixture in the vent circuit with risk of localized ignition and explosion	0.3	100	30	Medium	1. 64-PALL-002 on nitrogen production line to activate ESD1 (depressurized shut down of hydrogen circuit) 2. Hydrogen vent is equipped with liquid seal to prevent air ingress in the vent circuit and prevent potential formation of flammable mixture.	0.2	0.06	100	6	Low		
29	Control system	**Pressure measuring element on nitrogen production line** (64-PT-001A/B)	Blockage/plugged	Manual valve in the pressure transmitter nozzle left closed due to misoperation (fixed at start up)	Decrease of pressure in the nitrogen circuit with unavailability of hydrogen vent line flushing with potential for formation of flammable mixture in the vent circuit with risk of localized ignition and explosion	0.3	100	30	Medium	1. 64-PALL-002 on nitrogen production line to activate ESD1 (depressurized shut down of hydrogen circuit) 2. Hydrogen vent is equipped with liquid seal to prevent air ingress in the vent circuit and prevent potential formation of flammable mixture.	0.2	0.06	100	6	Low		

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30	Alarm systems	**Pressure measuring element in Instrument Air production line** (63-PT-003)	Fault	Instrument Failure (reading higher value than real)	Missed alarm activation with delay in intervention by operator with potential evolution to a more critical process condition due to low instrument air pressure	0.5	30	15	Medium	1. 63-PALL-004 activating ESD to pressurized shut down.	0.2	0.1	30	3	Low		
31	Alarm systems	**Pressure measuring element in Instrument Air production line** (63-PT-003)	Fault	Instrument Failure (reading lower value than real)	Spurious alarm activation with operational upset	0.5	30	15	Medium		1	0.5	30	15	Medium		
32	Alarm systems	**Pressure measuring element in Instrument Air production line** (63-PT-003)	Blockage/plugged	Manual valve in the pressure transmitter nozzle left closed due to misoperation	Missed alarm activation with delay in intervention by operator with potential evolution to a more critical process condition due to low instrument air pressure	0.5	30	15	Medium	1. 63-PALL-004 activating ESD to pressurized shut down.	0.2	0.1	30	3	Low		
33	Alarm systems	**Moisture measuring in Instrument Air production line** (63-AT-001)	Fault	Instrument Failure (reading lower value than real)	Missed alarm activation with delay in intervention by operator with potential evolution to a more critical process condition	0.5	30	15	Medium		1	0.5	30	15	Medium		
34	Alarm systems	**Moisture measuring in Instrument Air production line** (63-AT-001)	Fault	Instrument Failure (reading higher value than real)	Spurious alarm activation with operational upset	0.5	30	15	Medium		1	0.5	30	15	Medium		
35	Alarm systems	**Moisture measuring in Instrument Air production line** (63-AT-001)	Blockage/plugged	Manual valve in the pressure transmitter nozzle left closed due to misoperation	Missed alarm activation with delay in intervention by operator with potential evolution to a more critical process condition	0.5	30	15	Medium	1. High pressure alarm PAH001 in V-43003	1	0.5	30	15	Medium		

id	System	Element	Typology	Failure mode	Effects analysis	Original Threat Likelihood	Original Impact	Result	Risk Rating	Mitigating Measures	Mitigating Measures likelihood	Threat Likelihood	Impact	Mitigated Result	Mitigated Risk Rating	Recommendations	Notes
1	Gas detection	**Ultrasonic hydrogen upper deck** (950GZ-03101, 950GZ-03102, 950GZ-03103, 950GZ-03104, 950GZ-03105, 950GZ-03106, 950GZ-02117, 950GZ-02118, 950GZ-02119, 950GZ-02120, 950GZ-01101, 950GZ-01101)	Fault	Instrument failure (not measuring the gas leak, reduced failure rate being part of a safety loop)	Missed intervention leading to potential escalation of gas relase with consequent jet fire in case of ignition with potential for extensive damage to BLPH structure	0.2	100	20	Medium	1. Availability of other fire and gas network in the different areas of the BPLH	0.4	0.08	100	8	Low		
2	Gas detection	**Ultrasonic hydrogen upper deck** (950GZ-03101, 950GZ-03102, 950GZ-03103, 950GZ-03104, 950GZ-03105, 950GZ-03106, 950GZ-02117, 950GZ-02118, 950GZ-02119, 950GZ-02120, 950GZ-01101, 950GZ-01101)	Fault	Instrument failure (measuring a higher value than real, reduced failure rate being part of a safety loop)	Spurious depressurized shut down with gas release into the atmosphere and possibile jet fire from vent line in case of ignition. The extent of damage is very limited since the hydrogen circuit vent line is located in safe position in terms of radiation levels to process equipment and the platform is normally unmanned.	0.2	50	10	Medium	1. Availability of other fire and gas network in the different areas of the BPLH. 2. High flow alarm FAH001 on hydrogen vent line to stack	0.4	0.08	50	4	Low		
3	Gas detection	**Ultrasonic hydrogen upper deck** (950GZ-03101, 950GZ-03102, 950GZ-03103, 950GZ-03104, 950GZ-03105, 950GZ-03106, 950GZ-02117, 950GZ-02118, 950GZ-02119, 950GZ-02120, 950GZ-01101, 950GZ-01101)	Electrical failure	Instrument failure (measuring a higher value than real, reduced failure rate being part of a safety loop)	Spurious depressurized shut down with gas release into the atmosphere and possibile jet fire from vent line in case of ignition. The extent of damage is very limited since the hydrogen circuit vent line is located in safe position in terms of radiation levels to process equipment and the platform is normally unmanned.	0.2	50	10	Medium	1. Availability of other fire and gas network in the different areas of the BPLH. 2. High flow alarm FAH001 on hydrogen vent line to stack	0.4	0.08	50	4	Low		
4	Gas detection	**Point source hydrogen detectors in upper deck** (950GZ-02101, 950GZ-02102, 950GZ-02103, 950GZ-02104, 950GZ-02105, 950GZ-02106, 950GZ-02107, 950GZ-02108, 950GZ-02109, 950GZ-02110, 950GZ-02111, 950GZ-02112, 950GZ-02113, 950GZ-02114, 950GZ-02115, 950GZ-02116)	Fault	Instrument failure (not measuring the gas leak, reduced failure rate being part of a safety loop)	Missed intervention leading to potential escalation of gas relase with consequent jet fire in case of ignition with potential for extensive damage to BLPH structure	0.2	100	20	Medium	1. Availability of other fire and gas network in the different areas of the BPLH	0.4	0.08	100	8	Low		
5	Gas detection	**Point source hydrogen detectors in upper deck** (950GZ-02101, 950GZ-02102, 950GZ-02103, 950GZ-02104, 950GZ-02105, 950GZ-02106, 950GZ-02107, 950GZ-02108, 950GZ-02109, 950GZ-02110, 950GZ-02111, 950GZ-02112, 950GZ-02113, 950GZ-02114, 950GZ-02115, 950GZ-02116)	Fault	Instrument failure (measuring a higher value than real, reduced failure rate being part of a safety loop)	Spurious depressurized shut down with gas release into the atmosphere and possibile jet fire from vent line in case of ignition. The extent of damage is very limited since the hydrogen circuit vent line is located in safe position in terms of radiation levels to process equipment and the platform is normally unmanned.	0.2	50	10	Medium	1. Availability of other fire and gas network in the different areas of the BPLH. 2. High flow alarm FAH001 on hydrogen vent line to stack	0.4	0.08	50	4	Low		
6	Gas detection	**Point source hydrogen detectors in upper deck** (950GZ-02101, 950GZ-02102, 950GZ-02103, 950GZ-02104, 950GZ-02105, 950GZ-02106, 950GZ-02107, 950GZ-02108, 950GZ-02109, 950GZ-02110, 950GZ-02111, 950GZ-02112, 950GZ-02113, 950GZ-02114, 950GZ-02115, 950GZ-02116)	Electrical failure	Instrument failure (measuring a higher value than real, reduced failure rate being part of a safety loop)	Spurious depressurized shut down with gas release into the atmosphere and possibile jet fire from vent line in case of ignition. The extent of damage is very limited since the hydrogen circuit vent line is located in safe position in terms of radiation levels to process equipment and the platform is normally unmanned.	0.2	50	10	Medium	1. Availability of other fire and gas network in the different areas of the BPLH. 2. High flow alarm FAH001 on hydrogen vent line to stack	0.4	0.08	50	4	Low		
7	Gas detection	**Point source hydrogen detectors in lower deck** (950GZ-06201, 950GZ-06202, 950GZ-06203, 950GZ-06204, 950GZ-06205, 950GZ-06206, 950GZ-05101, 950GZ-05102, 950GZ-05103, 950GZ-04213, 950GZ-04214,950GZ-04215, 950GZ-04216, 950GZ-04217, 950GZ-04218)	Fault	Instrument failure (not measuring the gas leak, reduced failure rate being part of a safety loop)	Missed intervention leading to potential escalation of gas relase with consequent jet fire in case of ignition with potential for extensive damage to BLPH structure	0.2	100	20	Medium	1. Availability of other fire and gas network in the different areas of the BPLH	0.4	0.08	100	8	Low		
8	Gas detection	**Point source hydrogen detectors in lower deck** (950GZ-06201, 950GZ-06202, 950GZ-06203, 950GZ-06204, 950GZ-06205, 950GZ-06206, 950GZ-05101, 950GZ-05102, 950GZ-05103, 950GZ-04213, 950GZ-04214,950GZ-04215, 950GZ-04216, 950GZ-04217, 950GZ-04218)	Fault	Instrument failure (measuring a higher value than real, reduced failure rate being part of a safety loop)	Spurious depressurized shut down with gas release into the atmosphere and possibile jet fire from vent line in case of ignition. The extent of damage is very limited since the hydrogen circuit vent line is located in safe position in terms of radiation levels to process equipment and the platform is normally unmanned.	0.2	50	10	Medium	1. Availability of other fire and gas network in the different areas of the BPLH. 2. High flow alarm FAH001 on hydrogen vent line to stack	0.4	0.08	50	4	Low		
9	Gas detection	**Point source hydrogen detectors in lower deck** (950GZ-06201, 950GZ-06202, 950GZ-06203, 950GZ-06204, 950GZ-06205, 950GZ-06206, 950GZ-05101, 950GZ-05102, 950GZ-05103, 950GZ-04213, 950GZ-04214,950GZ-04215, 950GZ-04216, 950GZ-04217, 950GZ-04218)	Electrical failure	Instrument failure (measuring a higher value than real, reduced failure rate being part of a safety loop)	Spurious depressuried shut down with gas release into the atmosphere and possibile jet fire from vent line in case of ignition. The extent of damage is very limited since the hydrogen circuit vent line is located in safe position in terms of radiation levels to process equipment and the platform is normally unmanned.	0.2	50	10	Medium	1. Availability of other fire and gas network in the different areas of the BPLH. 2. High flow alarm FAH001 on hydrogen vent line to stack	0.4	0.08	50	4	Low		
10	Gas detection	**Point source hydrogen detectors in lower deck PS shut down** (950GZ-04207, 950GZ-04208, 950GZ-04209, 950GZ-04210, 950GZ-04211, 950GZ-04212, 950GZ-04201, 950GZ-04206, 950GZ-04203, 950GZ-04204, 950GZ-04205,950GZ-04206)	Fault	Instrument failure (not measuring the gas leak, reduced failure rate being part of a safety loop)	Missed intervention leading to potential escalation of gas relase with consequent jet fire in case of ignition with potential for extensive damage to BLPH structure	0.2	100	20	Medium	1. Availability of other fire and gas network in the different areas of the BPLH	0.4	0.08	100	8	Low		
11	Gas detection	**Point source hydrogen detectors in lower deck PS shut down** (950GZ-04207, 950GZ-04208, 950GZ-04209, 950GZ-04210, 950GZ-04211, 950GZ-04212, 950GZ-04201, 950GZ-04206, 950GZ-04203, 950GZ-04204, 950GZ-04205,950GZ-04206)	Fault	Instrument failure (measuring a higher value than real, reduced failure rate being part of a safety loop)	Spurious pressurized shut down with stop of production.	0.2	40	8	Low	1. Availability of other fire and gas network in the different areas of the BPLH. 2. High flow alarm FAH001 on hydrogen vent line to stack	0.4	0.08	40	3.2	Low		

id	System	Element	Typology	Failure mode	Effects analysis	Original Threat Likelihood	Original Impact	Result	Risk Rating	Mitigating Measures	Mitigating Measures likelihood	Threat Likelihood	Impact	Mitigated Result	Mitigated Risk Rating	Recommendations	Notes
12	Gas detection	**Point source hydrogen detectors in lower deck PS shut down** (950GZ-04207, 950GZ-04208, 950GZ-04209, 950GZ-04210, 950GZ-04211, 950GZ-04212, 950GZ-04201, 950GZ-04206, 950GZ-04203, 950GZ-04204, 950GZ-04205,950GZ-04206)	Electrical failure	Instrument failure (measuring a higher value than real, reduced failure rate being part of a safety loop)	Spurious pressurized shut down with stop of production.	0.2	40	8	Low	1. Availability of other fire and gas network in the different areas of the BPLH. 2. High flow alarm FAH001 on hydrogen vent line to stack	0.4	0.08	40	3.2	Low		
13	Fire detection	**UV-IR Flame detectors in upper deck** (950FZ-03101, 950GZ-03102, 950GZ-03103, 950GZ-03104, 950FZ-02101, 950GZ-02102, 950GZ-02103, 950GZ-02104, 950FZ-01101, 950GZ-01102, 950GZ-01103, 950GZ-01104)	Fault	Instrument failure (not measuring the gas leak, reduced failure rate being part of a safety loop)	Missed intervention leading to potential escalation of gas relase with consequent jet fire in case of ignition with potential for extensive damage to BLPH structure	0.2	100	20	Medium	1. Availability of other fire and gas network in the different areas of the BPLH	0.4	0.08	100	8	Low		
14	Fire detection	**UV-IR Flame detectors in upper deck** (950FZ-03101, 950GZ-03102, 950GZ-03103, 950GZ-03104, 950FZ-02101, 950GZ-02102, 950GZ-02103, 950GZ-02104, 950FZ-01101, 950GZ-01102, 950GZ-01103, 950GZ-01104)	Fault	Instrument failure (measuring a higher value than real, reduced failure rate being part of a safety loop)	Spurious depressurized shut down with gas release into the atmosphere and possibile jet fire from vent line in case of ignition. The extent of damage is very limited since the hydrogen circuit vent line is located in safe position in terms of radiation levels to process equipment and the platform is normally unmanned.	0.2	50	10	Medium	1. Availability of other fire and gas network in the different areas of the BPLH. 2. High flow alarm FAH001 on hydrogen vent line to stack	0.4	0.08	50	4	Low		
15	Fire detection	**UV-IR Flame detectors in upper deck** (950FZ-03101, 950GZ-03102, 950GZ-03103, 950GZ-03104, 950FZ-02101, 950GZ-02102, 950GZ-02103, 950GZ-02104, 950FZ-01101, 950GZ-01102, 950GZ-01103, 950GZ-01104)	Electrical failure	Instrument failure (measuring a higher value than real, reduced failure rate being part of a safety loop)	Spurious depressurized shut down with gas release into the atmosphere and possibile jet fire from vent line in case of ignition. The extent of damage is very limited since the hydrogen circuit vent line is located in safe position in terms of radiation levels to process equipment and the platform is normally unmanned.	0.2	50	10	Medium	1. Availability of other fire and gas network in the different areas of the BPLH. 2. High flow alarm FAH001 on hydrogen vent line to stack	0.4	0.08	50	4	Low		