Base Load Power Hub (BLPH)

Quantitative Risk Assessment (QRA)

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Table of contents

1 INTRODUCTION 8
1.1 PROJECT OVERVIEW 8
1.1.1 Project Location 8
1.1.2 Project Concept 9
2 EXECUTIVE SUMMARY 11
2.1 MAIN REFERENCES 13
2.2 DEFINITIONS AND ABBREVIATIONS 14
2.2.1 Definitions 14
2.2.2 Abbreviations 16
3 STRUCTURE OF THE REPORT 17
4 RISK ANALYSIS 18
4.1 hazard identification and failure case definition 19
4.1.1 Isolatable section identification 19
4.1.2 Loss of Containment Cases Identification and Selection 19
4.1.3 Risk from CPIs 21
4.2 FREQUENCY ANALYSIS 22
4.2.1 Isolatable section frequency analysis 22
4.2.2 Scenarios frequency analysis 23
4.2.3 Consequences analysis 24
4.3 Risk Calculation 25
4.3.1 LSIR calculation 25
4.3.2 QRA acceptability criteria 25
4.3.3 Platform manning level 26
5 RESULTS 27
5.1 LOCATION OF RELEASE IN THE PLATFORM 27
5.1.1 Scenario resummation for each deck 33
5.2 LSIR CONTRIBUTION 34
5.2.1 LSIR calculation for lower deck 34
5.2.2 LSIR calculation for upper deck 40

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5.2.3 LSIR conclusion 45
5.3 IRPA CALCULATION 46
5.3.1 Process hazard risk 46
5.3.2 Non Process hazard risk 47
5.3.3 Total IRPA results 49
6 CONCLUSIONS AND RECOMMENDATIONS 50
6.1 QRA CONCLUSIONS 50
ATTACHMENT 1 ISOLATABLE SECTIONS ON P&ID 51
ATTACHMENT 2 PARTS COUNT RESULTS 57
ATTACHMENT 3 EVENT TREE ANALYSIS 66
ATTACHMENT 4 A LOCS AND SCENARIOS (RS SCOPE OF WORK) 71
ATTACHMENT 4 B LOCS AND SCENARIOS (CPIs PACKAGE) 76
ATTACHMENT 4 C DETAILED ANALYSIS OF EXPLOSION SCENARIOS WITHIN PLATFORM BOUNDARY 78
ATTACHMENT 5 QRA: LSIR FROM LOWER DECK 107
ATTACHMENT 6 QRA: LSIR FROM UPPER DECK 112
ATTACHMENT 7 QRA: ASSUMPTION REGISTER 117

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List of Figures

Figure 1 HOLLANDSE KUST NOORD WIND PARK Location Map 8
Figure 2 - Wind Park Details 9
Figure 3 – BLPH Concept 9
Figure 4 – QRA acceptability criteria 25
Figure 5 – Section 1 piping routing 27
Figure 6 – Section 1 scenario consequences (37.5 kW/m^2) 28
Figure 7 – Section 2 LOC 2.1 piping location 29
Figure 8 – Section 2 LOC 2.1 scenarios consequences (37.5 kW/m^2) 29
Figure 9 – Section 2 LOC 2.2 piping routing 30
Figure 10 – Section 2 LOC 2.2 scenarios consequences (37.5 kW/m^2) 31
Figure 11 – Section 3 piping routing 32
Figure 12 – Section 3 scenario consequences (37.5 kW/m^2) 33
Figure 13 –- LSIR for lower deck 35
Figure 14 – Jet fire contribution to LSIR for lower deck 36
Figure 15 – Flash fire contribution to LSIR for lower deck 38
Figure 16 – VCE contribution to LSIR for lower deck 39
Figure 17 –- LSIR for upper deck 40
Figure 18 – Jet fire contribution to LSIR for upper deck 42
Figure 19 – Flash fire contribution to LSIR for upper deck 44
Figure 20 – Flash fire contribution to LSIR for lower deck 45
Figure 21 – P&ID isolatable section 1 52
Figure 22 – P&ID isolatable section 3 53
Figure 23 – P&ID isolatable section 1,2 54
Figure 24 – P&ID isolatable section 2,3 55
Figure 25 – P&ID isolatable section 2 56

List of tables

Table 1 - Reference Documents 13
Table 2 - Definitions 15

Table 3 - Abbreviations 16
Table 4 – Isolatable section limits 19
Table 5 – LOCs from isolatable sections 20
Table 6 – LOCs operative conditions 20
Table 7 – LOC frequency of occurrence 23
Table 8 – IRPA acceptability criteria 26
Table 9 – LSIR values for main platform area on lower deck 35
Table 10 – LSIR values for main platform area on upper deck 41
Table 11 – IRPA values 46
Table 12 – FAR calculation 47
Table 13 – IRPA for occupational risk 48
Table 14 – IRPA for dropped object 48
Table 15 – IRPA for ship collision 48
Table 16 – IRPA for structural hazards 49
Table 17 –Total IRPA calculation 49
Table 18 - Definitions 121
Table 19 – Abbreviations 122
Table 20 – Assumption sheet template 123
Table 21 – Assumption #1 124
Table 22 – Assumption #2 125
Table 23 – Assumption #3 127
Table 24 – Assumption #4 128
Table 25 – Assumption #5 130
Table 26 – Assumption #6 132
Table 27 – Assumption #7 134
Table 28 – Assumption #8 135
Table 29 – Assumption #9 137
Table 30 – Assumption #10 139
Table 31 – Assumption #11 140
Table 32 – Assumption #12 141
Table 33 – Assumption #13 142
Table 34 – Assumption #14 143

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Table 35 – Assumption #15 144
Table 36 – Assumption #16 145

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.

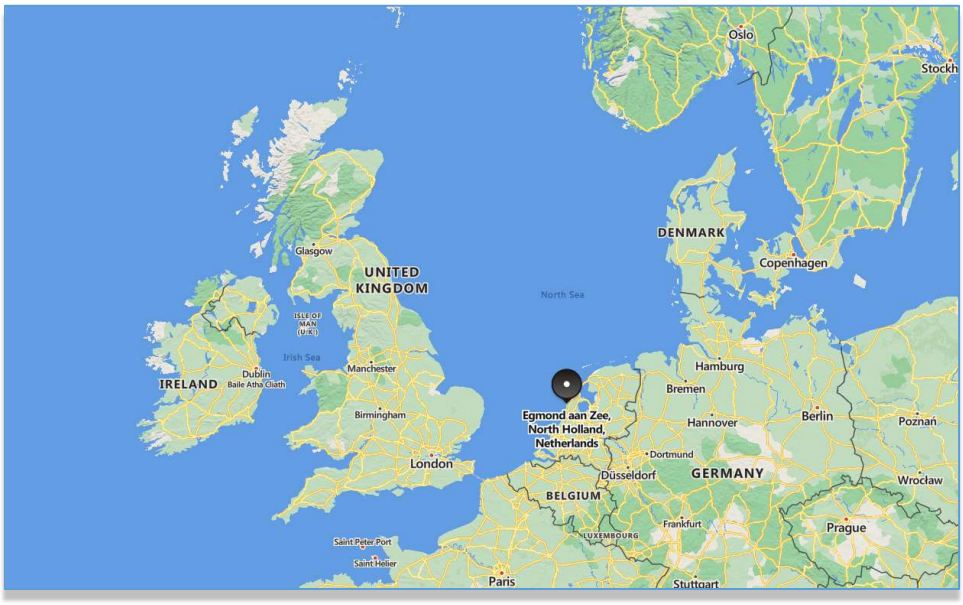


Figure 1 HOLLANDSE KUST NOORD WIND PARK Location Map

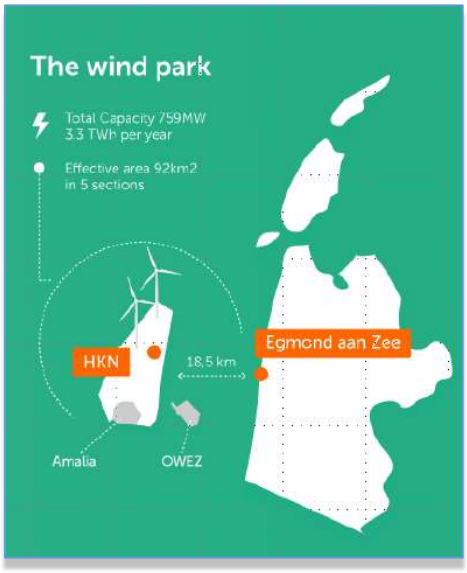


Figure 2 - Wind Park Details

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 topsides 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.

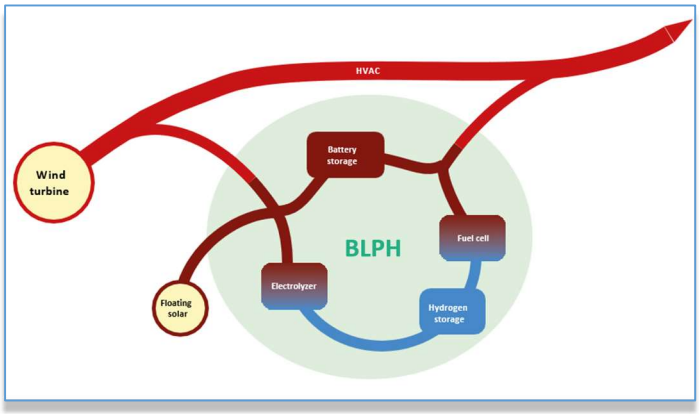


Figure 3 – BLPH Concept

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.

2 EXECUTIVE SUMMARY

This document has the purpose of detailing the results of the Quantified Risk assessment (QRA) study for the new Base Load Power Hub (BLPH) which will be installed in the framework of HOLLANDSE KUST NOORD WIND PARK Project. The scope of this document is limited to the topsides structure and associated facilities up until connection with the monopile, and include the risk related to CPIs packages in service when operator presence is foreseen. The monopile itself is not within the scope of this document.

Following objectives are included in the scope of the study:

- to identify fire and explosion scenarios from the equipment inside the scope of work;
- to calculate damage distances for fire, explosion and flammable release scenarios to determine potential for impact on the health of operators;
- suggest suitable risk reduction measures, if required.

To achieve this objective, a thorough analysis has been made on all hazardous substance and streams within the new equipment part of the project.

Parts count approach has been applied to identify all of the possible sources of loss of containment (lines, flanges, valves, equipment) and consequently to calculate the corresponding leakage frequencies for all the section of the plant with hazardous substances.

The system has been segmented into isolatable sections, for the identification of Loss of containment cases (LOC). Each isolatable section is characterized by one or more LOCs, on the basis of characteristics of the handled fluid.

Three leak size categories have been identified for a wider representation of the risk by different LOCs. The consequence assessment has been performed with the software PHAST from DNV. All the identified scenarios have been located in the plot plan. With application of a dedicated software, it has been possible to combine their contribution to determine the impact of new equipment in the scope of the project in order to evaluate the acceptability of fire and explosion scenarios.

The main findings of the QRA study are reported below.

- Based on LSIR curves, it is possible to conclude that the risk at lower deck shows low values compared with the risk at upper deck area. The maximum calculated value of the LSIR is equal to 3.0E-05 occ/year.

  The main contribution to the risk at the lower deck comes from VCE scenario: as discussed in the report, the VCE from thermal runway of BESS system shows frequency of occurrence equal to 1.0E-05 occ/year, which is higher than other scenarios such as jet fire and flash fire scenarios. In addition, the VCE contribution for lower deck considers also the contribution of VCE from other section located in the upper deck: according to damage thresholds, in case of explosion, potential impact on operator at lower deck is expected. In conclusion, the contribution to the total risk from jet fire and flash fire for lower deck is lower compared to the VCE risk, considering also the contribution from upper deck.

- The upper deck shows higher risk, both in terms of frequency of occurrence and damage distances, due to the presence of the H_2 storage system, confirming that the risk coming from section 2 is the "worst case" in terms of risk from the platform. The maximum calculated value of the LSIR is equal to 6.3 E-05 occ/year.

  Jet fire shows a significant contribution, involving all the platform area with frequency about 1.0E-05 occ/year. For this case, the jet fire from LOC 2.2 is the worst-case scenario. For upper deck, the explosion contribution, even if still in the order of 1-0E-05 occ/year, is lower than the contribution of jet fire scenarios, which covers the entire platform area.

- Process IRPA for operator, for each area of the platform, is always lower than target frequency of 1.0E-06 occ/year, as expected, due mainly to the minimized time at platform and the conditions of the platform itself. The risk is classified inside the "acceptable" region based on acceptability criteria and no additional barrier is deemed necessary.

- IRPA risk screening vs. tolerability criteria highlight that no intolerable risks are experienced. The highest contribution is the one associated to non-process hazards (96%), while the one associated to process hazard (fire and explosion scenarios) contributes only for 4% to the total IRPA.

2.1 MAIN REFERENCES

Ref.	Description
1	123A90-DDL-SAF-LIS-30014 – Assumption Register
2	K559-2254-SE-REP-007 - Fire and Explosion Risk Analyses (FERA) (note: study for FEED phase)
3	BLPH_MODEL_11-01-24 (3D model of platform)
4	123A90-DDL-PR-RE-80040 – Process Design Philosophy
5	123A90-DDL-PR-DG-80003 rev 01 //123A90-DDL-PR-DG-80005 rev 01- PFD
6	123A90-DDL-PR-PID-80011, rev 01//123A90-DDL-PR-PID-80020 rev01, – P&ID
7	123A90-DDL-SAF-RE-30046 – HSE Design Philosophy, rev 01, 16/10/2023
8	123A90-DDL-PR-BL-80002 – H&MB, rev 01, 09/11/2023
9	K559-2254-PM-PLN-003 – BDEP – Basic Design Engineering Package revision 1
10	Packages FERA assessment rev 1.0
11	IOGP Report 434-12 Occupational risk - 2010
12	IOGP 434-16 Ship/installation collisions – 2010
13	IOGP 434-13 Structural risk for offshore installations- 2010
14	IOGP 434-8 Mechanical lifting failures- 2010
15	IOGP 434-5 Human factors in QRA- 2010

Table 1 - Reference Documents

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2.2 DEFINITIONS AND ABBREVIATIONS

2.2.1 Definitions

COMPANY or Client (CPY):	Crosswind
EPC CONTRACTOR (CTR):	ROSETTI MARINO S.p.A.
PROJECT:	HOLLANDSE KUST NOORD WIND PARK Project
CONSEQUENCES	The outcome of an event. For the purpose of this project, the outcome is identified in terms of harm to exposed persons and assets.
EVENT	Occurrence or change of a particular set of circumstances.
EVENT TREE	Logical qualitative and quantitative representation of accident sequences, from initial release to final scenarios (fire, explosion, and flammable / toxic gas dispersion).
FAILURE	Damage of equipment which can lead to release of substances from the process.
FIRE	The outcome of combustion of flammable substance released in the atmosphere as a consequence of a LOC, which can produce effects to exposed persons and to process equipment and structure due to thermal radiation.
FLASH FIRE	An accelerated combustion of a vapor cloud without significant overpressure consequences.
FREQUENCY	The estimated number of events per defined unit of time (normally refereed to one-year time).
IRPA	Frequency at which an individual may be expected to sustain lethal levels of harm from the realisation of specified hazards. It is usually taken to be the risk of death and expressed as a risk per year.
HAZARD	Situation having the potential to cause harm, including ill health and injury, damage to property, production losses, or increased liabilities
IGNITION	(probability): A number in a scale from 0 to 1 which expresses the likelihood that ignition event will occur, based on substances characteristic.
JET FIRE	It is a turbulent diffusion flame resulting from the combustion of a fuel continuously released with some significant momentum in a particular direction or directions. Jet fires can arise from releases of gaseous, flashing liquid (two phase) and pure liquid inventories.
LSIR	Risk expressed as likelihood of fatality per year at a particular location on the basis of continuous exposure (24 hours per day, and 365 days per year)

LOC	Loss of Containment. The event associated with the release of a hazardous substance from equipment leading to a potential accident scenario
PARTS COUNT	The counting of any piece of equipment pertaining to a given isolatable section. This task is handled in order to calculate a generic leak frequency value for generic types of cause
QRA	Quantitative Risk Assessment. For the purpose of this study, a comprehensive risk evaluation focused on the identification of the impact to persons (workers) due to effects of accident scenarios due to LOCs of hazardous substance handled in equipment to be installed during project development. Due to location of the installation, external risk for external people is considered not applicable.
RANDOM LOSS	A loss of containment from piping and equipment due to random causes which leads to a release of a hazardous substance in the environment.
RECOMMENDATIONS	Improvements /actions required to reduce the identified risk if not acceptable.
RISK	Combination of frequency and consequence of scenarios. For the purpose of the present project, the risk is evaluated on exposed persons and on project equipment, due to the effects of events caused by LOC of hazardous substances
RISK CONTOUR	A risk contour is the locus of points that geographically describes the location of a specific risk level. This risk will be defined by a pre-determined type of harm (e.g., fatality) at a specific frequency (e.g., 1.0 x 10-6/year).
SCENARIO	The final form assumed by the development of the accidental sequence started by a LOC, in terms of fire, explosion, and/or flammable / toxic gas dispersion in the atmosphere.
STABILITY CLASS	Characteristic state of the atmosphere that influences the dispersion of gas. The higher the stability, the lower is the dilution effect due to vertical air movement.

Table 2 - Definitions

2.2.2 Abbreviations

ALARP	As Low As Reasonably Practicable
BESS	Battery Energy Storage System
BDV	Blow own valve
BLPH	Base Load Power Hub
BMS	Battery Management System
CPI	Company Provided Item
DNV	Det Norske Veritas
ESD	Emergency Shut-Down
ETA	Event Tree Analysis
FAR	Fatal Accidental Rate
H&MB	Heat and Material Balance
HyRAM	Hydrogen Risk Assessment Model
HKN	Hollandse Kust Noord
HSE	Health, Safety and Environment
IOGP	International Association of Oil & Gas Producers
IRPA	Individual Risk Per Annum
LFL	Lower Flammable Limit
LSIR	Location Specific Individual Risk
LOC	Loss Of Containment
MW	Megawatt
P&ID	Piping and Instrumentation Diagram
PFD	Process Flow Diagram
PHAST	DNC software for modelling discharge, dispersion, fires, explosion and toxic effect of a wide range of loss of containment scenarios.
QRA	Quantitative Risk Assessment
SDV	Shut Down Valve
VCE	Vapour Cloud Explosion
VooW	Van Oord Offshore Wind
WTG	Wind Turbine Generator

Table 3 - Abbreviations

3 STRUCTURE OF THE REPORT

The Report is structured in the following parts:

- QRA summary report, which includes:
  - Introduction to the project and scope of present QRA,
  - Executive summary, which reports main results,
  - Risk analysis, where the methodology is fully described and applied to the platform, in order to calculate frequency of occurrence and damage distances of each scenarios;
  - Results, where are detailed the iso-contours from the resummation of scenarios;
  - Conclusion and recommendation, where the identified risk is compared to the acceptability criteria and some recommendations are raised.
- Attachment, including:
  - Attachment 1: Isolatable Section identification on PFDs.
  - Attachment 2: Parts count results.
  - Attachment 3: Event Tree Analysis.
  - Attachment 4A: Summary table listing all LOCs and Scenarios (RM scope of work).
  - Attachment 4B: Summary table listing all LOCs and Scenarios (CPIs package).
  - Attachment 4C: Detailed analysis of explosion scenarios within platform boundary
  - Attachment 5: LSIR from lower deck.
  - Attachment 6: LSIR from upper deck .
  - Attachment 7: Extract of the document "Assumption Register", doc n 123A90-DDL-SAF-LIS-30014 – rev2

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4 RISK ANALYSIS

The QRA study is aimed at the definition of the risk as a combination between the frequency of occurrence of dangerous scenarios and relevant consequences. The studies have been developed according to the following steps:

- Hazard Identification and Failure case definition: identification of isolatable sections of the unit and LOC cases, analysis of process conditions, layout constraints and failure case foreseen for each section;
- Frequency analysis: assessment of LOC cases frequency, assignment of immediate/delayed ignition probability, and determination of the associated scenarios' frequencies for each LOC case;
- Consequences analysis: assessment of damage distances of each identified scenario;
- Risk calculation: the combination of damage distances and frequency for each scenario on the platform plot plan and development of contours from the overall risk grid values;
- Risk comparison with a standard: the calculated risk level is finally compared with Risk Tolerability Criteria to evaluate its acceptability.

More details like hazard identification, frequency, consequences modelling, and main assumption are described in the Assumption register document [1]. For completeness, an extract from this document is also reported in Attachment 7.

The application of the methodology is reported in the following paragraphs.

4.1 HAZARD IDENTIFICATION AND FAILURE CASE DEFINITION

The QRA study needs to consider the risk coming from the equipment in the scope of the project, both from Company (CPIs) and EPC Contractor.

For storage vessels and interconnection lines, in the scope of EPC contractor, the risk is calculated on the basis of part count and consequence simulation.

On chapter 4.1.3 the risk from CPIs package is summarized, on the basis of detailed study provided by CW regarding expected LOC and damage distances [10]

4.1.1 Isolatable section identification

The isolatable sections identification allows recognizing the number of equipment to be considered for LOC frequency, on the basis of the methodology criteria illustrated in [1]. In the below table the isolatable sections are summarized. The isolatable sections include the equipment in the scope of the project which handled, in the normal operative condition, hazardous fluids.

The isolatable sections on P&ID [6] are reported in **Attachment 1**.

#	Isolatable section	Description	Isolatable section boundary
1	Electrolyser A-20000 area and purification	Electrolyser connection piping to storage	From Electrolyser package A-20000 up to 25-SDV-001
2	Storage system area	Storage vessel V-25001 A/B/C/D/E/F and connected piping	From 25-SDV-001 to 25-BDV-003 (upstream vessels); 25-BDV-005/007/010/013/016/019 (located on storage vessels) and 25-BDV-022, 25-SDV-023 (downstream vessels).
3	Fuel Cell package A-80000 area	Fuel Cell connection piping to storage	From 25-BDV-022 to fuel cell package A-80000

Table 4 – Isolatable section limits

4.1.2 Loss of Containment Cases Identification and Selection

The selection of LOC cases takes into consideration the risks associated to process hazards for the isolatable section. The following table shows the LOC cases identified for each isolatable section.

#	Isolatable section	Description	LOC cases	
1	Electrolyser A-20000 area and purification	Electrolyser connection piping to storage	1.1	Release from electrolyser outlet piping to storage section
2	Storage system area	Storage vessel V-25001 A/B/C/D/E/F and connected piping	2.1	Release from storage connection piping (1.5 inches)

#	Isolatable section	Description	LOC cases	
			2.2	Release from BDV connecting piping on top of storage vessel (3 inches)
3	Fuel Cell package A-80000 area	Fuel Cell connection piping to storage	3.1	Release from vessels outlet piping to fuel cell package

Table 5 – LOCs from isolatable sections

For isolatable section 2, two reference LOC are identified:

- LOC 2.1, which represent the possible release from the inlet and outlet piping from the storage vessels. These piping, which connect all the vessels, are well distributed on upper deck, with length of about 110 meters and 1" diameter, and about 40 meters for 1.5 inches.
- LOC 2.2, which represent the possible release from the piping which connect each vessel to the proper BDV valves. These piping are located on platform above each vessel, with length of about 2 meters and 3" diameter. Considering the specific location and the expected consequences due diameter, an additional LOC was performed for such equipment.

The reference operative conditions for each isolatable section are reported in the table below.

LOC cases		Stream number	Pressure (barg)	Temperature (C°)	Volume (m3)	Hold up of isolatable section (piping+equipment, Kg)
1.1	Release from electrolyser outlet piping to storage section	02	30	65	0.02	0.05 kg
2.1	Release from storage connection piping (1.5 inches) (note 1)	02	30	65	0.18 + 96 (single storage)	0.4 (piping) + 1200 kg (200 kg each vessel)
2.2	Release from BDV connecting piping on top of storage vessel (3 inches)	02	30	65	0.18 + 96 (single storage)	0.4 (piping) + 1200 kg (200 kg each vessel)
3.1	Release from vessels outlet piping to fuel cell package (note 2)	05	30	25	0.08	0.2 kg

Table 6 – LOCs operative conditions

Note 1: The hydrogen storage system consists of 6 horizontal vessels (V-25001A/B/C/D/E/F), with a combined total storage of 1200 kg. As for process information, all vessels are aligned with the process, meaning that, in case of release, the hold up of all vessels can be potentially involved in the release (SDV valves are locate upstream and downstream the storage section).

Note 2: Inside the isolatable section 3 is located the pressure controller (25-PIC-025A) which reduce the pressure for 30 to 6.5 barg. Anyway, as a conservative approach, for consequences simulation the pressure

upstream 25-PIC-025A is considered as reference for consequences calculation for the isolatable section (30 barg instead 6.5barg).

Each LOC was analysed in terms of release with n. 3 different opening sizes, as reported below:

small hole: 5 mm;

medium hole: 25 mm;

large hole: full bore.

4.1.3 Risk from CPIs

There are 3 CPI packages in the CW scope:

- Electrolyser,
- Fuel cell,
- BESS,

each of these packages have a fire/explosion risk. Detailed information about calculation methodology and assumptions are reported in project documentation [10]; main results in term of frequencies of occurrence and damage distances are summarized in the present chapter.

According to project philosophy and detailed technical query, in case of operator presence in platform, the Electrolyser and the Fuel cell package are not in service, meaning that not H_2 production is foreseen, thus the risk from such equipment are excluded from calculation.

BESS

Regarding BESS, a possible hydrogen build up during a Thermal Runaway (TR) and consequent explosion inside the container is considered, both in term of frequency of occurrence and damage distances.

Results of frequency and consequences simulation are reported in Attachment 4B.
Note than "missiles" from the container itself have been excluded in the escalation potential, due uncertainty regarding possible formation, direction and impact energy.

4.2 FREQUENCY ANALYSIS

4.2.1 Isolatable section frequency analysis

In terms of frequency, the overall value associated with LOC cases on each isolatable section has been calculated applying the parts count method. On the basis of P&IDs and unit layout, the numbers of components (valves, flanges, equipment, and pipe length) have been identified in the LOC source in order to perform a parts count. Parts count results have been combined with the basic failure frequencies, in order to calculate all leakage frequencies for each hole size. The main findings of parts count for each LOC are included in Attachment 2.

For frequency calculation, as a conservative approach, all the equipment is considered continuously in function (365/365 days). Anyway, considering the scope of the plant, some system can be not continuously in service.

For instance, the Fuel Cell and electrolyzed package are not in operation due process requirements, meaning that also the connection piping from storage vessels is not in function, leading to decrease the risk, in terms of frequency (due some not-operating hours) and in term of consequences (piping is isolated from the storage).

Note that the full-bore release diameter depends on the size of each piping where LOC is located. In the following table, overall release frequency for each LOC is summarized, considering the no. 3 associated opening sizes.

Section	LOC cases		Small release (occ/year)	Medium release (occ/year)	Full bore (occ/year)	
			5mm	25mm	Diameter mm	Frequency
1	1.1	Release from electrolyser outlet piping to storage section	3.0E-04	1.8E-04	Note 1	
2	2.1	Release from storage connection piping (1.5 inches)	5.6E-03	3.3E-03	37.5 (1.5 inches)	3.4E-04
	2.2	Release from BDV connecting piping on top of storage vessel (3 inches)	1.0E-03	4.3E-04	75 (3 inches)	1.7E-04
3	3.1	Release from vessels outlet piping to fuel cell package	9.3E-04	5.0E-04	50 (2 inches)	4.1E-05

Table 7 – LOC frequency of occurrence

Note 1: for section 1, the equipment show diameter equal to 1", meaning that the 25 mm case correspond full-bore case.

4.2.2 Scenarios frequency analysis

In case of ignition of hydrogen, following scenarios are possible:

- Jet fire (in case of immediate ignition);
- Flash fire (in case of delayed ignition);
- Vapor Cloud Explosion (in case of delayed ignition in confined area);
- dispersion in the atmosphere (without ignition).

In order to qualify and quantify all potential outcome scenarios, the "Event Tree" technique is applied.

The "Event Tree" technique is a logical qualitative and quantitative representation of accident sequences, from initial release to final scenarios (fire, explosion, and dispersion), taking into consideration substances characteristic, released mass, process condition and ignition probability.

According to assumption register, the event tree includes the probability of failure of ESD system: in case of effective intervention of ESD system, the duration of scenarios will be limited by the hold up of the isolatable section after the SDV valves closure ("isolated scenarios"), instead, in case of ineffective intervention of ESD system ("not-isolated scenarios"), the scenarios duration continues according to the process parameters and is not limited by the closure of SDV valves.

Considering that the scope of QRA is to identify the risk for operator, for risk resummation all the scenarios was included, without taking credit of jet fire duration: also jet fire with low duration (e.g. jet fire originated from medium or large holes of isolated cases) could have a severe impact on operators.

Thus, the frequency of occurrence of each hazardous scenarios reported in Attachment 3 is equal to the sum of "isolated" and "not-isolated" scenarios.

4.2.3 Consequences analysis

The study on the physical effects of each identified scenario (radiation, overpressure, etc.) has been performed applying the dedicated software package Phast released by DNV (release 9), with the damage threshold limits established in "Assumption register" [1].

The package has been used to calculate the following effects:

- radiation curves associated with fire scenarios (jet fire);
- overpressure values associated with explosions;
- flammable concentration profile associated with gas dispersion.

The selection of the threshold values allows the determination of the risk for operators in terms of radiation, flammable gas concentration and overpressure.

The orientation of the release is an important factor because it defines the orientation of jet fires and their impact. The orientations of release are modelled as follows:

- horizontal non-impinged for jet fire, in order to maximize damage distances scenarios.
- horizontal (50 % of probability) and down impingement (50 % of probability) for flammable gas dispersion (which leads to explosion), in order to maximize damage distances scenarios.

Damage distances associated with each basic LOC and generated scenarios are provided in Attachment 4A

In order to properly calculate the expected consequences in case of explosion, a detailed analysis was performed with the aim to identify, for each LOC, the amount of flammable gas included in the platform boundary. In other terms, only the flammable mass within the platform is considered for explosion calculation. Thus, for each LOC, four release direction are considered (north, south, east, west) and, on the basis of maximum extension of LFL gas clouds and platform boundary, a percentage of LFL involved in the platform is obtained, and consequently, the flammable mass involved in the explosion for such direction. This flammable mass is selected for consequences simulation.

In terms of frequency, the total frequency of occurrence is subdivided considering the four main direction before the risk resummation. This approach allows a more detailed calculation of explosion scenarios for each LOC considering the main direction of the release and the flammable mass involved in each explosion.

Detailed calculation of consequences and frequency of occurrence, for each direction, is reported in Attachment 4C.

4.3 RISK CALCULATION

4.3.1 LSIR calculation

The Location Specific Individual Risk (LSIR) is the expected frequency of death of a hypothetical person assumed to be continuously present at a specific location. It is usually expressed as a risk of fatality per year and presented in form of risk contours. The risk exposure is calculated for all identified hazards and each contribution is summed to provide the overall risk for the area of the installation.

The main steps for risk contours calculation are reported below:

- frequency calculation of the hazardous scenario (VCE, flash fire, jet fire events);
- calculation of consequence of each scenario (in terms of thermal flux or flammable gas cloud extension or overpressure);
- assessment of fatality probability for each scenario consequences;
- geo-referencing of each scenario in the plant layout;
- contour plot calculation by definition of a squared grid around the plant.

Calculations will be performed by application of a dedicated ArcGis 9.3 model for geographical data management. The software provides the sub-division of the overall complex by means of a specific grid. In each position (x,y) of the grid, the total frequency is calculated as composition (numerical sum) of the frequencies of impact of the single impact scenario.

4.3.2 QRA acceptability criteria

QRA results have been compared to acceptable risk criteria in order to provide risk-based support to suggest appropriate actions focused on risk reduction for exposed personnel.

The following graph represents risk acceptability as a function of individual risk frequency (fatality per year).

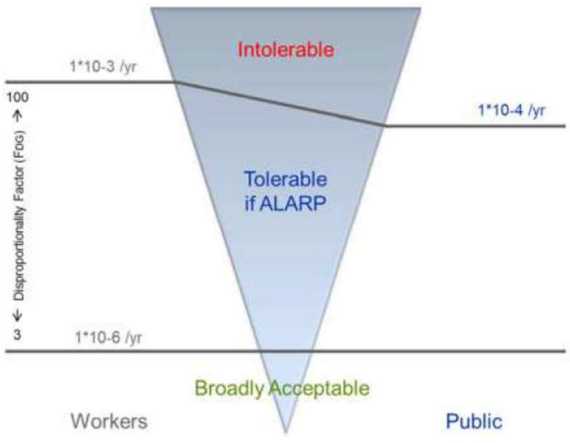


Figure 4 – QRA acceptability criteria

This approach is related to the identification of three risk regions (unacceptable, ALARP and broadly acceptable), to which is assigned different frequency values for unacceptable risk threshold. Reference Individual Risk acceptability thresholds are indicated in the following table.

LOCATION	**IRPA (fatality/ year)**		
	Risk region: **Unacceptable**	**Risk region:** **ALARP**	**Risk region:** **Broadly acceptable**
Platform area	> 1 x 10-03	1 x 10-03 ≥ IR ≤ 1 x 10-06	IR < 1 x 10-06

Table 8 – IRPA acceptability criteria

Considering the location of the platform, risk for public is considered not applicable and are not calculated in the risk evaluation.

4.3.3 Platform manning level

Considering that the platform is unmanned and not normal operation which requires operator intervention are foreseen, the expected people presence is due only for planned maintenance activities. Additionally, operators shall go to the platform only when the system is depressurized, so hydrogen risk is minimised. Nevertheless, in order to be conservative, the analysis was carried out assuming the pressurized system in normal conditions.

At this stage of the project, planned maintenance activities are foreseen for 1 day each 6 months, meaning 2 days (16 hours) in 365 days (8760 hours), for a maximum of 10 operators. The presence factor is equal to 0.0018. The real people exposure allows a more realistic estimate of the risk for each operator.

5 RESULTS

5.1 LOCATION OF RELEASE IN THE PLATFORM

In the present chapter, a description of the release locations in each deck is reported, in order to identify the contribution on the risk for the operator in each deck.

Section 1

The isolatable section 1 includes the connection piping from the electrolyser up to the isolation valve 25-SDV-001 located upstream the storage vessels section. Considering that the piping size is equal to 1", according to procedure, two release hole was calculated (5 mm and 25 mm, corresponding to full bore rupture); the release rate is equal to 0.03 and 0.76kg/s respectively. Due to limited piping extension (about 33 meters), the hold up of the section is low.

In the following figure is reported (in a simplified way) the main piping route on 3D model. The piping, starting from electrolyser package up to 25-SDV-001 valve, are located almost for the entire route below the upper level; only in proximity of the valve, the line passes through the upper-level plated level.

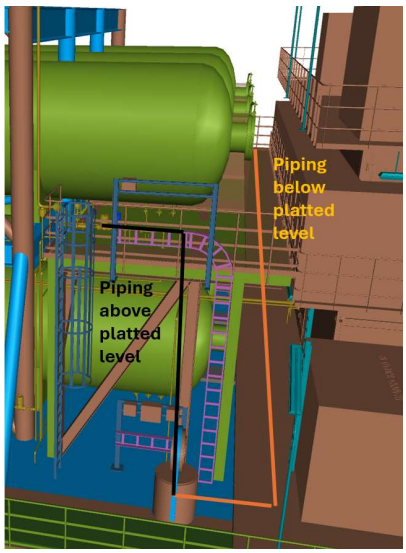


Figure 5 – Section 1 piping routing

In the following figure is reported (as example) the calculated damage distances on piping route for the 37.5 kW/m^2 threshold from jet fire from 5 and 25 mm release, which correspond to 100% fatality.

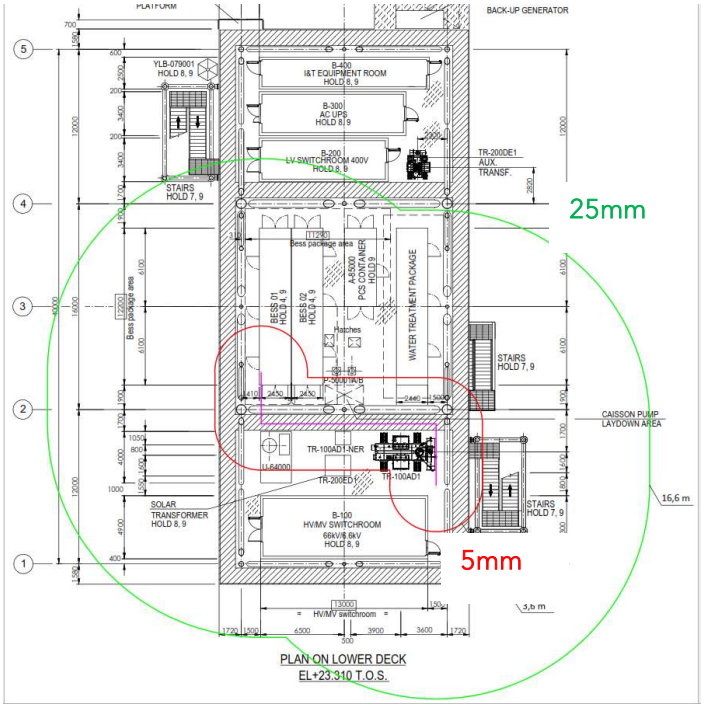


Figure 6 – Section 1 scenario consequences (37.5 kW/m²)

On the basis of piping route, it is possible to conclude that the major effect of section 1 for jet fire and flash fire is expected in the lower deck. In the contrary, VCE scenarios can show severe impact on structures, potentially involved also upper deck. Same consideration is applicable to BESS system, which is located in the lower deck.

Jet fire from Section 2

The isolatable section 2 includes the piping from the electrolyser package (25-SDV-002), the six storage vessel and the piping up to the fuel cell package (25-SDV-023). Two reference scenarios were selected, on the basis of piping diameter and release location.

LOC 2.1: Release from storage connection piping (1.5 inches)

The piping connecting the storage vessels are distributed in the upper level (inlet ant outlet line from the vessel) with maximum size equal to 1.5"; according to procedure, three release hole was calculated (5 mm, 25 mm and 37.5 mm); the release rate is equal to 0.03, 0.76 and 1.70 kg/s respectively.

The piping, starting from the valve 25-SDV-001, includes the inlet main header and the outlet main header from the vessels, up to valve 25-SDV-023. The piping is located at different height in upper level and includes the hold up of all vessels (about 1200 kg).

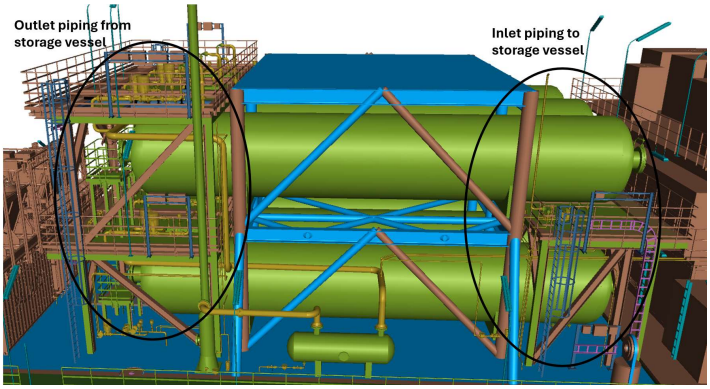


Figure 7 – Section 2 LOC 2.1 piping location

In the following figure is reported (as example) the calculated damage distances on piping route for the 37.5 kW/m^2 threshold from jet fire from 5, 25 and 50 mm release, which correspond to 100% fatality.

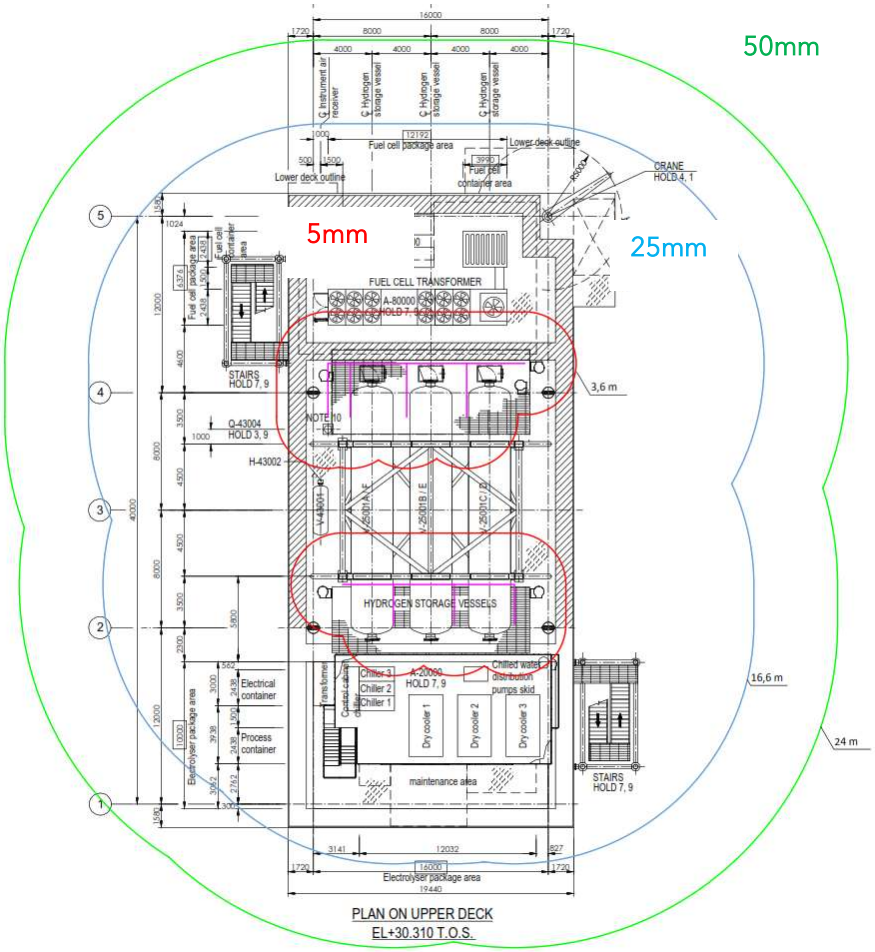


Figure 8 – Section 2 LOC 2.1 scenarios consequences (37.5 kW/m^2)

On the basis of piping route, it is possible to conclude that the major effect of section 2, LOC 2.1 for jet fire and flash fire is expected in the upper deck. Regarding lower deck, considering the presence of a plated area, the thermal radiation will be limited, at least for the required time to operator to ensure a safety evacuation from the platform.

In the contrary, VCE scenarios can show severe impact on structures, potentially involved also lower deck.

LOC 2.2: Release from BDV connecting piping on top of storage vessel (3 inches)

Each storage vessel is provided with a BDV connected by a 3 inches lines. According to procedure, three release hole was calculated (5 mm, 25 mm and 75 mm); the release rate is equal to 0.03, 0.76 and 7.0 kg/s respectively.

In the following figure is reported (in a simplified way) the main location of the piping in the 3D model. The piping is located at different height in upper level, above each storage vessel.

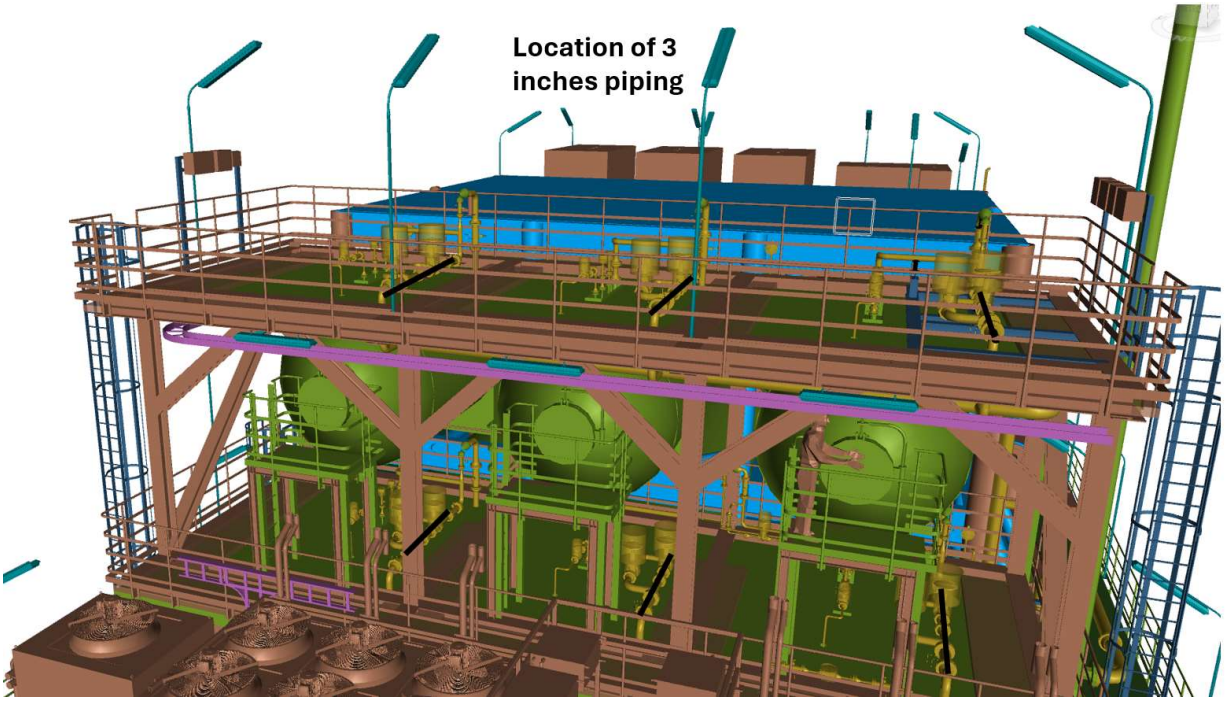


Figure 9 – Section 2 LOC 2.2 piping routing

In the following figure is reported (as example) the calculated damage distances on piping route for the 37.5 kW/m^2 threshold from jet fire from 5,25 and 75 mm release, which correspond to 100% fatality.

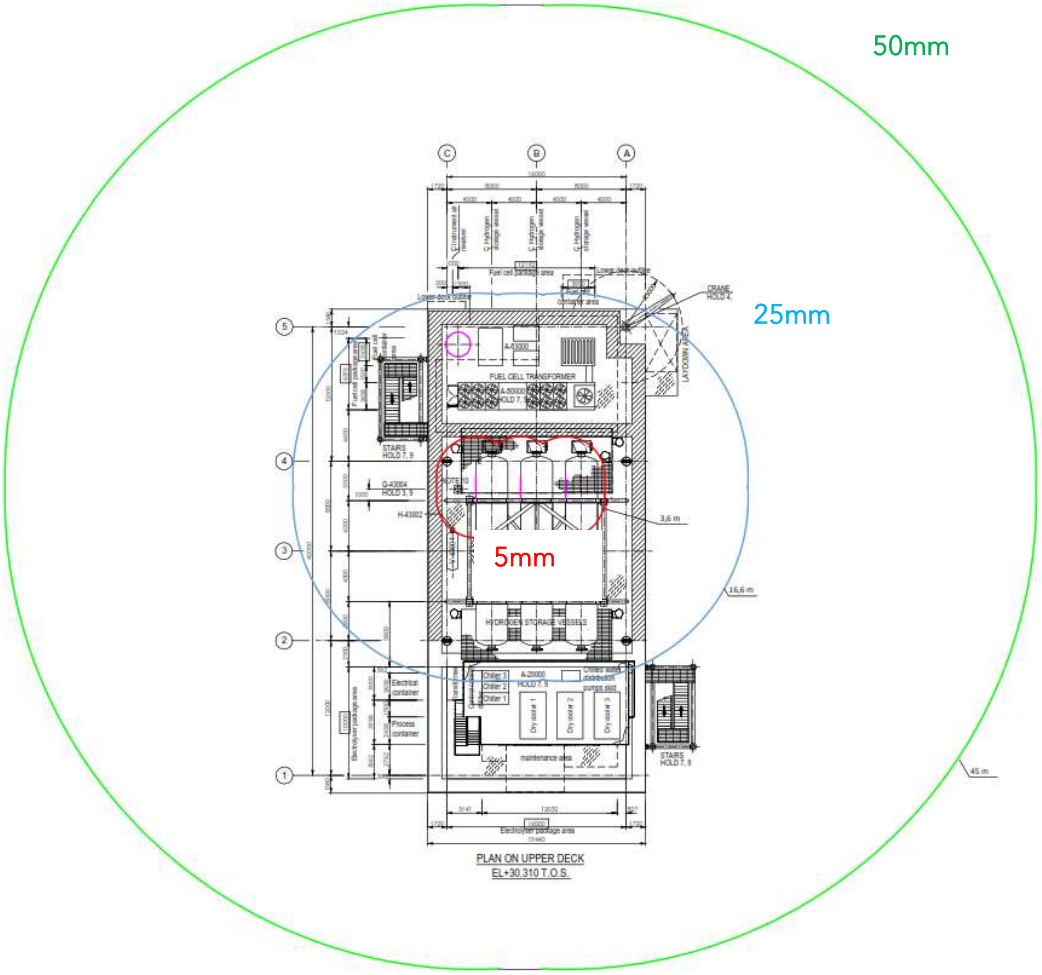


Figure 10 – Section 2 LOC 2.2 scenarios consequences (37.5 kW/m²)

On the basis of piping route, it is possible to conclude that the major effect of section 2, LOC 2.2 for jet fire and flash fire is expected in the upper deck. Regarding lower deck, considering the presence of a plated area, the thermal radiation will be limited, at least for the required time to operator to ensure a safety evacuation from the platform.

In the contrary, VCE scenarios can show severe impact on structures, potentially involved also lower deck.

Jet fire from Section 3

The isolatable section 3 includes the piping from the storage section (valve 25-SDV-023) up to the fuel cell package. Considering that the maximum piping size is equal to 2", according to procedure, three release hole was calculated (5 mm, 25 mm and 50 mm); the release rate is equal to 0.03, 0.8 and 3.2 kg/s respectively. Due to limited piping extension (about 60 meters), the hold up of the section is low.

In the following figure is reported (in a simplified way) the main piping route on 3D model. The piping, starting from the valve 25-SDV-023, are located almost for the entire route below the upper level; only in proximity of the valve, the line is located above the plated upper level.

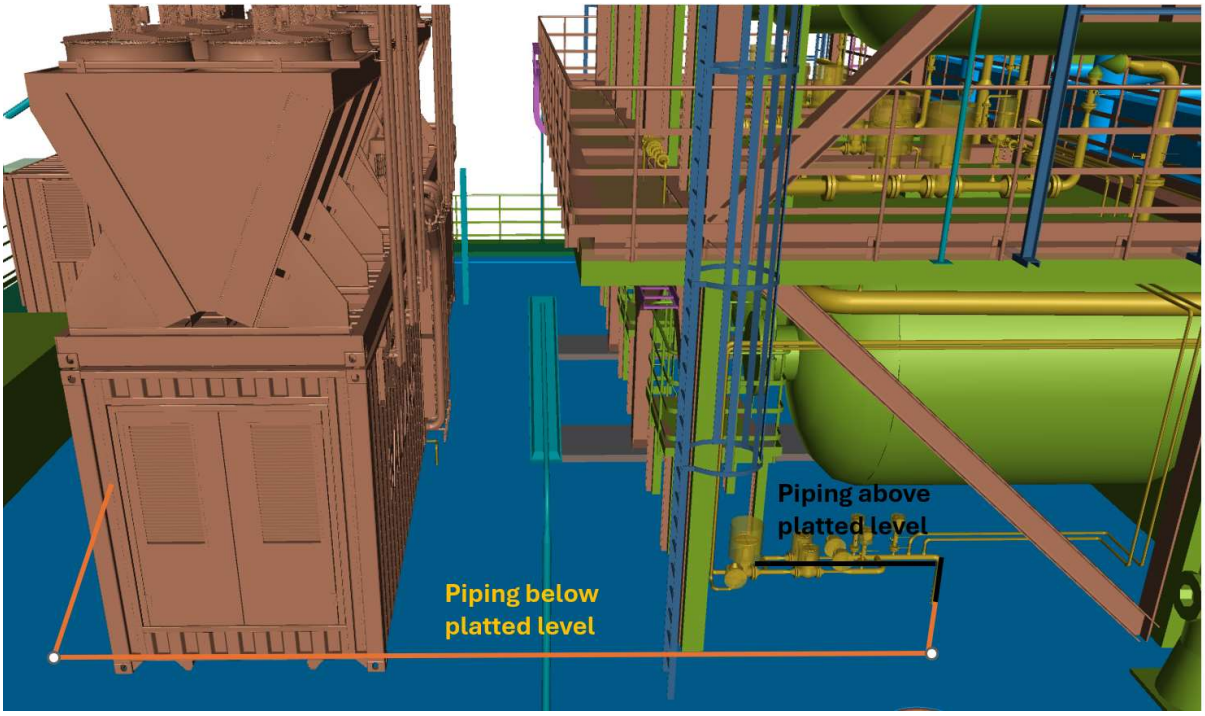


Figure 11 – Section 3 piping routing

In the following figure is reported (as example) the calculated damage distances on piping route for the 37.5 kW/m^2 threshold from jet fire from 5,25 and 50 mm release, which correspond to 100% fatality.

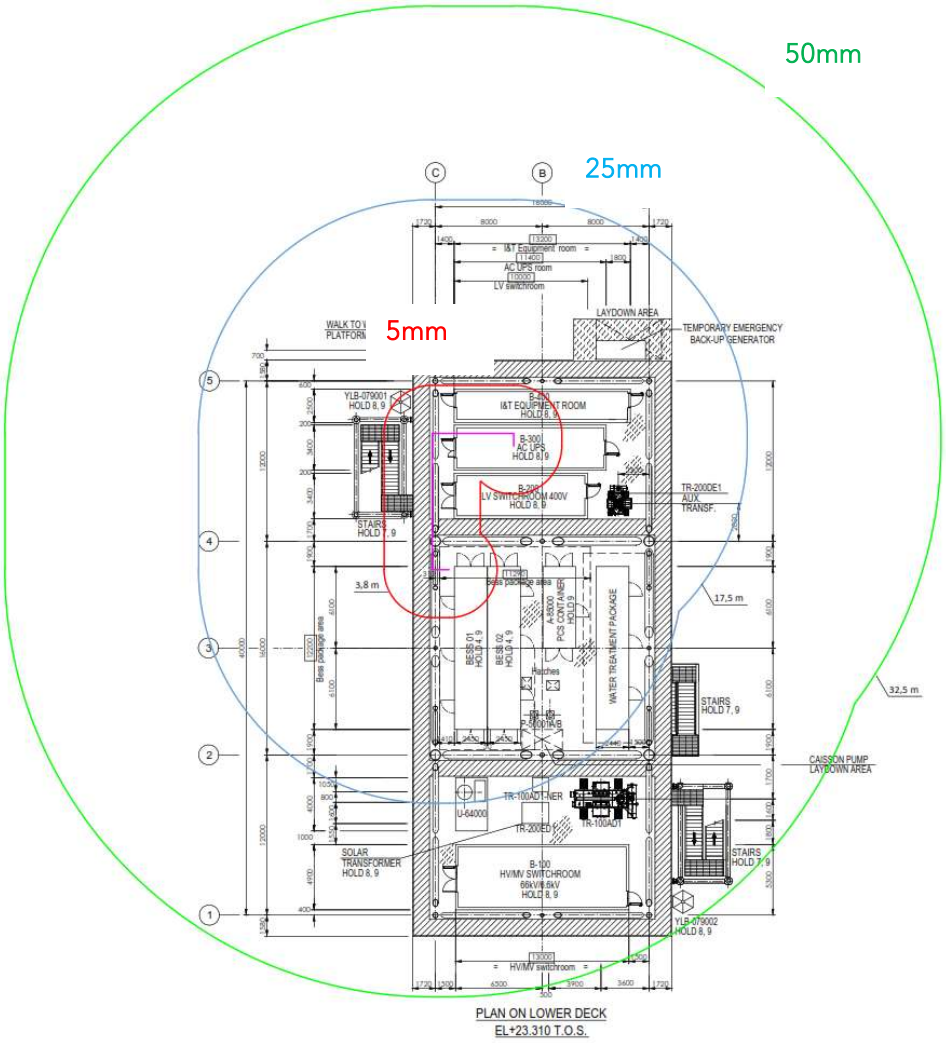


Figure 12 – Section 3 scenario consequences (37.5 kW/m²)

On the basis of piping route, it is possible to conclude that the major effect of section 3 for jet fire and flash fire is expected in the lower deck. In the contrary, VCE scenarios can show severe impact on structures, potentially involved also upper deck.

5.1.1 Scenario resummation for each deck

On the basis of location of the release, the risk for each deck is calculated as below:

- Lower deck: all scenarios (jet fire, flash fire, VCE) from section 1, section 2 and BESS, including all VCE scenarios from section 2 (LOC 2.1 and LOC 2.2).

- Upper deck: all scenarios (jet fire, flash fire, VCE) from section 2 (LOC 2.1 and LOC 2.2), including all VCE scenarios from section 1,3 and BESS.

In other terms, the VCE scenario are considered able to involves all the decks, without take credit of the release location (according to the high overpressure values, it is expected potentially severe injuries to operator in both the decks).

5.2 LSIR CONTRIBUTION

The analysis illustrated here below is based on the criteria of risk acceptability provided in chapter 4.3.

The LSIR curve, which illustrate the potential frequency of fatality for a person continuously exposed (24 h/day, 365 days/year) to the effects of the accidents originating from the platform equipment are reported in Attachment 5 and 6.

In particular, in Attachment 5 is reported the LSIR calculated from the resummation of all scenarios which shows impact on lower deck, as detailed in chapter 5.1. In addition, the contribution of each scenario typology to the total risk for lower deck is calculated:

- in figure 14 is calculated the LSIR contribution from thermal radiation of jet fire;
- in figure 15 is calculated the LSIR contribution from flammable gas dispersion (flash fire);
- in figure 16 is calculated the LSIR contribution from VCE.

In Attachment 6 is reported the LSIR calculated from the resummation of all scenarios which shows impact on upper deck, as detailed in chapter 5.1. In addition, the contribution of each scenario typology to the total risk for lower deck is calculated:

- in figure 10 is calculated the LSIR contribution from thermal radiation of jet fire;
- in figure 19 is calculated the LSIR contribution from flammable gas dispersion (flash fire);
- in figure 20 is calculated the LSIR contribution from VCE.

5.2.1 LSIR calculation for lower deck

In figure 13 (reported in Attachment 5 and below) is show the LSIR contribution from all scenarios which show impact on lower deck. The risk from lower deck is calculated considering the resummation of scenarios coming from isolatable section 1 and 3: as for platform layout, the piping routing of such section are located below upper deck platform and included explosion from BESS, which is located in the lower deck. In addition, explosion from section 2 located in upper deck are included in calculation. The expected scenarios are in the order of 10-20 meters for jet fire and well lower to 90 meters for flash fire and explosion, mainly due to the limited flow rate and process condition. The risk curve equal to 1.0E-05 occ/year is located in the inner part of the deck, and cover some part of piping from section 3. In this location, the overlapping of scenarios is higher, and in addition, the contribution of VCE from BESS is not negligible (BESS explosion is

in the order of 1.0E-05 occ/year). The maximum LSIR values are about 3.0E-05 occ/year, located on BESS system.



Figure 13 -- LSIR for lower deck

In the following table, the LSIR values for main areas of lower deck is reported.

Area	LSIR (occ/year)
BESS cabinets	3.0E-05
Water treatment package	1.5E-05
B-100 (switch room)	6.2-06
B-200 (LV switch room)	2.5E-05
B-300 (AC UPS)	2.3E-05
B-400 (I&T room)	1.8E-05
A-8500 PCS container	2.2E-05
Secondary Muster point	1.5E-05

Table 9 – LSIR values for main platform area on lower deck

LSIR contribution for lower deck

Jet fire contribution

In figure 14 (reported in Attachment 5) LSIR curves calculated by the resummation of jet fire scenarios, each characterized by frequency of occurrence, fatality factor and damage distance are reported. As for assumption register, three thresholds for fatality are considered:

- 37.5 kW/m^2; probability of fatality equal to 100%;
- 12.5 kW/m^2; probability of fatality equal to 30%;
- 4.73 kW/m^2; probability of fatality equal to 3%.

The figure 14 is also reported below for completeness.



Figure 14 – Jet fire contribution to LSIR for lower deck

Jet fire scenarios are characterized by damage distances generally in the order of 10-20 meters for 37.5 kW/m^2 and 12.5 kW/m^2 threshold and up to 30/40 meters for 4.73 kW/m^2 threshold. The most critical scenario is the jet fire from full-bore cases from section 3, characterized by large release flow rate (coming

from 2 inches lines), which shows higher damage distance (30 meters for 37.5 kW/m^2 , 40 m for 12.5 kW/m^2 threshold, and 50 meters for 4.73 kW/m^2 threshold). In terms of risk calculation, the jet fire is considered as a circle near the release point, with a directionality factor (1/8) of the frequency in order to take into account the possible different orientation of the jet. Jet Fire direction is assumed not affected by the wind rose distribution (in terms of wind direction), but only to the probability of stability class, as for assumption register (weather condition 2F, 6%; 5D 50%, 10D 44% of total time).

The maximum value of the contribution to LSIR for Jet Fire is about 4.5E-06 occ/year

Flash fire contribution

In figure 12 (reported in Attachment 5) LSIR curves calculated by the resummation of flash fire scenarios, each characterized by frequency of occurrence, fatality factor and damage distance are reported. As for assumption register, two thresholds for fatality are considered:

- LFL; probability of fatality equal to 100%;
- LFL/2; probability of fatality equal to 50%.

The figure 12 is also reported below for completeness.

Flash fire scenarios are characterized by frequency of occurrence slight lower compared to jet fire. On the basis of assumption register, delayed ignition is split 50:50 between flash fire an VCE, meaning that the frequency of occurrence of flash fire is the same of VCE.

Regarding damage distances, two release direction are calculated, horizontal and down impingement, in order to maximize damage distances. For each case, down impingement shows damage distance higher than horizontal release.

In terms of risk calculation, the flash fire is assumed affected by the wind rose distribution (in terms of wind direction), meaning that there are directions with higher probability compared to other, with lead to the characteristic shape of flash fire contours.

The maximum value of the contribution to LSIR for Flash Fire is equal to 1.8E-06 occ/year and is localized in the north-east direction, in correspondence of prevailing wind direction.



Figure 15 – Flash fire contribution to LSIR for lower deck

VCE contribution

In figure 16 (reported in Attachment 5) LSIR curves calculated by the resummation of VCE scenarios, each characterized by frequency of occurrence, fatality factor and damage distance are reported. As for assumption register, two thresholds for fatality are considered:

- 0.5 bar; probability of fatality equal to 100%;
- 0.3; probability of fatality equal to 50%.

The figure 16 is also reported below for completeness.



Figure 16 – VCE contribution to LSIR for lower deck

On the basis of assumption register, delayed ignition is split 50:50 between VCE and flash fire scenarios, meaning that the frequency of occurrence of VCE is the same of flash fire. As previously reported on chapter 4.2.3, in order to properly calculate the expected consequences in case of explosion, a detailed analysis was performed with the aim to identify, for each LOC, the amount of flammable gas included in the platform boundary. In other terms, only the flammable mass within the platform is considered for explosion calculation. The VCE consequences are assumed not affected by the wind rose distribution (in terms of wind direction), but only to the probability of stability class, as for assumption register (weather condition 2F, 6%; 5D 50%, 10D 44% of total time).

The maximum value of the contribution to LSIR for VCE is about 2.5E-05 occ/year and is localized in the inner part of the platform, in correspondence of BESS storage system. The curves of 1.0E-05 occ/year extends up to 10-20 meters from the centre of platform, covering all platform area. This curve is mainly due to 0.5 bar threshold, which show comparable distances and higher frequency (fatality factor equal to 100%).

The curves of 1.0E-06 occ/year extends up to 40 meters from the platform area; the main contribution coming from 0.3 bar threshold, which is characterized by damage distance in the order of 30-40 meters and lower frequency (fatality factor equal to 50%).

As already discussed, this resummation includes also the contribution of explosion from the section located in the upper deck, which show, on the basis of frequency of occurrence and damage distance, a significant contribution to the total risk.

5.2.2 LSIR calculation for upper deck

In figure 17 (reported in Attachment 6 and below) is show the LSIR contribution from all scenarios which show impact on upper deck. The risk from upper deck is calculated considering the resummation of scenarios coming from isolatable section 2 (LOC 21. And 2.2) and included explosion from BESS and from section 1 and 3 located in the lower deck. The maximum frequency of occurrence is about 6.3 E-05 occ/year and is localized in the inner part of the platform. The 1.0E-05 occ/year curve covers all platform area. This frequency of occurrence is the results of combination of scenarios with higher damage distances of flash fire, jet fire and VCE scenarios. Also for the 1-0E-05 occ/year curve, the main contribution coming from jet fire and VCE scenarios. However, the curve is slight shaped by the wind direction, indicating that the main contribution is due to VCE and jet fire scenario (only flash fire scenario is affected by wind rose distribution). The 1.0E-06 occ/year curve extends very far from the platform, at about 150 meters; the main contribution coming from flash fire scenarios, LFL/2 thresholds. LFL/2 is characterized by higher damage distance and lower frequency of occurrence compared to LFL, due to 50% fatality. The 1E-06 occ/year curve is shaped by the wind direction, confirms that the mainly contribution is coming from flash fire scenarios rather than VCE.

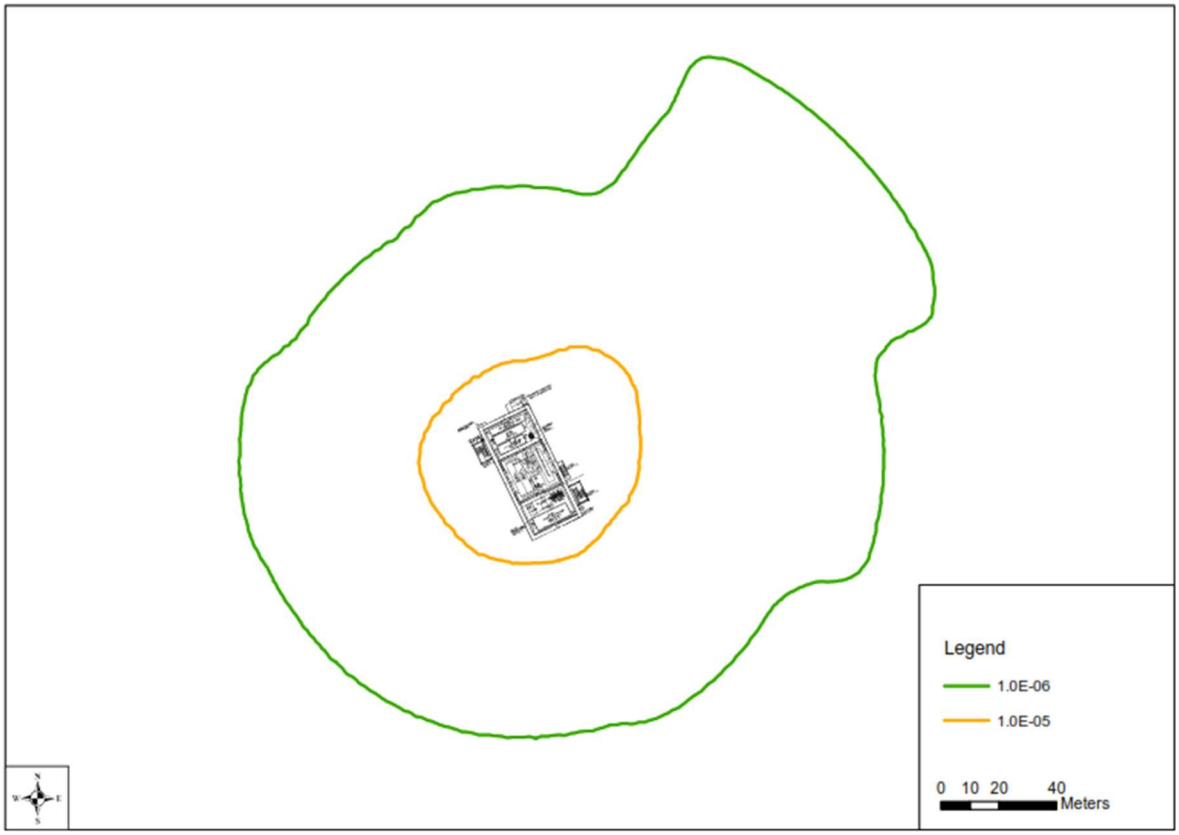


Figure 17 –- LSIR for upper deck

In the following table, the LSIR values for main areas of the platform (upper deck) are reported.

Area	LSIR (occ/year)
A-8000 package (Fuel cell)	5.0E-05
A-2000 electrolyzer package)	3.3E-05
Hydrogen storage vessels	6.3 E-05

Table 10 – LSIR values for main platform area on upper deck

LSIR contribution for upper deck

Jet fire contribution

In figure 18 (reported in Attachment 6) LSIR curves calculated by the resummation of jet fire scenarios, each characterized by frequency of occurrence, fatality factor and damage distance are reported. As for assumption register, three thresholds for fatality are considered:

- 37.5 kW/m^2; probability of fatality equal to 100%;
- 12.5 kW/m^2; probability of fatality equal to 30%;
- 4.73 kW/m^2; probability of fatality equal to 3%.

The figure 18 is also reported below for completeness.

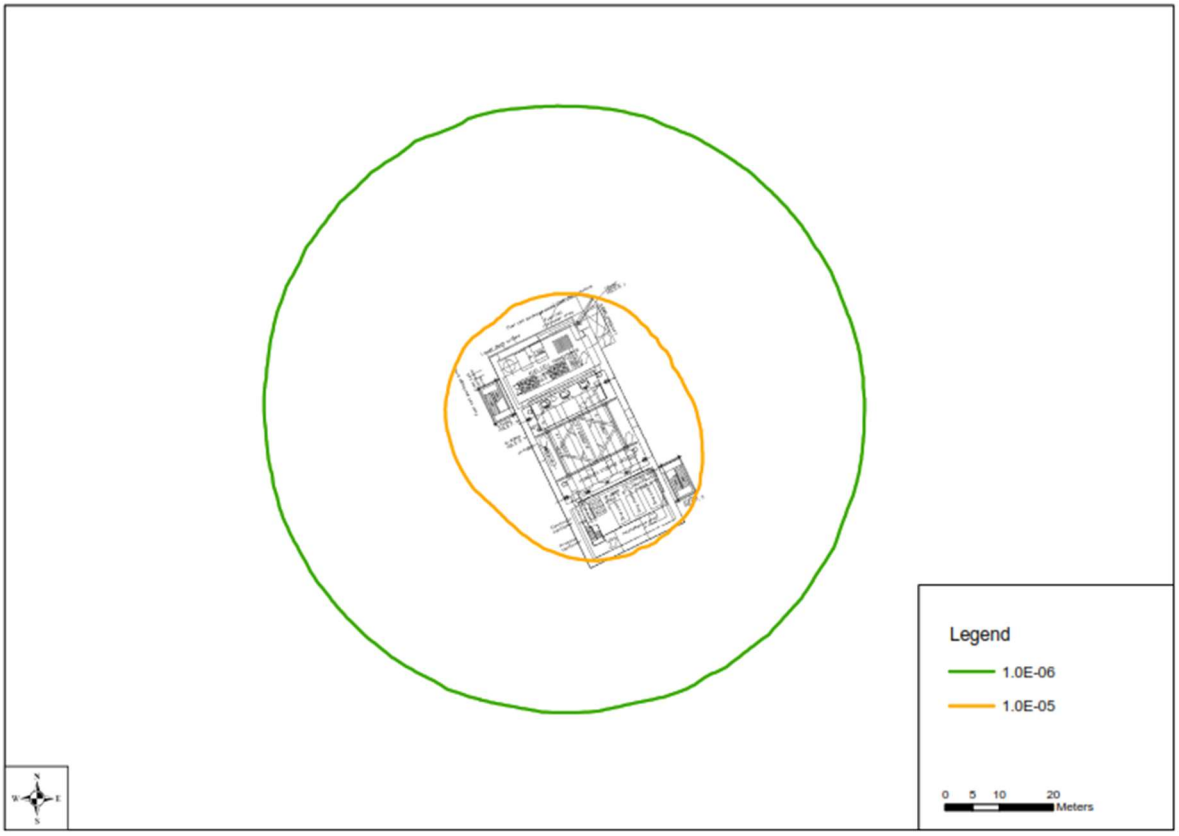


Figure 18 – Jet fire contribution to LSIR for upper deck

Jet fire scenarios are characterized by higher frequency of occurrence compared to other scenarios, with damage distances generally in the order of 10-20 meters for 37.5 kW/m^2 and 12.5 kW/m^2 threshold and up to 30/40 meters for 4.73 kW/m^2 threshold. The most critical scenario is the jet fire from full-bore cases of LOC 2.2, characterized by large release flow rate (coming from 3 inches lines), which shows higher damage distance (40/50 meters for 37.5 kW/m^2 and 12.5 kW/m^2 threshold, up to 70 meters for 4.73 kW/m^2 threshold) with higher frequency of occurrence (compare to other full-bore rupture) due the higher ignition probability.

In terms of risk calculation, the jet fire is considered as a circle near the release point, with a directionality factor (1/8) of the frequency in order to take into account the possible different orientation of the jet. Jet Fire direction is assumed not affected by the wind rose distribution (in terms of wind direction), but only to the probability of stability class, as for assumption register (weather condition 2F, 6%; 5D 50%, 10D 44% of total time).

The maximum value of the contribution to LSIR for Jet Fire is about 3.3E-05 occ/year and is localized in the inner part of the platform, in correspondence of storage vessel. Considering the expected damage distance of jet fire and the platform dimension, a significant resummation of jet fire scenario is foreseen.

The curves of 1.0E-05 occ/year extends up to 20-30 meters from the centre of platform, covering all platform area. This curve is mainly due to 37.5 kW/m^2 and 12.5 kW/m^2 threshold, which show comparable distances and higher frequency (fatality factor equal to 100% and 30%).

The curves of 1.0E-06 occ/year extends up to 70 meters from the platform area; the main contribution coming from 4.73 kW/m^2 threshold, which is characterized by higher damage distance and lower frequency (fatality factor equal to 3%).

Flash fire contribution

In figure 19 (reported in Attachment 6) LSIR curves calculated by the resummation of flash fire scenarios, each characterized by frequency of occurrence, fatality factor and damage distance are reported. As for assumption register, two thresholds for fatality are considered:

- LFL; probability of fatality equal to 100%;
- LFL/2; probability of fatality equal to 50%.

The figure 19 is also reported below for completeness.

Flash fire scenarios are characterized by frequency of occurrence slight lower compared to jet fire. On the basis of assumption register, delayed ignition is split 50:50 between flash fire an VCE, meaning that the frequency of occurrence of flash fire is the same of VCE.

Regarding damage distances, two release direction are calculated, horizontal and down impingement, in order to maximize damage distances. For each case, down impingement shows damage distance higher than horizontal release.

In terms of risk calculation, the flash fire is assumed affected by the wind rose distribution (in terms of wind direction), meaning that there are directions with higher probability compared to other, with lead to the characteristic shape of flash fire contours.

The maximum value of the contribution to LSIR for Flash Fire is equal to 1.2E-05 occ/year and is localized in the north-east direction, in correspondence of prevailing wind direction. The main contribution for the curves of 1.0E-05 occ/year is due to LFL scenario, which are characterized with higher frequency of occurrence (fatality factor equal to 100%).

The curves of 1.0E-06 occ/year extends up to 150 meters from the platform area; the main contribution coming from LFL/2 threshold, which is characterized by higher damage distance and lower frequency (fatality factor equal to 50%) compared to LFL.



Figure 19 – Flash fire contribution to LSIR for upper deck

VCE contribution

In figure 20 (reported in Attachment 5) LSIR curves calculated by the resummation of VCE scenarios, each characterized by frequency of occurrence, fatality factor and damage distance are reported. As for assumption register, two thresholds for fatality are considered:

- 0.5 bar; probability of fatality equal to 100%;
- 0.3; probability of fatality equal to 50%.

The figure 20 is also reported below for completeness.



Figure 20 – Flash fire contribution to LSIR for lower deck

As already discussed in the report, for both the deck, the resummation considers the contribution of all VCE scenarios. This means that the VCE contribution for the upper deck is the same of lower deck.

5.2.3 LSIR conclusion

On the basis of LSIR curves, it is possible to concluded that the risk from lower deck show low values compared to upper deck section. The main contribution to the risk in the lower deck coming from VCE scenario: as already discussed in the report, the VCE from thermal runway of BESS system shows frequency of occurrence equal to 1.0E-05 occ/year, which is higher than other scenarios as jet fire and flash fire scenarios. In addition, the VCE contribution for lower deck considers also the contribution of VCE from other section located in the upper deck: according to damage thresholds, in case of explosion, potential impact on operator in lower deck should be expected. In conclusion, the contribution to the total risk from jet fire and flash fire for lower deck is lower compared to the VCE risk, considering also the contribution from upper deck.

The upper deck shows higher risk, both in terms of frequency of occurrence and damage distances, due the presence of H_2 storage system, confirming that the risk from section 2 is the "worst case" in terms of risk from the platform. In particular, jet fire shows significant contribution, involving al the platform area with frequency

about 1.0E-05 occ/year. For this case, the jet fire from LOC 2.2 is the worst-case scenario. For upper deck, the explosion contribution, even if still in the order of 1-0E-05 occ/year, is lower than the contribution of jet fire scenarios, which covers the entire platform area.

5.3 IRPA CALCULATION

5.3.1 Process hazard risk

For the evaluation of acceptability of individual risk for operator, it is required to evaluate the real exposure of people of the risk from the platform, named IRPA. This is a more realistic estimate of the risk for an individual, taking account of them being at different locations for different periods of time. Risk estimates from LSIR curves shall be converted to this form before comparing with risk tolerability criteria. Considering that no detailed information about work position of each maintenance personnel is present, the maximum working hours in each position is calculated, considering a 50:50 manning distribution for each deck. On the basis of project documentations, presence factor considers a total of 16 hours/year for each operator;, assuming a 50:50 distribution, the presence factor for each deck is equal to 9.1E-04 (8 hours for each deck).

Area		Frequency of occurrence (occ/year)	Presence factor	IRPA
Lower deck	BESS cabinets	3.0E-05	9.1E-04	2.7E-08
	Water treatment package	1.5E-05		1.4E-08
	B-100 (switch room)	6.2E-06		5.6E-09
	B-200 (LV switch room)	2.5E-05		2.3E-08
	B-300 (AC UPS)	2.3E-05		2.1E-08
	B-400 (I&T room)	1.8E-05		1.6E-08
	A-8500 PCS container	2.2E-05		2.0E-08
	Secondary Muster point	1.5E-05		1.4E-08
Upper deck	A-8000 package (Fuel cell)	5.0E-05		4.6E-08
	A-2000 electrolyzer package)	3.3E-05		3.0E-08
	Hydrogen storage vessels	6.3E-05		5.7E-08

Table 11 – IRPA values

In conclusion, considering that the exact time spent by the operator on each location is it not possible to identify, as conservative approach, in order to identify the total IRPA for each operator from process hazard, the highest values of calculated IRPA from each deck is considered as a reference:

- 2.7E-08 for lower deck, considering and exposure of 8 hours;

- 5.7E-08 for upper deck. considering and exposure of 8 hours.

Considering than the operator spent 16 hour in the platform, equally distributed between upper and lower deck, the total IRPA for process for a typical operator is equal to 8.5E-08, which is the sum of IRPA from 8 working hours on lower deck and 8 working hours on upper deck.

This value of IRPA is considered representative for the risk of a reference operator in the platform. Note that IRPA from process in each area of the platform is always lower than target frequency of 1.0E-06 occ/year. The risk is classified inside the "acceptable" region based on acceptability criteria.

5.3.2 Non Process hazard risk

QRA is concerned mainly with the assessment of "Process Risk", i.e. the risk deriving for handling flammable substances in the production process. In general, worker can be subject to other work-related hazards, depending on specific job, such as transportation accidents, or occupational incidents unrelated with loss of containment events in the process areas. The overall level of risk which a worker of a given industry sector subject to, may be generically assessed using statistical data, such as Fatality Accident Rate In this section of the report non-process hazards scenarios risk results are reported for the followings:

- Occupational Hazards;
- Dropped Object Hazards;
- Ship Collision;
- Structural Failures.

Occupational Hazards Risk Results

Occupational Risks have been assessed starting from Occupational FAR (Fatal Accidental Rate) values obtained from [11] and their specific modification factor applied to take into account specific functions and region and 16 hours of work activities.

Worker group	Overall Worldwide FAR Value	Function modification FAR (production)	Location Modification Factor (europe-offshore)	Calculated FAR (x 10^8 hours)
Operators in upper/lower deck (Company employees)	1.37	1.6	2.94	6.45

Table 12 – FAR calculation

On the basis of the Occupational FAR values and taking into account manning levels the following occupational IRPA indexes per each worker group (operator on upper/lower deck) have been assessed, considering 16 hours on platform for each operator.

Worker group	Calculated FAR (x 10^8 hours)	Worked Hours/y	Occupational IRPA (ev/y)
Platform operators	6.45	16	1.0E-06

Table 13 – IRPA for occupational risk

Dropped Object Hazards Risk Results

IRPA due dropped object risk have been assessed starting from frequency databases derived from [14], assuming a number of lift equal to 10 (to be considered as conservative values). During crane activity on the platform, operators are required to follows dedicate procedure, in order to prevent accidents by falling objects. A possible operator injury is possible only considering contemporary dropped object from the crane and incorrect application of operative procedure [15].

In the table below the risk for operator due falling object is calculated.

Worker group	Dropped Object Probabilities for Fixed Installations (per lift, <1 ton)	Lifts number in a year	Incorrect application procedure (simple tasks, minimum stress, per demand)	Dropped Object IRPA (ev/y)
Platform operators	4.5E-05	10	1E-03	4.5E-07

Table 14 – IRPA for dropped object

In the calculation it is assumed that people struck by falling object be fatally injured.

Ship Collision Risk Results

IRPA Ship collision risks have been assessed starting from Collision frequency databases derived from [12] and associated to specific information regarding operator presence (16 hour in a year, equal to a factor of 0.002).

Worker group	Collision frequency (per unit year)-fixed installation(events/y)	Modification Factors for Operating Regions (Europe)	Modification Factors for type of damage (Severe+ Total loss)	Modification Factors for presence of personnel on platform	Ship Collision IRPA (events/y)
Platform operators	5.7E-04	9.55	0.05	0.002	5.44E-07

Table 15 – IRPA for ship collision

In the calculation it is assumed that people due ship impact be fatally injured.

Structural Failure Hazards Risk Results

Risks associated to structural failure have been assessed considering the type of installation (Fixed Unit), the workers and the type of damage generated (Severe + Total loss). IRPA structural failure risks have been assessed from [13] and associated to specific information for the platform and operator presence (16 hour in a year, equal to a factor of 0.002).

Severe events can be due to:

- extreme weather;
- marine corrosion;
- fatigue;
- foundation failure;
- construction defects;
- design errors;
- earthquakes.

Worker group	Structural Failure (ev/y) – Fixed Unit	Modification Factors for presence of personnel	Structural Failure IRPA (ev/y) – Fixed Unit
Platform operators	7.4E-06	0.002	1.48E-08

Table 16 – IRPA for structural hazards

In the calculation it is assumed that people due platform structural failure be fatally injured.

5.3.3 Total IRPA results

The overall IRPA per worker has been obtained by summing up all contributors listed in the above chapter, each with proper assumption and consideration.

Worker group	Process IRPA	Occupational IRPA	Dropped Object IRPA	Ship Collision IRPA	Structural Failure IRPA	Total IRPA
Platform operators	8.5E-08	1.0E-06	4.5E-07	5.44E-07	1.48E-08	2.1E-06

Table 17 –Total IRPA calculation

The highest contribute is the one associated to non-process hazards (96%), while the one associated to process hazard contributes only for 4% to the total IRPA.

Even with conservative approach, the total IRPA for operator are below the intolerable level, falling inside the "ALARP region".

6 CONCLUSIONS AND RECOMMENDATIONS

6.1 QRA CONCLUSIONS

On basis of the results of the QRA study, following considerations apply:

- On the basis of LSIR curves, it is possible to conclude that the risk from lower deck show low values compared to upper deck section. The maximum calculated value of the LSIR is equal to 3.0E-05 occ/year.

  The main contribution to the risk in the lower deck coming from VCE scenario: as already discussed in the report, the VCE from thermal runway of BESS system shows frequency of occurrence equal to 1.0E-05 occ/year, which is higher than other scenarios such as jet fire and flash fire scenarios. In addition, the VCE contribution for lower deck considers also the contribution of VCE from other section located in the upper deck: according to damage thresholds, in case of explosion, potential impact on operator in lower deck should be expected. In conclusion, the contribution to the total risk from jet fire and flash fire for lower deck is lower compared to the VCE risk, considering also the contribution from upper deck.

- The upper deck shows higher risk, both in terms of frequency of occurrence and damage distances, due the presence of H_2 storage system, confirming that the risk from section 2 is the "worst case" in terms of risk from the platform. The maximum calculated value of the LSIR is equal to 6.3 E-05 occ/year.

  In particular, jet fire shows significant contribution, involving all the platform area with frequency about 1.0E-05 occ/year. For this case, the jet fire from LOC 2.2 is the worst-case scenario. For upper deck, the explosion contribution, even if still in the order of 1-0E-05 occ/year, is lower than the contribution of jet fire scenarios, which covers the entire platform area.

- Process IRPA for operator, for each area of the platform, is always lower than target frequency of 1.0E-06 occ/year. The risk is classified inside the "acceptable" region based on acceptability criteria and no additional barrier is deemed necessary.

- IRPA risk screening vs. tolerability criteria highlight that no intolerable risks are experienced. The highest contribution is the one associated to non-process hazards (96%), while the one associated to process hazard contributes only for 4% to the total IRPA.

ATTACHMENT 1

ISOLATABLE SECTIONS ON P&ID

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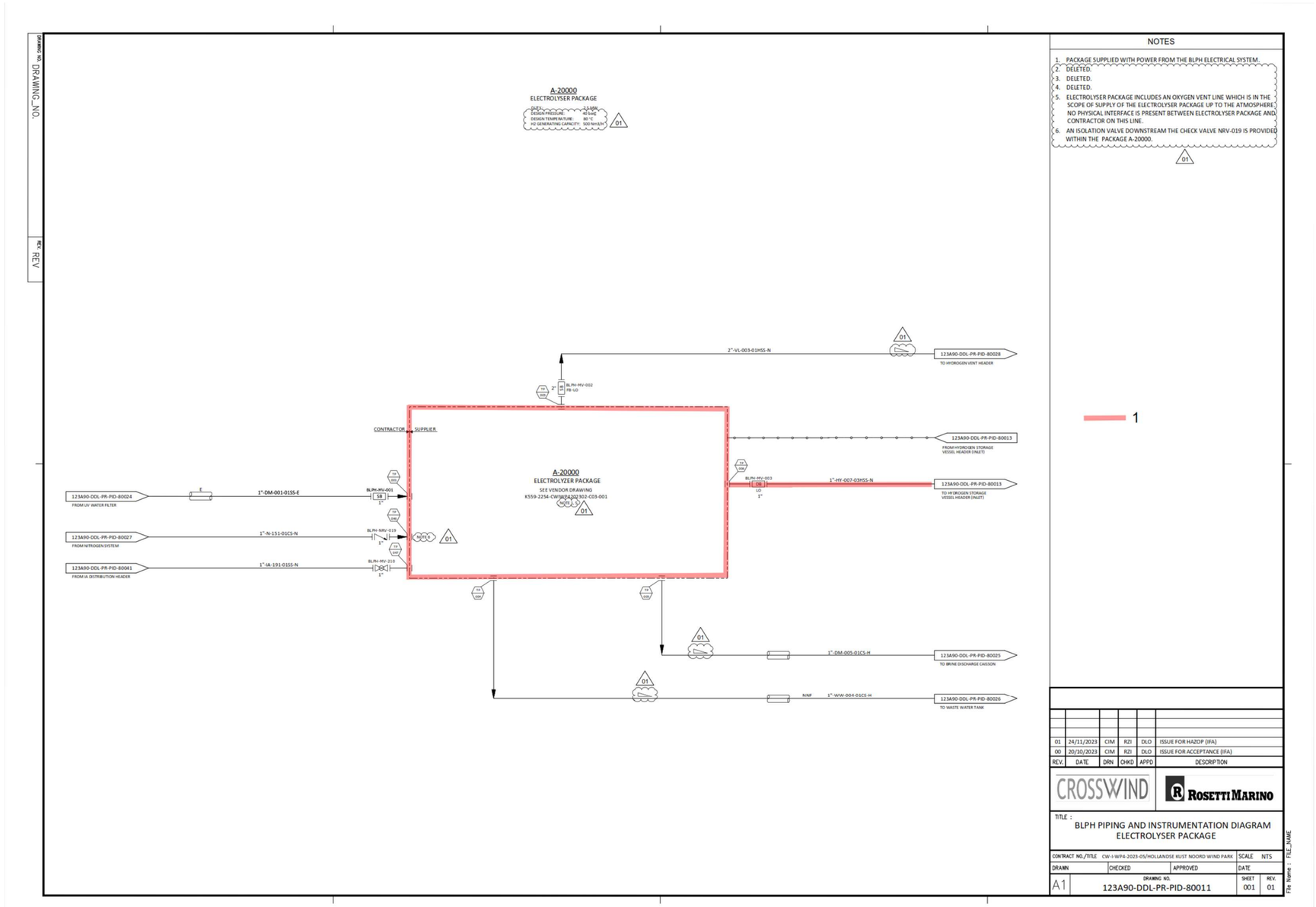


Figure 21 – P&ID isolatable section 1

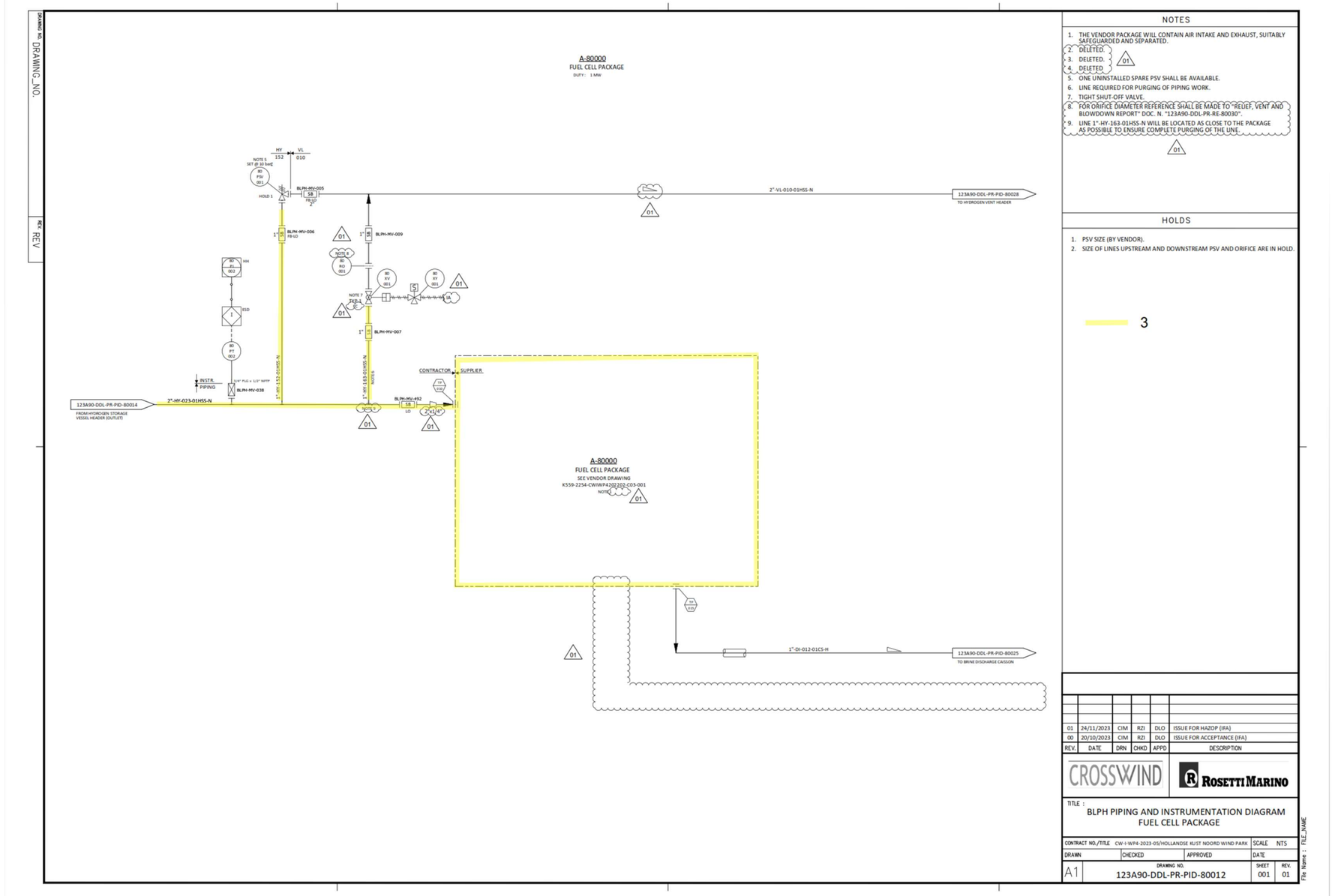


Figure 22 – P&ID isolatable section 3

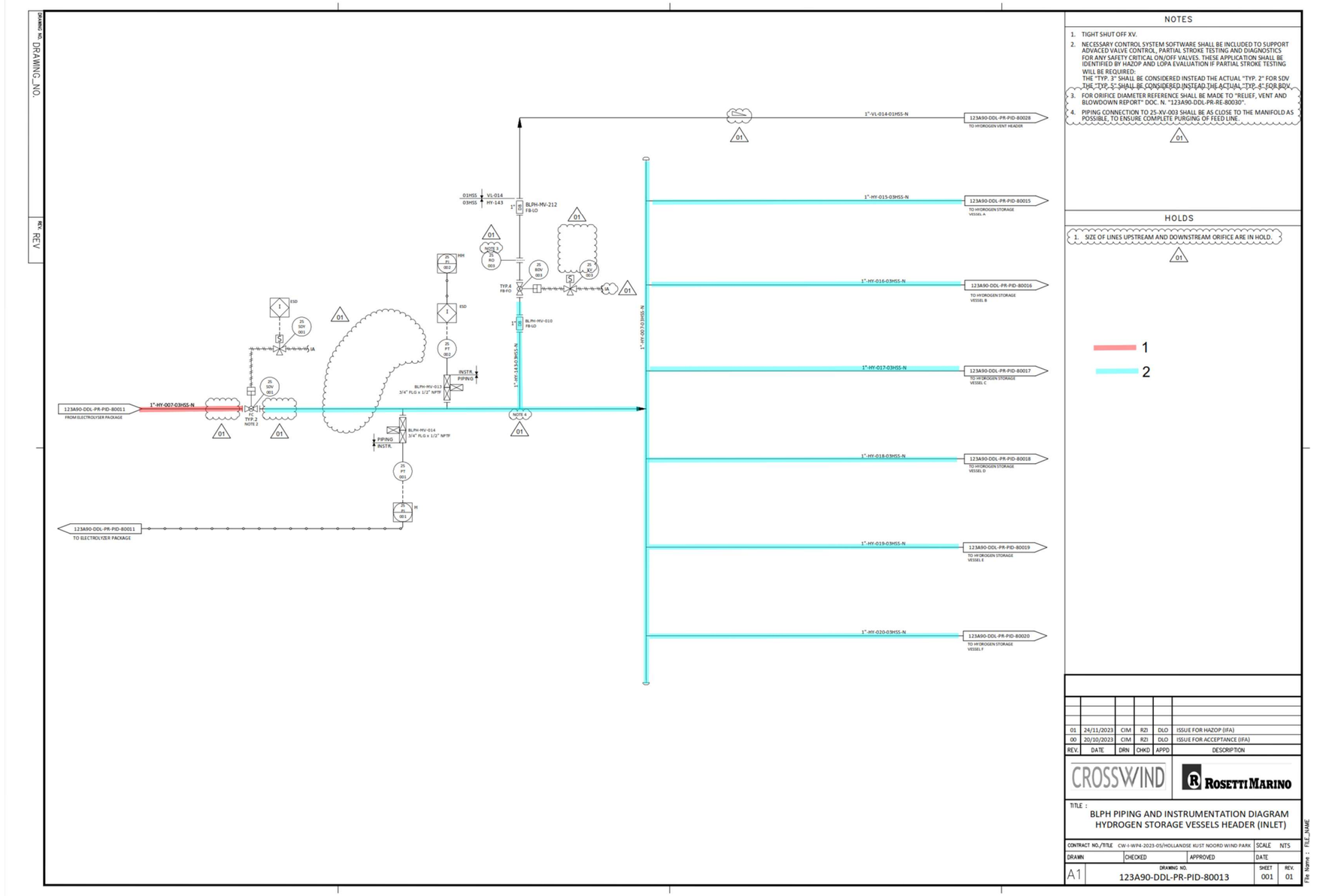


Figure 23 – P&ID isolatable section 1,2

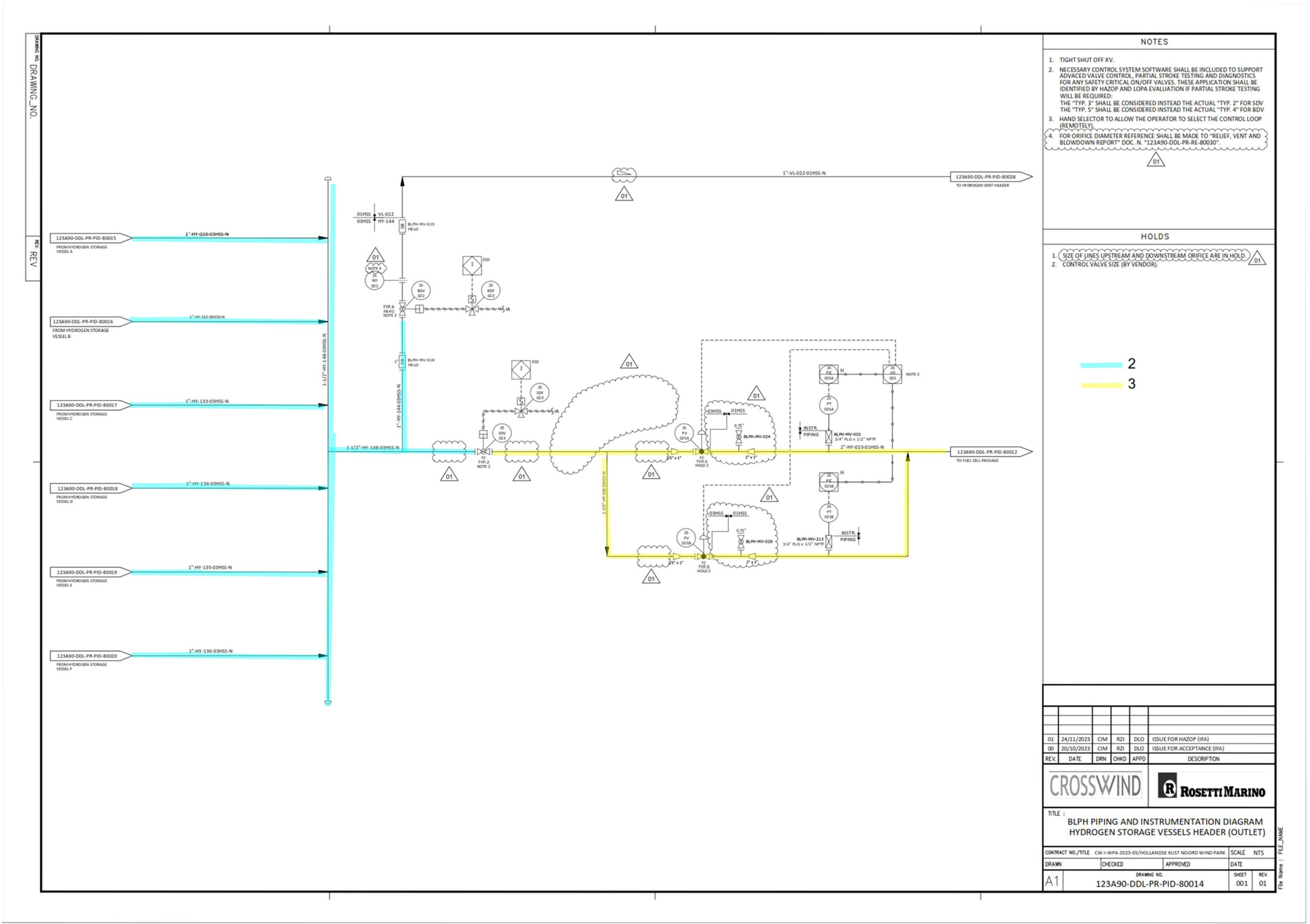


Figure 24 – P&ID isolatable section 2,3

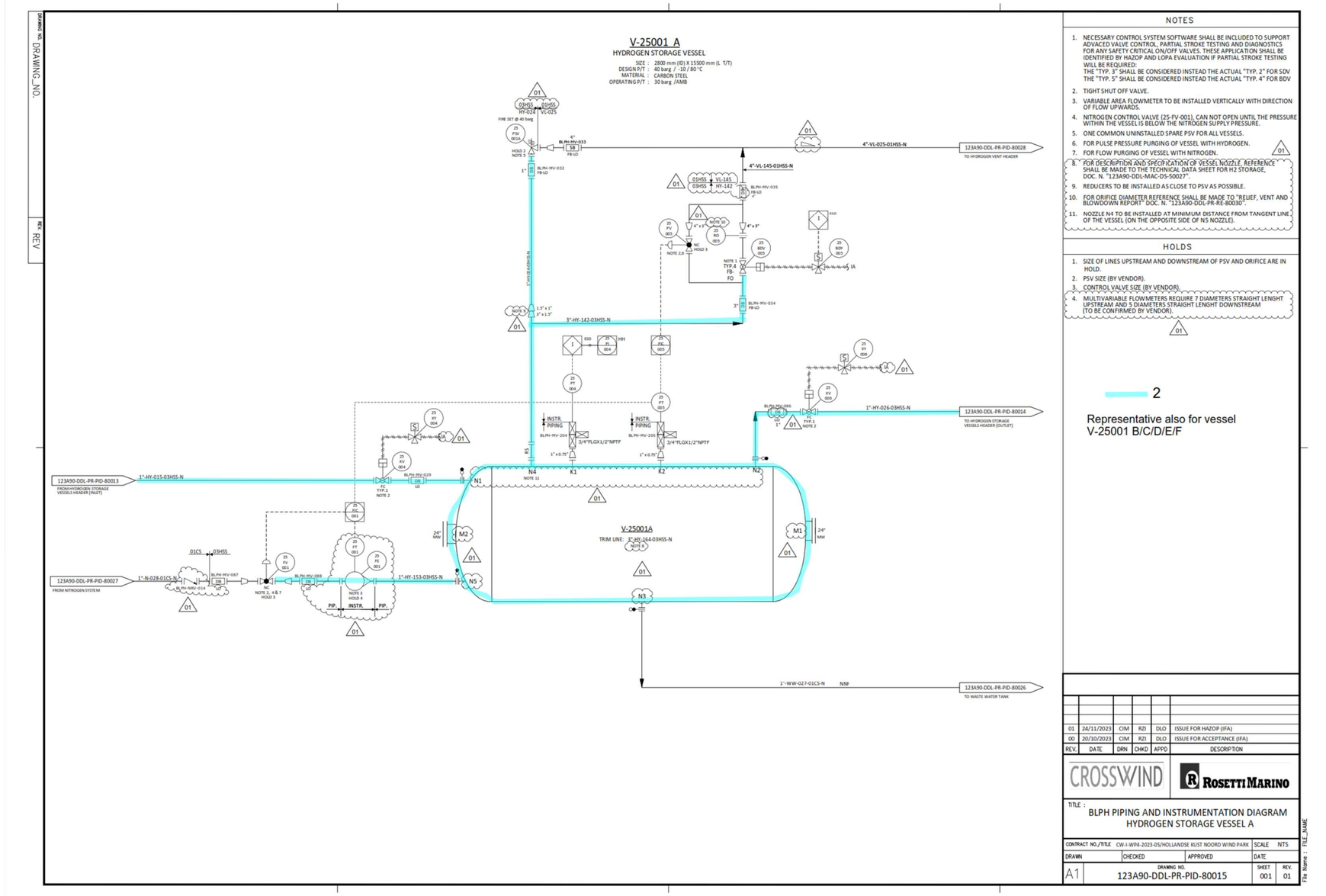


Figure 25 – P&ID isolatable section 2

ATTACHMENT 2 PARTS COUNT RESULTS

Section / LOC	Overall section Frequency (occ./year)		
	Type of release		
	5 mm	25 mm	Total Rupture (25 mm)
Section 1, LOC 1.1	3.0E-04	1.8E-04	-

Piping release frequencies				
Piping Diameter	**Length (m)**	**5 mm**	**25 mm**	**Total Rupture (25 mm)**
1"	32.5	2.1E-04	1.2E-04	N.A.
1.5"	-	-	-	-
2"	-	-	-	-
3"	-	-	-	-
Total	**32.5**	**2.1E-04**	**1.2E-04**	**-**

Flanges release frequencies				
Flanges Diameter	**Amount**	**5 mm**	**25 mm**	**Total Rupture (25 mm)**
1"	7	1.4E-05	9.0E-06	N.A.
1.5"	-	-	-	-
2"	-	-	-	-
3"	-	-	-	-
Total	**7**	**1.4E-05**	**9.0E-06**	**-**

Manual valves release frequencies				
Manual valves Diameter	**Amount**	**5 mm**	**25 mm**	**Total Rupture (25 mm)**
1"	3	2.40E-05	2.2E-05	N.A.
1.5"	-	-	-	-
2"	-	-	-	-
3"	-	-	-	-
Total	**3**	**2.40E-05**	**2.19E-05**	**-**

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Automatic valves release frequencies				
Automatic valves Diameter	**Amount**	**5 mm**	**25 mm**	**Total Rupture (25 mm)**
1"	1	5.8E-05	3.0E-05	N.A.
1.5"	-	-	-	-
2"	-	-	-	-
3"	-	-	-	-
Total	1	**5.80E-05**	**3.03E-05**	**-**

Section / LOC	Overall section Frequency (occ./year)		
	Type of release		
	5 mm	25 mm	Total Rupture (37.5 mm, 1.5 inches)
Section 2, LOC 2.1	5.6E-03	3.3E-03	3.4E-04

Piping release frequencies				
Piping Diameter	**Length (m)**	**5 mm**	**25 mm**	**Total Rupture (37.5 mm, 1.5 inches)**
1"	113.3	7.3E-04	4.3E-04	N.A.
1.5"	40.2	2.6E-04	1.1E-04	4.0E-05
2"	-	-	-	-
3"	-	-	-	-
Total	**153.4**	**9.8E-04**	**5.4E-04**	**4.0E-05**

Flanges release frequencies				
Flanges Diameter	**Amount**	**5 mm**	**25 mm**	**Total Rupture (37.5 mm, 1.5 inches)**
1"	217	4.3E-04	2.8E-04	N.A.
1.5"	1	2.0E-06	9.10E-07	3.8E-07
2"	-	-	-	-
3"	-	-	-	-
Total	**218**	**4.4E-04**	**2.8E-04**	**3.8E-07**

Manual valves release frequencies				
Manual valves Diameter	**Amount**	**5 mm**	**25 mm**	**Total Rupture (37.5 mm, 1.5 inches)**
1"	78	6.2E-04	5.7E-04	N.A.
1.5"	-	-	-	-
2"	-	-	-	-
3"	-	-	-	-
Total	**78**	**6.2E-04**	**5.7E-04**	**-**

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Automatic valves release frequencies				
Automatic valves Diameter	**Amount**	**5 mm**	**25 mm**	**Total Rupture (37.5 mm, 1.5 inches)**
1"	26	1.5E-03	7.9E-04	N.A.
1.5"	1	5.8E-05	2.3E-05	7.3E-06
2"	-	-	-	-
3"	-	-	-	-
Total	27	**1.6E-03**	**8.1E-04**	**7.3E-06**

Instrument connection release frequencies				
Instrument connections	**Amount**	**5 mm**	**25 mm**	**Total Rupture (37.5 mm, 1.5 inches)**
Connections	20	1.0E-03	5.4E-04	N.A.
Total	**20**	**1.0E-03**	**5.4E-04**	**0.00E+00**

Vessel (inlets 50 to 150 mm diameter) release frequencies				
Vessel	**Amount**	**5 mm**	**25 mm**	**Total Rupture (37.5 mm, 1.5 inches)**
Size < 150 mm	6	1.0E-03	5.6E-04	2.9E-04
Total	**6**	**1.0E-03**	**5.6E-04**	**2.9E-04**

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Section / LOC	Overall section Frequency (occ./year)		
	Type of release		
	5 mm	25 mm	Total Rupture (75 mm, 3 inches)
Section 2, LOC 2.2	1.0E-03	4.3E-04	1.7E-04

Piping release frequencies				
Piping Diameter	**Length (m)**	**5 mm**	**25 mm**	**Total Rupture (75 mm, 3 inches)**
1"	-	-	-	N.A.
1.5"	-	-	-	-
2"	-	-	-	-
3"	13.2	8.4E-05	3.7E-05	1.3E-05
Total	**13.2**	**8.4E-05**	**3.7E-05**	**1.3E-05**

Flanges release frequencies				
Flanges Diameter	**Amount**	**5 mm**	**25 mm**	**Total Rupture (75 mm, 3 inches)**
1"	-	-	-	N.A.
1.5"	-	-	-	-
2"	-	-	-	-
3"	42	8.4E-05	3.8E-05	1.6E-05
Total	**42**	**8.4E-05**	**3.8E-05**	**1.6E-05**

Manual valves release frequencies				
Manual valves Diameter	**Amount**	**5 mm**	**25 mm**	**Total Rupture (75 mm, 3 inches)**
1"	-	-	-	N.A.
1.5"	-	-	-	-
2"	-	-	-	-
3"	18	1.4E-04	8.3E-05	4.9E-05
Total	**18**	**1.4E-04**	**8.3E-05**	**4.9E-05**

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Automatic valves release frequencies				
Automatic valves Diameter	**Amount**	**5 mm**	**25 mm**	**Total Rupture (75 mm, 3 inches)**
1"	-	-	-	N.A.
1.5"	-	-	-	-
2"	-	-	-	-
3"	12	7.0E-04	2.8E-04	8.8E-05
Total	12	**7.0E-04**	**2.8E-04**	**8.8E-05**

Section / LOC	Overall section Frequency (occ./year)		
	Type of release		
	5 mm	25 mm	Total Rupture (50 mm, 2 inches)
Section 3, LOC 3.1	9.3E-04	5.0E-04	4.1E-05

Piping release frequencies				
Piping Diameter	**Length (m)**	**5 mm**	**25 mm**	**Total Rupture (50 mm, 2 inches)**
1"	35.2	2.3E-04	1.3E-04	N.A.
1.5"	-	-	-	-
2"	24.75	1.6E-04	6.9E-05	2.5E-05
3"	0	0.00E+00	0.00E+00	0.00E+00
Total	**59.95**	**3.8E-04**	**2.0E-04**	**2.5E-05**

Flanges release frequencies				
Flanges Diameter	**Amount**	**5 mm**	**25 mm**	**Total Rupture (50 mm, 2 inches)**
1"	16	3.2E-05	2.0E-05	N.A.
1.5"	1	2.0E-06	9.1E-07	3.8E-07
2"	4	8.0E-06	3.6E-06	1.5E-06
3"	-	-	-	-
Total	**21**	**4.2E-05**	**2.5E-05**	**1.9E-06**

Manual valves release frequencies				
Manual valves Diameter	**Amount**	**5 mm**	**25 mm**	**Total Rupture (50 mm, 2 inches)**
1"	8	6.4E-05	5.8E-05	N.A.
1.5"	-	-	-	-
2"	-	-	-	-
3"	-	-	-	-
Total	**8**	**6.4E-05**	**5.8E-05**	**-**

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Automatic valves release frequencies				
Automatic valves Diameter	**Amount**	**5 mm**	**25 mm**	**Total Rupture (50 mm, 2 inches)**
1"	3	1.7E-04	9.1E-05	N.A.
1.5"	-	-	-	-
2"	2	1.2E-04	4.6E-05	1.5E-05
3"	-	-	-	-
Total	5	**2.9E-04**	**1.4E-04**	**1.5E-05**

Instrument connection release frequencies				
Instrument connections	**Amount**	**5 mm**	**25 mm**	**Total Rupture (50 mm, 2 inches)**
Connections	3	1.5E-04	8.1E-05	N.A.
Total	**3**	**1.5E-04**	**8.1E-05**	**0.00E+00**

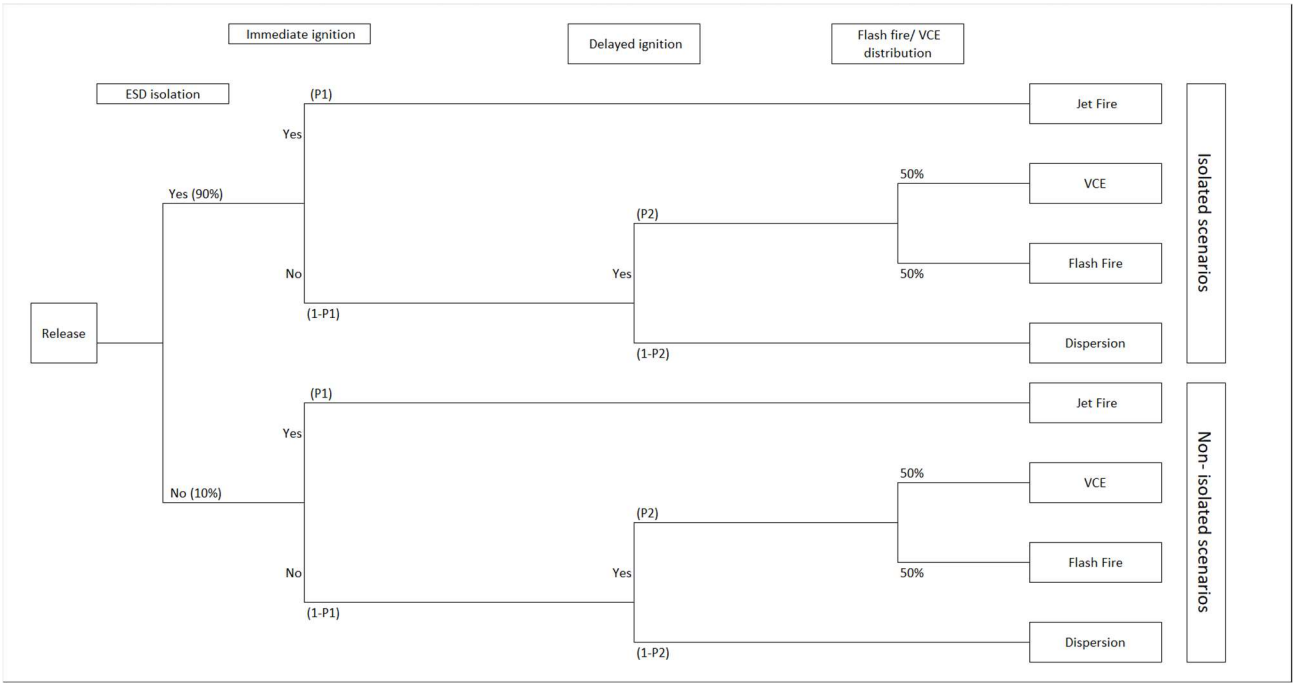
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ATTACHMENT 3
EVENT TREE ANALYSIS

Scenario types and frequency is depending on the release and its evolution in the environment. In case of release and ignition of flammable gas clouds, following scenarios are expected:

- Jet fire (immediate ignition);
- Flash fire (delayed ignition);
- Confined Vapor Cloud Explosion (delayed ignition);

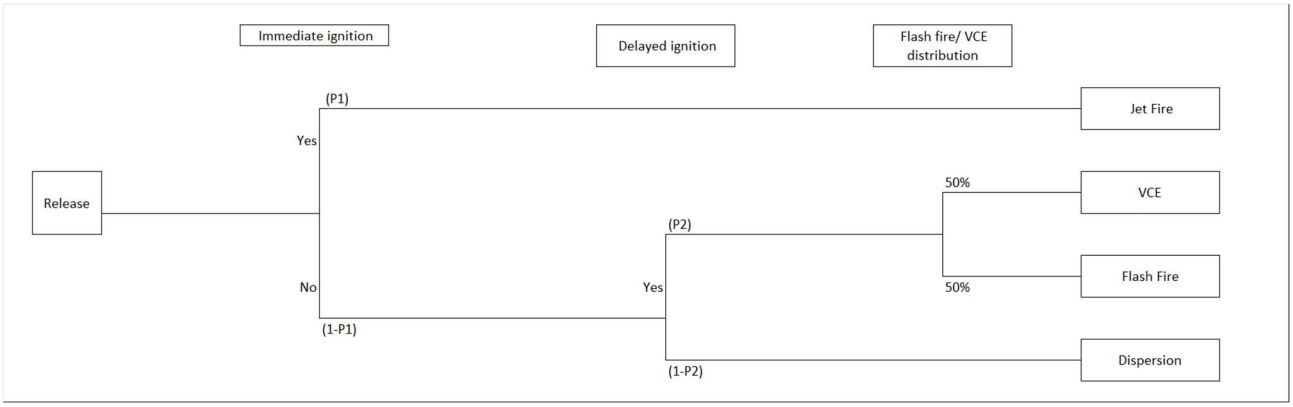
In order to qualify and quantify all potential outcome scenarios, the "Event Tree" technique is applied. The "Event Tree" technique is logical qualitative and quantitative representation of accident sequences, from initial release to final scenarios (fire, explosion and dispersion). The event tree considers, on the basis of release rate, the immediate ignition (P1) which determine Jet fire scenario and delayed ignition (P2) which determine flash fire and explosion scenarios. The event tree also considers the failure of the ESD system (which is assumed 90% reliable) and in the below figure is reported.



Considering that the scope of QRA is to identify the risk for operator, for risk resummation all the scenarios was included, without taking credit of jet fire duration: also jet fire with low duration (e.g. jet fire originated from medium or large holes of isolated cases) could have a severe impact on operators.

Thus, the frequency of occurrence of each hazardous scenarios is equal to the sum of "isolated" and "not-isolated" scenarios.

The event tree for QRA calculation is summarized below. (refer to assumption register, assumption 4).



For additional information, regarding P1 e P2 definition, refer to Assumption register.

Section 1

Hole size	Frequency LOC	Weather	Release Rate (kg/s)	Jet Fire		Flash Fire Scenario Horizontal		VCE Scenario Horizontal		Flash Fire Scenario Down Impingement		VCE Scenario Down Impingement	
				Probability	Frequency (occ./year)	Probability	Frequency (occ./year)	Probability	Frequency (occ./year)	Probability	Frequency (occ./year)	Probability	Frequency (occ./year)
5	3.0E-04	F2	0.03	8.0E-03	1.5E-07	9.9E-04	1.8E-08	9.9E-04	1.8E-08	9.9E-04	1.8E-08	9.9E-04	1.8E-08
		D5	0.03	8.0E-03	1.2E-06	9.9E-04	1.5E-07	9.9E-04	1.5E-07	9.9E-04	1.5E-07	9.9E-04	1.5E-07
		D10	0.03	8.0E-03	1.1E-06	9.9E-04	1.3E-07	9.9E-04	1.3E-07	9.9E-04	1.3E-07	9.9E-04	1.3E-07
25	1.8E-04	F2	0.76	5.3E-02	5.9E-07	6.4E-03	7.1E-08	6.4E-03	7.1E-08	6.4E-03	7.1E-08	6.4E-03	7.1E-08
		D5	0.76	5.3E-02	4.9E-06	6.4E-03	5.9E-07	6.4E-03	5.9E-07	6.4E-03	5.9E-07	6.4E-03	5.9E-07
		D10	0.76	5.3E-02	4.3E-06	6.4E-03	5.2E-07	6.4E-03	5.2E-07	6.4E-03	5.2E-07	6.4E-03	5.2E-07

Note:
"Probability" column is the sum of probability for "isolated" and "not isolated" scenarios combined with the ignition probability (P1, P2) as for relevant scenario.
"Frequency" is the sum of frequency for "isolated" and "not isolated" scenarios.
Weather condition distribution (2F 6%; 5D 50%, 10D 44% of total time) is included in the column "Frequency" for each scenario.
Distribution between horizontal and down impingement for flammable gas dispersion and explosion is assumed 50:50.

Section 2 LOC 2.1

Hole size	Frequency LOC	Weather	Release Rate (kg/s)	Jet Fire		Flash Fire Scenario Horizontal		VCE Scenario Horizontal		Flash Fire Scenario Down Impingement		VCE Scenario Down Impingement	
				Probability	Frequency (occ./year)	Probability	Frequency (occ./year)	Probability	Frequency (occ./year)	Probability	Frequency (occ./year)	Probability	Frequency (occ./year)
5	5.6E-03	F2	0.03	8.0E-03	2.7E-06	9.9E-04	3.4E-07	9.9E-04	3.4E-07	9.9E-04	3.4E-07	9.9E-04	3.4E-07
		D5	0.03	8.0E-03	2.3E-05	9.9E-04	2.8E-06	9.9E-04	2.8E-06	9.9E-04	2.8E-06	9.9E-04	2.8E-06
		D10	0.03	8.0E-03	2.0E-05	9.9E-04	2.5E-06	9.9E-04	2.5E-06	9.9E-04	2.5E-06	9.9E-04	2.5E-06
25	3.3E-03	F2	0.76	5.3E-02	1.0E-05	6.4E-03	1.3E-06	6.4E-03	1.3E-06	6.4E-03	1.3E-06	6.4E-03	1.3E-06
		D5	0.76	5.3E-02	8.7E-05	6.4E-03	1.1E-05	6.4E-03	1.1E-05	6.4E-03	1.1E-05	6.4E-03	1.1E-05
		D10	0.76	5.3E-02	7.7E-05	6.4E-03	9.3E-06	6.4E-03	9.3E-06	6.4E-03	9.3E-06	6.4E-03	9.3E-06
37.5 (1.5 inches)	3.4E-04	F2	1.70	5.3E-02	1.1E-06	6.4E-03	1.3E-07	6.4E-03	1.3E-07	6.4E-03	1.3E-07	6.4E-03	1.3E-07
		D5	1.70	5.3E-02	9.1E-06	6.4E-03	1.1E-06	6.4E-03	1.1E-06	6.4E-03	1.1E-06	6.4E-03	1.1E-06
		D10	1.70	5.3E-02	8.0E-06	6.4E-03	9.6E-07	6.4E-03	9.6E-07	6.4E-03	9.6E-07	6.4E-03	9.6E-07

Note:
"Probability" column is the sum of probability for "isolated" and "not isolated" scenarios combined with the ignition probability (P1, P2) as for relevant scenario.
"Frequency" is the sum of frequency for "isolated" and "not isolated" scenarios.
Weather condition distribution (2F 6%; 5D 50%, 10D 44% of total time) is included in the column "Frequency" for each scenario.
Distribution between horizontal and down impingement for flammable gas dispersion and explosion is assumed 50:50.

Section 2 LOC 2.2

Hole size	Frequency LOC	Weather	Release Rate (kg/s)	Jet Fire		Flash Fire Scenario Horizontal		VCE Scenario Horizontal		Flash Fire Scenario Down Impingement		VCE Scenario Down Impingement	
				Probability	Frequency (occ./year)	Probability	Frequency (occ./year)	Probability	Frequency (occ./year)	Probability	Frequency (occ./year)	Probability	Frequency (occ./year)
5	1.0E-03	F2	0.03	8.0E-03	4.8E-07	9.9E-04	6.0E-08	9.9E-04	6.0E-08	9.9E-04	6.0E-08	9.9E-04	6.0E-08
		D5	0.03	8.0E-03	4.0E-06	9.9E-04	5.0E-07	9.9E-04	5.0E-07	9.9E-04	5.0E-07	9.9E-04	5.0E-07
		D10	0.03	8.0E-03	3.6E-06	9.9E-04	4.4E-07	9.9E-04	4.4E-07	9.9E-04	4.4E-07	9.9E-04	4.4E-07
25	4.3E-04	F2	0.76	5.3E-02	1.4E-06	6.4E-03	1.7E-07	6.4E-03	1.7E-07	6.4E-03	1.7E-07	6.4E-03	1.7E-07
		D5	0.76	5.3E-02	1.2E-05	6.4E-03	1.4E-06	6.4E-03	1.4E-06	6.4E-03	1.4E-06	6.4E-03	1.4E-06
		D10	0.76	5.3E-02	1.0E-05	6.4E-03	1.2E-06	6.4E-03	1.2E-06	6.4E-03	1.2E-06	6.4E-03	1.2E-06
75 (3 inches)	1.7E-04	F2	7.06	2.3E-01	2.3E-06	2.3E-02	2.3E-07	2.3E-02	2.3E-07	2.3E-02	2.3E-07	2.3E-02	2.3E-07
		D5	7.06	2.3E-01	1.9E-05	2.3E-02	1.9E-06	2.3E-02	1.9E-06	2.3E-02	1.9E-06	2.3E-02	1.9E-06
		D10	7.06	2.3E-01	1.7E-05	2.3E-02	1.7E-06	2.3E-02	1.7E-06	2.3E-02	1.7E-06	2.3E-02	1.7E-06

Note:
"Probability" column is the sum of probability for "isolated" and "not isolated" scenarios combined with the ignition probability (P1, P2) as for relevant scenario.
"Frequency" is the sum of frequency for "isolated" and "not isolated" scenarios.
Weather condition distribution (2F 6%; 5D 50%, 10D 44% of total time) is included in the column "Frequency" for each scenario.
Distribution between horizontal and down impingement for flammable gas dispersion and explosion is assumed 50:50.

Section 3

Hole size	Frequency LOC	Weather	Release Rate (kg/s)	Jet Fire		Flash Fire Scenario Horizontal		VCE Scenario Horizontal		Flash Fire Scenario Down Impingement		VCE Scenario Down Impingement	
				Probability	Frequency (occ./year)	Probability	Frequency (occ./year)	Probability	Frequency (occ./year)	Probability	Frequency (occ./year)	Probability	Frequency (occ./year)
5	9.3E-04	F2	0.03	8.0E-03	4.5E-07	9.9E-04	5.5E-08	9.9E-04	5.5E-08	9.9E-04	5.5E-08	9.9E-04	5.5E-08
		D5	0.03	8.0E-03	3.7E-06	9.9E-04	4.6E-07	9.9E-04	4.6E-07	9.9E-04	4.6E-07	9.9E-04	4.6E-07
		D10	0.03	8.0E-03	3.3E-06	9.9E-04	4.1E-07	9.9E-04	4.1E-07	9.9E-04	4.1E-07	9.9E-04	4.1E-07
25	5.0E-04	F2	0.80	5.3E-02	1.6E-06	6.4E-03	1.9E-07	6.4E-03	1.9E-07	6.4E-03	1.9E-07	6.4E-03	1.9E-07
		D5	0.80	5.3E-02	1.3E-05	6.4E-03	1.6E-06	6.4E-03	1.6E-06	6.4E-03	1.6E-06	6.4E-03	1.6E-06
		D10	0.80	5.3E-02	1.2E-05	6.4E-03	1.4E-06	6.4E-03	1.4E-06	6.4E-03	1.4E-06	6.4E-03	1.4E-06
50 (2 inches)	4.1E-05	F2	3.2	5.3E-02	1.3E-07	6.4E-03	1.6E-08	6.4E-03	1.6E-08	6.4E-03	1.6E-08	6.4E-03	1.6E-08
		D5	3.2	5.3E-02	1.1E-06	6.4E-03	1.3E-07	6.4E-03	1.3E-07	6.4E-03	1.3E-07	6.4E-03	1.3E-07
		D10	3.2	5.3E-02	9.6E-07	6.4E-03	1.2E-07	6.4E-03	1.2E-07	6.4E-03	1.2E-07	6.4E-03	1.2E-07

Note:
"Probability" column is the sum of probability for "isolated" and "not isolated" scenarios combined with the ignition probability (P1, P2) as for relevant scenario.
"Frequency" is the sum of frequency for "isolated" and "not isolated" scenarios.
Weather condition distribution (2F 6%; 5D 50%, 10D 44% of total time) is included in the column "Frequency" for each scenario.
Distribution between horizontal and down impingement for flammable gas dispersion and explosion is assumed 50:50.

ATTACHMENT 4 A

LOCS AND SCENARIOS (RS SCOPE OF WORK)

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Section 1 Horizontal

Hole size(mm)	Pressure (barg)	Temperature (C°)	Weather	Release Rate (kg/s)	Release duration (s)	Jet Fire scenario (m)			Flash Fire Scenario (m)		VCE Scenario (m)						
						37.5 kW/m2	12.5 kW/m2	4.73 kW/m2	LFL	LFL/2	Flammable gas (kg)	0.50 bar	0.3 5 bar	0.3 bar	0.27 bar	0.15 bar	0.07 bar
5	30	65	F2	0.03	615	3.6	4.4	5.5	5.7	11.0	0.02	3.0	3.7	4.0	4.3	6.5	12.0
			D5	0.03	615	3.6	4.4	5.5	6.0	10.5	0.01	2.3	3.0	3.3	3.5	5.0	9.5
			D10	0.03	615	3.6	4.4	5.5	5.5	9.5	0.008	2.0	2.5	2.8	3.0	3.4	8.0
25	30	65	F2	0.76	301	16.6	20.5	27.0	27.5	43.0	1.79	11.7	15.0	16.0	17.0	26.0	47.5
			D5	0.76	301	16.6	20.5	27.0	32.0	53.0	1.28	10.5	13.4	14.5	15.6	23.4	43.0
			D10	0.76	301	16.6	20.5	27.0	32.5	59.0	0.95	9.7	12.0	13.5	14.5	21.5	49.5

The damage distances for VCE scenarios are calculated considering the involvement of all released mass in the explosion. For QRA explosion risk resummation, a more detailed analysis regarding explosion mass within the platform boundary was performed. These results are reported in Attachment 4C.

Section 1 Down

Hole size(mm)	Pressure (barg)	Temperature (C°)	Weather	Release Rate (kg/s)	Release duration (s)	Flash Fire Scenario (m)		VCE Scenario (m)						
						LFL	LFL/2	Flammable gas (kg)	0.50 bar	0.35 bar	0.3 bar	0.27 bar	0.15 bar	0.07 bar
5	30	65	F2	0.03	615	6.7	9.3	0.04	3.4	4.3	4.7	5.0	7.5	14.0
			D5	0.03	615	8.0	12.2	0.04	3.4	4.4	4.7	5.0	7.5	14.0
			D10	0.03	615	7.6	12.0	0.03	3.0	4.0	4.4	4.5	7.0	13.0
25	30	65	F2	0.76	301	23.3	27.5	2.0	12.0	15.0	17.0	18.0	26.8	49.0
			D5	0.76	301	32.0	38.7	1.6	11.6	14.7	16.0	17.0	25.5	47.0
			D10	0.76	301	92.5	161.0	2.7	14.0	17.5	19.0	20.5	30.5	56.0

The damage distances for VCE scenarios are calculated considering the involvement of all released mass in the explosion. For QRA explosion risk resummation, a more detailed analysis regarding explosion mass within the platform boundary was performed. These results are reported in Attachment 4C.

Section 2 LOC 2.1 Horizontal

Hole size(mm)	Pressure (barg)	Temperature (C°)	Weather	Release Rate (kg/s)	Release duration (s)	Jet Fire scenario (m)				Flash Fire Scenario (m)		VCE Scenario (m)						
						Jet Length (m)	37.5 kW/m2	12.5 kW/m2	4.73 kW/m2	LFL	LFL/2	Flammable gas (kg)	0.50 bar	0.35 bar	0.30 bar	0.27 bar	0.15 bar	0.07 bar
5	30	65	F2	0.03	4200	3.5	3.6	4.4	5.5	5.7	11.0	0.02	3.0	3.7	4.0	4.3	6.5	12.0
			D5	0.03	4200	3.5	3.6	4.4	5.5	6.0	10.5	0.01	2.3	3.0	3.3	3.5	5.0	9.5
			D10	0.03	4200	3.5	3.6	4.4	5.5	5.5	9.5	0.008	2.0	2.5	2.8	3.0	4.4	8.0
25	30	65	F2	0.76	3900	15.3	16.6	20.5	27.0	27.5	43.0	1.8	11.7	15.0	16.0	17.0	26.0	47.5
			D5	0.76	3900	15.3	16.6	20.5	27.0	32.0	53.0	1.3	10.5	13.4	14.5	15.6	23.4	43.0
			D10	0.76	3900	15.3	16.6	20.5	27.0	32.5	59.0	0.95	9.7	12.0	13.5	14.5	21.5	49.5
37.5 (1.5 inches)	30	65	F2	1.7	2810	22.0	24.0	30.0	39.5	39.0	57.0	4.3	16.5	21.0	23.0	24.5	36.5	66.0
			D5	1.7	2810	22.0	24.0	30.0	39.5	47.0	70.0	3.9	16.0	20.0	22.0	23.5	35.0	64.0
			D10	1.7	2810	22.0	24.0	30.0	39.5	49.5	79.5	3.0	14.5	18.0	20.0	21.5	32.0	58.0

The damage distances for VCE scenarios are calculated considering the involvement of all released mass in the explosion. For QRA explosion risk resummation, a more detailed analysis regarding explosion mass within the platform boundary was performed. These results are reported in Attachment 4C.

Section 2 LOC 2.1 Down

Hole size(mm)	Pressure (barg)	Temperature (C°)	Weather	Release Rate (kg/s)	Release duration (s)	Flash Fire Scenario (m)		VCE Scenario (m)						
						LFL	LFL/2	Flammable gas (kg)	0.50 bar	0.35 bar	0.30 bar	0.27 bar	0.15 bar	0.07 bar
5	30	65	F2	0.03	4200	6.7	9.3	0.04	3.4	4.3	4.7	5.0	7.5	14.0
			D5	0.03	4200	8.0	12.2	0.04	3.4	4.4	4.7	5.0	7.5	14.0
			D10	0.03	4200	7.6	12.0	0.03	3.0	4.0	4.4	4.5	7.0	13.0
25	30	65	F2	0.76	3900	23.3	27.5	2.0	12.0	15.0	17.0	18.0	26.8	49.0
			D5	0.76	3900	32.0	38.7	1.6	11.6	14.7	16.0	17.0	25.5	47.0
			D10	0.76	3900	92.5	161.0	2.7	14.0	17.5	19.0	20.5	30.5	56.0
37.5 (1.5 inches)	30	65	F2	1.7	2810	29.0	34.0	4.9	17.0	22.0	24.0	25.5	38.0	69.0
			D5	1.7	2810	38.5	46.0	4.6	16.5	21.0	23.0	24.5	36.5	67.0
			D10	1.7	2810	127.0	215.0	7.9	20.0	25.0	27.5	29.0	43.5	80.0

The damage distances for VCE scenarios are calculated considering the involvement of all released mass in the explosion. For QRA explosion risk resummation, a more detailed analysis regarding explosion mass within the platform boundary was performed. These results are reported in Attachment 4C.

Section 2 LOC 2.2 Horizontal

Hole size(mm)	Pressure (barg)	Temperature (C°)	Weather	Release Rate (kg/s)	Release duration (s)	Jet Fire scenario (m)				Flash Fire Scenario (m)		VCE Scenario (m)						
						Jet Length (m)	37.5 kW/m2	12.5 kW/m2	4.73 kW/m2	LFL	LFL/2	Flammable gas (kg)	0.50 bar	0.35 bar	0.3 bar	0.27 bar	0.15 bar	0.07 bar
5	30	65	F2	0.03	14600	3.5	3.6	4.4	5.5	5.7	11.0	0.02	3.0	3.7	4.0	4.3	6.5	12.0
			D5	0.03	14600	3.5	3.6	4.4	5.5	6.0	10.5	0.01	2.3	3.0	3.3	3.5	5.0	9.5
			D10	0.03	14600	3.5	3.6	4.4	5.5	5.5	9.5	0.008	2.0	2.5	2.8	3.0	4.4	8.0
25	30	65	F2	0.76	6460	15.3	16.6	20.5	27.0	27.5	43.0	1.8	11.7	15.0	16.0	17.0	26.0	47.5
			D5	0.76	6460	15.3	16.6	20.5	27.0	32.0	53.0	1.3	10.5	13.4	14.5	15.6	23.4	43.0
			D10	0.76	6460	15.3	16.6	20.5	27.0	32.5	59.0	0.95	9.7	12.0	13.5	14.5	21.5	49.5
75 (3 inches)	30	65	F2	7.06	723	42.0	45.5	57.5	76.5	68.0	93.0	36.3	32.7	41.0	45.0	45.8	72.0	132.5
			D5	7.06	723	42.0	45.5	57.5	76.5	81.0	108.0	26.7	30.0	37.5	41.0	44.0	65.5	120.5
			D10	7.06	723	42.0	45.5	57.5	76.5	88.0	123.0	20.2	27.0	34.0	37.5	40.0	60.0	110.0

The damage distances for VCE scenarios are calculated considering the involvement of all released mass in the explosion. For QRA explosion risk resummation, a more detailed analysis regarding explosion mass within the platform boundary was performed. These results are reported in Attachment 4C.

Section 2 LOC 2.2 Down

Hole size(mm)	Pressure (barg)	Temperature (C°)	Weather	Release Rate (kg/s)	Release duration (s)	Flash Fire Scenario (m)		VCE Scenario (m)						
						LFL	LFL/2	Flammable gas (kg)	0.50 bar	0.35 bar	0.3 bar	0.27 bar	0.15 bar	0.07 bar
5	30	65	F2	0.03	14600	6.7	9.3	0.04	3.4	4.3	4.7	5.0	7.5	14.0
			D5	0.03	14600	8.0	12.2	0.04	3.4	4.4	4.7	5.0	7.5	14.0
			D10	0.03	14600	7.6	12.0	0.03	3.0	4.0	4.4	4.5	7.0	13.0
25	30	65	F2	0.76	6460	23.3	27.5	2.0	12.0	15.0	17.0	18.0	26.8	49.0
			D5	0.76	6460	32.0	38.7	1.6	11.6	14.7	16.0	17.0	25.5	47.0
			D10	0.76	6460	92.5	161.0	2.7	14.0	17.5	19.0	20.5	30.5	56.0
75 (3 inches)	30	65	F2	7.06	723	44.0	51.0	39.3	34.0	43.0	47.0	50.0	74.5	137.0
			D5	7.06	723	54.0	62.5	29.0	30.5	38.5	42.0	45.0	67.5	124.0
			D10	7.06	723	69.0	85.0	23.7	28.5	36.0	40.0	42.5	63.0	116.0

The damage distances for VCE scenarios are calculated considering the involvement of all released mass in the explosion. For QRA explosion risk resummation, a more detailed analysis regarding explosion mass within the platform boundary was performed. These results are reported in Attachment 4C.

Section 3 Horizontal

Hole size(mm)	Pressure (barg)	Temperature (C°)	Weather	Release Rate (kg/s)	Release duration (s)	Jet Fire scenario (m)				Flash Fire Scenario (m)		VCE Scenario (m)						
						Jet Length (m)	37.5 kW/m2	12.5 kW/m2	4.73 kW/m2	LFL	LFL/2	Flammable gas (kg)	0.50 bar	0.35 bar	0.3 bar	0.27 bar	0.15 bar	0.07 bar
5	30	25	F2	0.03	660	3.6	3.8	4.5	5.7	6.0	11.5	0.031	3.0	4.0	4.2	4.5	6.5	12.5
			D5	0.03	660	3.6	3.8	4.5	5.7	6.0	11.0	0.015	2.5	3.0	3.3	3.6	5.5	10.0
			D10	0.03	660	3.6	3.8	4.5	5.7	6.0	10.0	0.001	2.0	2.5	3.0	3.0	4.5	8.5
25	30	25	F2	0.80	302	16.0	17.5	21.5	28.0	29.0	44.5	2.3	12.0	15.0	16.5	18.0	26.5	48.0
			D5	0.80	302	16.0	17.5	21.5	28.0	34.0	54.5	1.5	11.0	14.0	15.5	16.5	24.5	46.0
			D10	0.80	302	16.0	17.5	21.5	28.0	34.5	62.0	1.1	10.0	13.0	14.0	15.0	22.0	41.0
50 (2 inches)	30	25	F2	3.2	61	30.0	32.5	40.5	53.5	51.0	72.0	13.4	24.0	30.0	33.0	35.5	52.0	97.0
			D5	3.2	61	30.0	32.5	40.5	53.5	62.0	86.0	9.7	21.0	26.0	29.0	31.0	47.0	86.0
			D10	3.2	61	30.0	32.5	40.5	53.5	67.0	99.0	7.5	19.0	24.0	26.0	28.0	42.0	78.0

The damage distances for VCE scenarios are calculated considering the involvement of all released mass in the explosion. For QRA explosion risk resummation, a more detailed analysis regarding explosion mass within the platform boundary was performed. These results are reported in Attachment 4C.

Section 3 Down

Hole size(mm)	Pressure (barg)	Temperature (C°)	Weather	Release Rate (kg/s)	Release duration (s)	Flash Fire Scenario (m)		VCE Scenario (m)						
						LFL	LFL/2	Flammable gas (kg)	0.50 bar	0.35 bar	0.3 bar	0.27 bar	0.15 bar	0.07 bar
5	30	25	F2	0.03	660	7.0	9.5	0.051	3.5	4.5	5.0	5.3	8.0	14.0
			D5	0.03	660	8.5	12.5	0.048	3.6	4.5	5.0	5.3	8.0	14.5
			D10	0.03	660	8.0	12.0	0.037	3.3	4.0	4.5	5.0	7.5	13.5
25	30	25	F2	0.80	302	24.0	28.0	2.6	12.0	15.5	17.0	18.0	27.0	50.0
			D5	0.80	302	35.0	42.0	1.9	12.0	15.0	17.0	18.0	27.0	49.0
			D10	0.80	302	98.0	166.0	3.1	14.5	18.5	20.0	21.5	32.0	58.0
50 (2 inches)	30	25	F2	3.2	61	35.5	41.0	15.3	25.0	31.5	34.5	36.5	54.5	101.0
			D5	3.2	61	45.5	53.5	11	22.0	28.0	30.5	32.5	49.0	89.0
			D10	3.2	61	60.0	74.5	9.3	21.0	26.5	29.0	31.0	46.0	85.0

The damage distances for VCE scenarios are calculated considering the involvement of all released mass in the explosion. For QRA explosion risk resummation, a more detailed analysis regarding explosion mass within the platform boundary was performed. These results are reported in Attachment 4C.

ATTACHMENT 4 B

LOCS AND SCENARIOS (CPIs PACKAGE)

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BESS

BESS TR explosion Scenario (m)		
Frequency of occurrence	**0. bar**	**0.3 bar**
1.0E-05	3.5	6.1

ATTACHMENT 4 C
DETAILED ANALYSIS OF EXPLOSION SCENARIOS WITHIN PLATFORM BOUNDARY

Section 1 Horizontal release ESD

Nor th

Hole size (mm)	Pressure (barg)	Temperature (C°)	Weather	Frequency (occ/year)	VCE Scenario (m)						
					Flammable gas (kg)	0.5 bar	0.35 bar	0.3 bar	0.27 bar	0.15 bar	0.07 bar
5	30	65	F2	4.00E-09	0.02	3.0	3.7	4.0	4.3	6.5	12.0
			D5	3.50E-08	0.01	2.3	3.0	3.3	3.5	5.0	9.5
			D10	3.00E-08	0.008	2.0	2.5	2.8	3.0	3.4	8.0
25	30	65	F2	1.60E-08	1.79	11.7	15.0	16.0	17.0	26.0	47.5
			D5	1.33E-07	1.22	10.5	13.4	14.5	15.5	23.4	43.0
			D10	1.18E-07	0.89	9.5	12.0	13.0	14.0	21.0	38.8

East-West

Hole size (mm)	Pressure (barg)	Temperature (C°)	Weather	Frequency (occ/year)	VCE Scenario (m)						
					Flammable gas (kg)	0.5 bar	0.35 bar	0.3 bar	0.27 bar	0.15 bar	0.07 bar
5	30	65	F2	8.00E-09	0.02	3	3.7	4	4.3	6.5	12
			D5	7.00E-08	0.01	2.3	3	3.3	3.5	5	9.5
			D10	6.00E-08	0.008	2	2.5	2.8	3	3.4	8
25	30	65	F2	3.20E-08	0.65	9.5	12.1	13.3	14.2	21.1	34.9
			D5	2.65E-07	0.40	7.3	9.3	10.1	10.8	16.1	29.7
			D10	2.35E-07	0.29	6.5	8.3	9.1	9.7	14.5	26.7

South

Hole size (mm)	Pressure (barg)	Temperature (C°)	Weather	Frequency (occ/year)	VCE Scenario (m)						
					Flammable gas (kg)	0.5 bar	0.35 bar	0.3 bar	0.27 bar	0.15 bar	0.07 bar
5	30	65	F2	4.00E-09	0.02	3.0	3.7	4.0	4.3	6.5	12.0
			D5	3.50E-08	0.01	2.3	3.0	3.3	3.5	5.0	9.5
			D10	3.00E-08	0.008	2.0	2.5	2.8	3.0	3.4	8.0
25	30	65	F2	1.60E-08	0.81	9.3	11.7	12.9	13.7	20.5	37.6
			D5	1.33E-07	0.50	7.9	10.0	10.9	11.7	17.4	32.0
			D10	1.18E-07	0.37	7.1	9.0	10.0	10.6	15.7	29.0

Note: For west-east direction is assumed same damage distance, thus the frequency of occurrence is doubled compared to other direction.

For the release point, refer to chapter 5.1 where the release point is reported in the layout.

Section 1 Horizontal release ESD FAILURE

North

Hole size (mm)	Pressure (barg)	Temperature (C°)	Weather	Frequency (occ/year)	VCE Scenario (m)						
					New Flammable gas (kg)	0.5 bar	0.35 bar	0.3 bar	0.27 bar	0.15 bar	0.07 bar
5	30	65	F2	4.50E-10	0.02	3.0	3.7	4.0	4.3	6.5	12.0
			D5	3.75E-09	0.01	2.3	3.0	3.3	3.5	5.0	9.5
			D10	3.25E-09	0.008	2.0	2.5	2.8	3.0	3.4	8.0
25	30	65	F2	1.78E-09	1.79	11.7	15.0	16.0	17.0	26.0	47.5
			D5	1.48E-08	1.22	10.5	13.4	14.5	15.5	23.4	43.0
			D10	1.30E-08	0.89	9.5	12.0	13.0	14.0	21.0	38.8

East-West

Hole size (mm)	Pressure (barg)	Temperature (C°)	Weather	Frequency (occ/year)	VCE Scenario (m)						
					New Flammable gas (kg)	0.5 bar	0.35 bar	0.3 bar	0.27 bar	0.15 bar	0.07 bar
5	30	65	F2	9.00E-10	0.02	3	3.7	4	4.3	6.5	12
			D5	7.50E-09	0.01	2.3	3	3.3	3.5	5	9.5
			D10	6.50E-09	0.008	2	2.5	2.8	3	3.4	8
25	30	65	F2	3.55E-09	0.65	9.5	12.1	13.3	14.2	21.1	34.9
			D5	2.95E-08	0.40	7.3	9.3	10.1	10.8	16.1	29.7
			D10	2.60E-08	0.29	6.5	8.3	9.1	9.7	14.5	26.7

South

Hole size (mm)	Pressure (barg)	Temperature (C°)	Weather	Frequency (occ/year)	VCE Scenario (m)						
					New Flammable gas (kg)	0.5 bar	0.35 bar	0.3 bar	0.27 bar	0.15 bar	0.07 bar
5	30	65	F2	4.50E-10	0.02	3.0	3.7	4.0	4.3	6.5	12.0
			D5	3.75E-09	0.01	2.3	3.0	3.3	3.5	5.0	9.5
			D10	3.25E-09	0.008	2.0	2.5	2.8	3.0	3.4	8.0
25	30	65	F2	1.78E-09	0.81	9.3	11.7	12.9	13.7	20.5	37.6
			D5	1.48E-08	0.50	7.9	10.0	10.9	11.7	17.4	32.0
			D10	1.30E-08	0.37	7.1	9.0	10.0	10.6	15.7	29.0

Note: For west-east direction is assumed same damage distance, thus the frequency of occurrence is doubled compared to other direction.

For the release point, refer to chapter 5.1 where the release point is reported in the layout.

Section 1 Down release ESD

North

Hole size (mm)	Pressure (barg)	Temperature (C°)	Weather	Frequency (occ/year)	VCE Scenario (m)						
					New Flammable gas (kg)	0.5 bar	0.35 bar	0.3 bar	0.27 bar	0.15 bar	0.07 bar
5	30	65	F2	4.00E-09	0.04	3.4	4.3	4.7	5	7.5	14
			D5	7.00E-08	0.04	3.4	4.4	4.7	5	7.5	14
			D10	6.00E-08	0.03	3	4	4.4	4.5	7	13
25	30	65	F2	3.20E-08	2	12	15	17	18	26.8	49
			D5	2.65E-07	1.5	11.4	14.4	15.8	16.9	25.1	46.1
			D10	2.35E-07	0.9	9.6	12.1	13.3	14.2	21.2	38.9

East-West

Hole size (mm)	Pressure (barg)	Temperature (C°)	Weather	Frequency (occ/year)	VCE Scenario (m)						
					New Flammable gas (kg)	0.5 bar	0.35 bar	0.3 bar	0.27 bar	0.15 bar	0.07 bar
5	30	65	F2	8.00E-09	0.04	3.4	4.3	4.7	5.0	7.5	14.0
			D5	7.00E-08	0.04	3.4	4.4	4.7	5.0	7.5	14.0
			D10	6.00E-08	0.03	3.0	4.0	4.4	4.5	7.0	13.0
25	30	65	F2	3.20E-08	0.86	9.4	12.0	13.1	14.0	20.9	38.3
			D5	2.65E-07	0.50	7.9	10.0	11.0	11.7	17.4	32.0
			D10	2.35E-07	0.29	6.5	8.3	9.1	9.7	14.5	26.7

South

Hole size (mm)	Pressure (barg)	Temperature (C°)	Weather	Frequency (occ/year)	VCE Scenario (m)						
					New Flammable gas (kg)	0.5 bar	0.35 bar	0.3 bar	0.27 bar	0.15 bar	0.07 bar
5	30	65	F2	4.00E-09	0.04	3.4	4.3	4.7	5	7.5	14
			D5	7.00E-08	0.04	3.4	4.4	4.7	5	7.5	14
			D10	6.00E-08	0.03	3	4	4.4	4.5	7	13
25	30	65	F2	3.20E-08	1.07	10.2	12.9	14.1	15.1	22.5	41.3
			D5	2.65E-07	0.63	8.5	10.8	11.8	12.6	18.8	34.6
			D10	2.35E-07	0.36	7.1	9	9.8	10.5	15.6	28.7

Note: For west-east direction is assumed same damage distance, thus the frequency of occurrence is doubled compared to other direction.

For the release point, refer to chapter 5.1 where the release point is reported in the layout.

Section 1 Down release ESD FAILURE

North

Hole size (mm)	Pressure (barg)	Temperature (C°)	Weather	Frequency (occ/year)	VCE Scenario (m)						
					New Flammable gas (kg)	0.5 bar	0.35 bar	0.3 bar	0.27 bar	0.15 bar	0.07 bar
5	30	65	F2	4.50E-10	0.04	3.4	4.3	4.7	5	7.5	14
			D5	3.75E-09	0.04	3.4	4.4	4.7	5	7.5	14
			D10	3.25E-09	0.03	3	4	4.4	4.5	7	13
25	30	65	F2	1.78E-09	2	12	15	17	18	26.8	49
			D5	1.48E-08	1.5	11.4	14.4	15.8	16.9	25.1	46.1
			D10	1.30E-08	0.9	9.6	12.1	13.3	14.2	21.2	38.9

East-West

Hole size (mm)	Pressure (barg)	Temperature (C°)	Weather	Frequency (occ/year)	VCE Scenario (m)						
					New Flammable gas (kg)	0.5 bar	0.35 bar	0.3 bar	0.27 bar	0.15 bar	0.07 bar
5	30	65	F2	9.00E-10	0.04	3.4	4.3	4.7	5.0	7.5	14.0
			D5	7.50E-09	0.04	3.4	4.4	4.7	5.0	7.5	14.0
			D10	6.50E-09	0.03	3.0	4.0	4.4	4.5	7.0	13.0
25	30	65	F2	3.55E-09	0.86	9.4	12.0	13.1	14.0	20.9	38.3
			D5	2.95E-08	0.50	7.9	10.0	11.0	11.7	17.4	32.0
			D10	2.60E-08	0.29	6.5	8.3	9.1	9.7	14.5	26.7

South

Hole size (mm)	Pressure (barg)	Temperature (C°)	Weather	Frequency (occ/year)	VCE Scenario (m)						
					New Flammable gas (kg)	0.5 bar	0.35 bar	0.3 bar	0.27 bar	0.15 bar	0.07 bar
5	30	65	F2	4.50E-10	0.04	3.4	4.3	4.7	5	7.5	14
			D5	3.75E-09	0.04	3.4	4.4	4.7	5	7.5	14
			D10	3.25E-09	0.03	3	4	4.4	4.5	7	13
25	30	65	F2	1.78E-09	1.072961373	10.2	12.9	14.1	15.1	22.5	41.3
			D5	1.48E-08	0.625	8.5	10.8	11.8	12.6	18.8	34.6
			D10	1.30E-08	0.364864865	7.1	9	9.8	10.5	15.6	28.7

Note: For west-east direction is assumed same damage distance, thus the frequency of occurrence is doubled compared to other direction.

For the release point, refer to chapter 5.1 where the release point is reported in the layout.

Section 2 (LOC 2.1) Horizontal release ESD

South

Hole size (mm)	Pressure (barg)	Temperature (C°)	Weather	Frequency (occ/year)	VCE Scenario (m)						
					New Flammable gas (kg)	0.5 bar	0.35 bar	0.3 bar	0.27 bar	0.15 bar	0.07 bar
5	30	65	F2	7.50E-08	0.02	3	3.7	4	4.3	6.5	12
			D5	6.25E-07	0.01	2.3	3	3.3	3.5	5	9.5
			D10	5.50E-07	0.008	2	2.5	2.8	3	4.4	8
25	30	65	F2	2.75E-07	1.8	11.7	15	16	17	26	47.5
			D5	2.38E-06	1.22	10.5	13.4	14.5	15.6	23.4	43
			D10	2.10E-06	0.88	9.5	12	13.2	14.1	21	38.6
37.5 (1.5 inches)	30	65	F2	3.00E-08	3.31	14.8	18.8	20.6	22	33	60.1
			D5	2.45E-07	2.49	13.5	17	18.7	20	30	54.7
			D10	2.18E-07	1.82	12.1	15.4	16.8	18	26.8	49.2

East-West

Hole size (mm)	Pressure (barg)	Temperature (C°)	Weather	Frequency (occ/year)	VCE Scenario (m)						
					New Flammable gas (kg)	0.5 bar	0.35 bar	0.3 bar	0.27 bar	0.15 bar	0.07 bar
5	30	65	F2	1.50E-07	0.02	3	3.7	4	4.3	6.5	12
			D5	1.25E-06	0.01	2.3	3	3.3	3.5	5	9.5
			D10	1.10E-06	0.008	2	2.5	2.8	3	4.4	8
25	30	65	F2	5.50E-07	0.65	8.6	11	12	12.7	19	34.9
			D5	4.75E-06	0.41	7.4	9.3	10.3	11	16.3	30
			D10	4.20E-06	0.29	6.6	8.3	9.1	9.7	14.5	26.7
37.5 (1.5 inches)	30	65	F2	6.00E-08	1.10	10.3	13	14.2	15.2	22.7	41.6
			D5	4.90E-07	0.83	9.3	11.9	13	13.9	20.6	37.9
			D10	4.35E-07	0.61	8.4	10.7	11.7	12.5	18.6	34.2

North

Hole size (mm)	Pressure (barg)	Temperature (C°)	Weather	Frequency (occ/year)	VCE Scenario (m)						
					New Flammable gas (kg)	0.5 bar	0.35 bar	0.3 bar	0.27 bar	0.15 bar	0.07 bar
5	30	65	F2	7.50E-08	0.02	3	3.7	4	4.3	6.5	12
			D5	6.25E-07	0.01	2.3	3	3.3	3.5	5	9.5
			D10	5.50E-07	0.008	2	2.5	2.8	3	4.4	8
25	30	65	F2	2.75E-07	0.74	9	11.4	12.5	13.3	19.9	36.5
			D5	2.38E-06	0.46	7.7	9.7	10.7	11.4	16.9	31.1
			D10	2.10E-06	0.33	6.9	8.7	9.5	10.2	15.2	27.9
37.5 (1.5 inches)	30	65	F2	3.00E-08	1.25	10.7	13.6	14.9	15.9	23.6	43.5
			D5	2.45E-07	0.94	9.8	12.3	13.5	14.4	21.5	39.5
			D10	2.18E-07	0.68	8.8	11.1	12.1	13	19.3	35.5

Note: For west-east direction is assumed same damage distance, thus the frequency of occurrence is doubled compared to other direction.
For the release point, refer to chapter 5.1 where the release point is reported in the layout.

Section 2 (LOC 2.1) Horizontal release ESD FAILURE

South

Hole size (mm)	Pressure (barg)	Temperature (C°)	Weather	Frequency (occ/year)	VCE Scenario (m)						
					New Flammable gas (kg)	0.5 bar	0.35 bar	0.3 bar	0.27 bar	0.15 bar	0.07 bar
5	30	65	F2	8.50E-09	0.02	3	3.7	4	4.3	6.5	12
			D5	7.00E-08	0.01	2.3	3	3.3	3.5	5	9.5
			D10	6.25E-08	0.008	2	2.5	2.8	3	4.4	8
25	30	65	F2	3.25E-08	1.8	11.7	15	16	17	26	47.5
			D5	2.75E-07	1.22	10.5	13.4	14.5	15.6	23.4	43
			D10	2.33E-07	0.88	9.5	12	13.2	14.1	21	38.6
37.5 (1.5 inches)	30	65	F2	3.25E-09	3.31	14.8	18.8	20.6	22	33	60.1
			D5	2.75E-08	2.49	13.5	17	18.7	20	30	54.7
			D10	2.40E-08	1.82	12.1	15.4	16.8	18	26.8	49.2

East-West

Hole size (mm)	Pressure (barg)	Temperature (C°)	Weather	Frequency (occ/year)	VCE Scenario (m)						
					New Flammable gas (kg)	0.5 bar	0.35 bar	0.3 bar	0.27 bar	0.15 bar	0.07 bar
5	30	65	F2	1.70E-08	0.02	3	3.7	4	4.3	6.5	12
			D5	1.40E-07	0.01	2.3	3	3.3	3.5	5	9.5
			D10	1.25E-07	0.008	2	2.5	2.8	3	4.4	8
25	30	65	F2	6.50E-08	0.65	8.6	11	12	12.7	19	34.9
			D5	5.50E-07	0.41	7.4	9.3	10.3	11	16.3	30
			D10	4.65E-07	0.29	6.6	8.3	9.1	9.7	14.5	26.7
37.5 (1.5 inches)	30	65	F2	6.50E-09	1.10	10.3	13	14.2	15.2	22.7	41.6
			D5	5.50E-08	0.83	9.3	11.9	13	13.9	20.6	37.9
			D10	4.80E-08	0.61	8.4	10.7	11.7	12.5	18.6	34.2

North

Hole size (mm)	Pressure (barg)	Temperature (C°)	Weather	Frequency (occ/year)	VCE Scenario (m)						
					New Flammable gas (kg)	0.5 bar	0.35 bar	0.3 bar	0.27 bar	0.15 bar	0.07 bar
5	30	65	F2	8.50E-09	0.02	3	3.7	4	4.3	6.5	12
			D5	7.00E-08	0.01	2.3	3	3.3	3.5	5	9.5
			D10	6.25E-08	0.008	2	2.5	2.8	3	4.4	8
25	30	65	F2	3.25E-08	0.74	9	11.4	12.5	13.3	19.9	36.5
			D5	2.75E-07	0.46	7.7	9.7	10.7	11.4	16.9	31.1
			D10	2.33E-07	0.33	6.9	8.7	9.5	10.2	15.2	27.9
37.5 (1.5 inches)	30	65	F2	3.25E-09	1.25	10.7	13.6	14.9	15.9	23.6	43.5
			D5	2.75E-08	0.94	9.8	12.3	13.5	14.4	21.5	39.5
			D10	2.40E-08	0.68	8.8	11.1	12.1	13	19.3	35.5

Note: For west-east direction is assumed same damage distance, thus the frequency of occurrence is doubled compared to other direction.
For the release point, refer to chapter 5.1 where the release point is reported in the layout.

Section 2 (LOC 2.1) down release ESD

South

Hole size (mm)	Pressure (barg)	Temperature (C°)	Weather	Frequency (occ/year)	VCE Scenario (m)						
					New Flammable gas (kg)	0.5 bar	0.35 bar	0.3 bar	0.27 bar	0.15 bar	0.07 bar
5	30	65	F2	7.50E-08	0.04	3.4	4.3	4.7	5	7.5	14
			D5	6.25E-07	0.04	3.4	4.4	4.7	5	7.5	14
			D10	5.50E-07	0.03	3	4	4.4	4.5	7	13
25	30	65	F2	2.75E-07	2	12	15	17	18	26.8	49
			D5	2.38E-06	1.50	11.4	14.4	15.8	16.9	25	46.2
			D10	2.10E-06	0.88	9.5	12	13.2	14.1	21	38.6
37.5 (1.5 inches)	30	65	F2	3.00E-08	4.90	17	22	24	25.5	38	69
			D5	2.45E-07	3.58	15.3	19.3	21.1	22.5	33.6	61.7
			D10	2.18E-07	1.87	12.3	15.5	17	18.1	27	49.7

East-West

Hole size (mm)	Pressure (barg)	Temperature (C°)	Weather	Frequency (occ/year)	VCE Scenario (m)						
					New Flammable gas (kg)	0.5 bar	0.35 bar	0.3 bar	0.27 bar	0.15 bar	0.07 bar
5	30	65	F2	1.50E-07	0.04	3.4	4.3	4.7	5	7.5	14
			D5	1.25E-06	0.04	3.4	4.4	4.7	5	7.5	14
			D10	1.10E-06	0.03	3	4	4.4	4.5	7	13
25	30	65	F2	5.50E-07	0.86	9.5	12	13.1	14	20.9	38.3
			D5	4.75E-06	0.50	7.9	10	10.9	11.7	17.4	32
			D10	4.20E-06	0.29	6.5	8.3	9.1	9.7	14.5	26.7
37.5 (1.5 inches)	30	65	F2	6.00E-08	1.69	11.9	15	16.4	17.5	26.1	48
			D5	4.90E-07	1.19	10.5	13.3	14.6	15.6	23.3	42.7
			D10	4.35E-07	0.62	8.5	10.7	11.8	12.5	18.8	34.4

North

Hole size (mm)	Pressure (barg)	Temperature (C°)	Weather	Frequency (occ/year)	VCE Scenario (m)						
					New Flammable gas (kg)	0.5 bar	0.35 bar	0.3 bar	0.27 bar	0.15 bar	0.07 bar
5	30	65	F2	7.50E-08	3.4	3.4	4.3	4.7	5	7.5	14
			D5	6.25E-07	3	3.4	4.4	4.7	5	7.5	14
			D10	5.50E-07	12	3	4	4.4	4.5	7	13
25	30	65	F2	2.75E-07	0.97	9.9	12.5	13.7	14.6	21.7	39.9
			D5	2.38E-06	0.57	8.3	10.4	11.4	12.2	18.2	33.4
			D10	2.10E-06	0.33	6.9	8.7	9.5	10.2	15.2	27.9
37.5 (1.5 inches)	30	65	F2	3.00E-08	1.91	12.4	15.6	17.1	18.3	27.2	50
			D5	2.45E-07	1.35	11	13.9	15.2	16.3	24.3	44.6
			D10	2.18E-07	0.70	8.8	11.2	12.3	13.1	19.5	35.8

Note: For west-east direction is assumed same damage distance, thus the frequency of occurrence is doubled compared to other direction.
For the release point, refer to chapter 5.1 where the release point is reported in the layout.

Section 2 (LOC 2.1) down release ESD FAILURE

South

Hole size (mm)	Pressure (barg)	Temperature (C°)	Weather	Frequency (occ/year)	VCE Scenario (m)						
					New Flammable gas (kg)	0.5 bar	0.35 bar	0.3 bar	0.27 bar	0.15 bar	0.07 bar
5	30	65	F2	8.50E-09	0.04	3.4	4.3	4.7	5	7.5	14
			D5	7.00E-08	0.04	3.4	4.4	4.7	5	7.5	14
			D10	6.25E-08	0.03	3	4	4.4	4.5	7	13
25	30	65	F2	3.25E-08	2	12	15	17	18	26.8	49
			D5	2.75E-07	1.50	11.4	14.4	15.8	16.9	25	46.2
			D10	2.33E-07	0.88	9.5	12	13.2	14.1	21	38.6
37.5 (1.5 inches)	30	65	F2	3.25E-09	4.90	17	22	24	25.5	38	69
			D5	2.75E-08	3.58	15.3	19.3	21.1	22.5	33.6	61.7
			D10	2.40E-08	1.87	12.3	15.5	17	18.1	27	49.7

East-West

Hole size (mm)	Pressure (barg)	Temperature (C°)	Weather	Frequency (occ/year)	VCE Scenario (m)						
					New Flammable gas (kg)	0.5 bar	0.35 bar	0.3 bar	0.27 bar	0.15 bar	0.07 bar
5	30	65	F2	1.70E-08	0.04	3.4	4.3	4.7	5	7.5	14
			D5	1.40E-07	0.04	3.4	4.4	4.7	5	7.5	14
			D10	1.25E-07	0.03	3	4	4.4	4.5	7	13
25	30	65	F2	6.50E-08	0.86	9.5	12	13.1	14	20.9	38.3
			D5	5.50E-07	0.50	7.9	10	10.9	11.7	17.4	32
			D10	4.65E-07	0.29	6.5	8.3	9.1	9.7	14.5	26.7
37.5 (1.5 inches)	30	65	F2	6.50E-09	1.69	11.9	15	16.4	17.5	26.1	48
			D5	5.50E-08	1.19	10.5	13.3	14.6	15.6	23.3	42.7
			D10	4.80E-08	0.62	8.5	10.7	11.8	12.5	18.8	34.4

North

Hole size (mm)	Pressure (barg)	Temperature (C°)	Weather	Frequency (occ/year)	VCE Scenario (m)						
					New Flammable gas (kg)	0.5 bar	0.35 bar	0.3 bar	0.27 bar	0.15 bar	0.07 bar
5	30	65	F2	8.50E-09	3.4	3.4	4.3	4.7	5	7.5	14
			D5	7.00E-08	3	3.4	4.4	4.7	5	7.5	14
			D10	6.25E-08	12	3	4	4.4	4.5	7	13
25	30	65	F2	3.25E-08	0.97	9.9	12.5	13.7	14.6	21.7	39.9
			D5	2.75E-07	0.57	8.3	10.4	11.4	12.2	18.2	33.4
			D10	2.33E-07	0.33	6.9	8.7	9.5	10.2	15.2	27.9
37.5 (1.5 inches)	30	65	F2	3.25E-09	1.91	12.4	15.6	17.1	18.3	27.2	50
			D5	2.75E-08	1.35	11	13.9	15.2	16.3	24.3	44.6
			D10	2.40E-08	0.70	8.8	11.2	12.3	13.1	19.5	35.8

Note: For west-east direction is assumed same damage distance, thus the frequency of occurrence is doubled compared to other direction.

For the release point, refer to chapter 5.1 where the release point is reported in the layout.

Section 2 (LOC 2.2) Horizontal release ESD

South

Hole size (mm)	Pressure (barg)	Temperature (C°)	Weather	Frequency (occ/year)	VCE Scenario (m)						
					New Flammable gas (kg)	0.5 bar	0.35 bar	0.3 bar	0.27 bar	0.15 bar	0.07 bar
5	30	65	F2	1.35E-08	0.02	3	3.7	4	4.3	6.5	12
			D5	1.13E-07	0.01	2.3	3	3.3	3.5	5	9.5
			D10	1.00E-07	0.01	2	2.5	2.8	3	4.4	8
25	30	65	F2	3.75E-08	1.80	11.7	15	16	17	26	47.5
			D5	3.00E-07	1.06	10.1	12.8	14	15	22.3	41.1
			D10	2.75E-07	0.76	9	11.5	12.6	13.4	20	36.8
75 (3 inches)	30	65	F2	5.25E-08	13.88	23.9	30.3	33.1	35.4	52.7	96.9
			D5	4.25E-07	8.57	20.4	25.8	28.2	30.1	44.9	82.5
			D10	3.75E-07	5.97	18	22.8	25	26.7	39.8	73.1

East -west

Hole size (mm)	Pressure (barg)	Temperature (C°)	Weather	Frequency (occ/year)	VCE Scenario (m)						
					New Flammable gas (kg)	0.5 bar	0.35 bar	0.3 bar	0.27 bar	0.15 bar	0.07 bar
5	30	65	F2	2.70E-08	0.02	3	3.7	4	4.3	6.5	12
			D5	2.25E-07	0.01	2.3	3	3.3	3.5	5	9.5
			D10	2.00E-07	0.01	2	2.5	2.8	3	4.4	8
25	30	65	F2	7.50E-08	0.72	8.9	11.3	12.4	13.2	19.7	36.1
			D5	6.00E-07	0.45	7.6	9.6	10.6	11.3	16.8	30.9
			D10	5.50E-07	0.32	6.8	8.6	9.4	10	15	27.6
75 (3 inches)	30	65	F2	1.05E-07	5.87	18	22.7	24.9	26.6	39.6	72.8
			D5	8.50E-07	3.63	15.3	19.3	21.2	22.7	33.7	62
			D10	7.50E-07	2.53	13.6	17.2	18.8	21	29.9	55

North

Hole size (mm)	Pressure (barg)	Temperature (C°)	Weather	Frequency (occ/year)	VCE Scenario (m)						
					New Flammable gas (kg)	0.5 bar	0.35 bar	0.3 bar	0.27 bar	0.15 bar	0.07 bar
5	30	65	F2	1.35E-08	2.30	3	3.7	4	4.3	6.5	12
			D5	1.13E-07	2.00	2.3	3	3.3	3.5	5	9.5
			D10	1.00E-07	11.70	2	2.5	2.8	3	4.4	8
25	30	65	F2	3.75E-08	0.98	9.9	12.5	13.7	14.6	21.8	40.1
			D5	3.00E-07	0.61	8.4	10.7	11.7	12.5	18.6	34.2
			D10	2.75E-07	0.44	7.6	9.6	10.5	11.2	16.7	30.7
75 (3 inches)	30	65	F2	5.25E-08	8.01	19.9	25.2	27.6	29.5	43.9	80.7
			D5	4.25E-07	4.94	17	21.4	23.5	25.1	37.4	68.7
			D10	3.75E-07	3.44	15	19	20.8	22.4	33.1	60.9

Note: For west-east direction is assumed same damage distance, thus the frequency of occurrence is doubled compared to other direction.
For the release point, refer to chapter 5.1 where the release point is reported in the layout.

Section 2 (LOC 2.2) Horizontal release ESD FAILURE

South

Hole size (mm)	Pressure (barg)	Temperature (C°)	Weather	Frequency (occ/year)	VCE Scenario (m)						
					New Flammable gas (kg)	0.5 bar	0.35 bar	0.3 bar	0.27 bar	0.15 bar	0.07 bar
5	30	65	F2	1.50E-09	0.02	3	3.7	4	4.3	6.5	12
			D5	1.25E-08	0.01	2.3	3	3.3	3.5	5	9.5
			D10	1.10E-08	0.01	2	2.5	2.8	3	4.4	8
25	30	65	F2	4.25E-09	1.80	11.7	15	16	17	26	47.5
			D5	3.50E-08	1.06	10.1	12.8	14	15	22.3	41.1
			D10	3.00E-08	0.76	9	11.5	12.6	13.4	20	36.8
75 (3 inches)	30	65	F2	5.75E-09	13.88	23.9	30.3	33.1	35.4	52.7	96.9
			D5	4.75E-08	8.57	20.4	25.8	28.2	30.1	44.9	82.5
			D10	4.25E-08	5.97	18	22.8	25	26.7	39.8	73.1

East-west

Hole size (mm)	Pressure (barg)	Temperature (C°)	Weather	Frequency (occ/year)	VCE Scenario (m)						
					New Flammable gas (kg)	0.5 bar	0.35 bar	0.3 bar	0.27 bar	0.15 bar	0.07 bar
5	30	65	F2	3.00E-09	0.02	3	3.7	4	4.3	6.5	12
			D5	2.50E-08	0.01	2.3	3	3.3	3.5	5	9.5
			D10	2.20E-08	0.01	2	2.5	2.8	3	4.4	8
25	30	65	F2	8.50E-09	0.72	8.9	11.3	12.4	13.2	19.7	36.1
			D5	7.00E-08	0.45	7.6	9.6	10.6	11.3	16.8	30.9
			D10	6.00E-08	0.32	6.8	8.6	9.4	10	15	27.6
75 (3 inches)	30	65	F2	1.15E-08	5.87	18	22.7	24.9	26.6	39.6	72.8
			D5	9.50E-08	3.63	15.3	19.3	21.2	22.7	33.7	62
			D10	8.50E-08	2.53	13.6	17.2	18.8	21	29.9	55

North

Hole size (mm)	Pressure (barg)	Temperature (C°)	Weather	Frequency (occ/year)	VCE Scenario (m)						
					New Flammable gas (kg)	0.5 bar	0.35 bar	0.3 bar	0.27 bar	0.15 bar	0.07 bar
5	30	65	F2	1.50E-09	2.30	3	3.7	4	4.3	6.5	12
			D5	1.25E-08	2.00	2.3	3	3.3	3.5	5	9.5
			D10	1.10E-08	11.70	2	2.5	2.8	3	4.4	8
25	30	65	F2	4.25E-09	0.98	9.9	12.5	13.7	14.6	21.8	40.1
			D5	3.50E-08	0.61	8.4	10.7	11.7	12.5	18.6	34.2
			D10	3.00E-08	0.44	7.6	9.6	10.5	11.2	16.7	30.7
75 (3 inches)	30	65	F2	5.75E-09	8.01	19.9	25.2	27.6	29.5	43.9	80.7
			D5	4.75E-08	4.94	17	21.4	23.5	25.1	37.4	68.7
			D10	4.25E-08	3.44	15	19	20.8	22.4	33.1	60.9

Note: For west-east direction is assumed same damage distance, thus the frequency of occurrence is doubled compared to other direction.

For the release point, refer to chapter 5.1 where the release point is reported in the layout.

Section 2 (LOC 2.2) down release ESD

South

Hole size (mm)	Pressure (barg)	Temperature (C°)	Weather	Frequency (occ/year)	VCE Scenario (m)						
					New Flammable gas (kg)	0.5 bar	0.35 bar	0.3 bar	0.27 bar	0.15 bar	0.07 bar
5	30	65	F2	1.35E-08	0.04	3.4	4.3	4.7	5	7.5	14
			D5	1.13E-07	0.04	3.4	4.4	4.7	5	7.5	14
			D10	1.00E-07	0.03	3	4	4.4	4.5	7	13
25	30	65	F2	3.75E-08	2.00	12	15	17	18	26.8	49
			D5	3.00E-07	1.30	10.9	13.7	15	16	23.9	44
			D10	2.75E-07	0.76	9	11.5	12.6	13.4	20	36.8
75 (3 inches)	30	65	F2	5.25E-08	23.22	28.4	35.9	39.4	42	62.6	115
			D5	4.25E-07	13.96	23.9	30.3	33.2	35.4	52.8	97
			D10	3.75E-07	8.93	20.6	26	28.6	30.5	45.5	83.6

East-west

Hole size (mm)	Pressure (barg)	Temperature (C°)	Weather	Frequency (occ/year)	VCE Scenario (m)						
					New Flammable gas (kg)	0.5 bar	0.35 bar	0.3 bar	0.27 bar	0.15 bar	0.07 bar
5	30	65	F2	2.70E-08	0.04	3.4	4.3	4.7	5	7.5	14
			D5	2.25E-07	0.04	3.4	4.4	4.7	5	7.5	14
			D10	2.00E-07	0.03	3	4	4.4	4.5	7	13
25	30	65	F2	7.50E-08	0.94	9.7	12.3	13.5	14.4	21.5	39.5
			D5	6.00E-07	0.55	8.1	10.3	11.3	12	18	33
			D10	5.50E-07	0.32	6.8	8.6	9.4	10	15	27.6
75 (3 inches)	30	65	F2	1.05E-07	9.83	21.3	27	29.6	31.6	47	86.4
			D5	8.50E-07	5.91	18	22.8	25	26.6	39.7	72.9
			D10	7.50E-07	3.78	15.5	19.6	21.5	22.9	34.2	62.8

North

Hole size (mm)	Pressure (barg)	Temperature (C°)	Weather	Frequency (occ/year)	VCE Scenario (m)						
					New Flammable gas (kg)	0.5 bar	0.35 bar	0.3 bar	0.27 bar	0.15 bar	0.07 bar
5	30	65	F2	1.35E-08	3.40	3	3.7	4	4.3	6.5	12
			D5	1.13E-07	3.00	2.3	3	3.3	3.5	5	9.5
			D10	1.00E-07	12.00	2	2.5	2.8	3	4.4	8
25	30	65	F2	3.75E-08	1.29	10.8	13.7	15	16	23.9	43.9
			D5	3.00E-07	0.75	9	11.4	12.5	13.4	19.9	36.6
			D10	2.75E-07	0.44	7.6	9.6	10.5	11.2	16.7	30.7
75 (3 inches)	30	65	F2	5.25E-08	13.40	23.7	29.9	32.8	35	52.1	95.8
			D5	4.25E-07	8.06	20	25.3	27.7	29.5	44	80.9
			D10	3.75E-07	5.15	17.2	21.7	23.8	25.4	37.9	69.7

Note: For west-east direction is assumed same damage distance, thus the frequency of occurrence is doubled compared to other direction.

For the release point, refer to chapter 5.1 where the release point is reported in the layout.

Section 2 (LOC 2.2) down release ESD FAILURE

South

Hole size (mm)	Pressure (barg)	Temperature (C°)	Weather	Frequency (occ/year)	VCE Scenario (m)						
					New Flammable gas (kg)	0.5 bar	0.35 bar	0.3 bar	0.27 bar	0.15 bar	0.07 bar
5	30	65	F2	1.50E-09	0.04	3.4	4.3	4.7	5	7.5	14
			D5	1.25E-08	0.04	3.4	4.4	4.7	5	7.5	14
			D10	1.10E-08	0.03	3	4	4.4	4.5	7	13
25	30	65	F2	4.25E-09	2.00	12	15	17	18	26.8	49
			D5	3.50E-08	1.30	10.9	13.7	15	16	23.9	44
			D10	3.00E-08	0.76	9	11.5	12.6	13.4	20	36.8
75 (3 inches)	30	65	F2	5.75E-09	23.22	28.4	35.9	39.4	42	62.6	115
			D5	4.75E-08	13.96	23.9	30.3	33.2	35.4	52.8	97
			D10	4.25E-08	8.93	20.6	26	28.6	30.5	45.5	83.6

East-West

Hole size (mm)	Pressure (barg)	Temperature (C°)	Weather	Frequency (occ/year)	VCE Scenario (m)						
					New Flammable gas (kg)	0.5 bar	0.35 bar	0.3 bar	0.27 bar	0.15 bar	0.07 bar
5	30	65	F2	3.00E-09	0.04	3.4	4.3	4.7	5	7.5	14
			D5	2.50E-08	0.04	3.4	4.4	4.7	5	7.5	14
			D10	2.20E-08	0.03	3	4	4.4	4.5	7	13
25	30	65	F2	8.50E-09	0.94	9.7	12.3	13.5	14.4	21.5	39.5
			D5	7.00E-08	0.55	8.1	10.3	11.3	12	18	33
			D10	6.00E-08	0.32	6.8	8.6	9.4	10	15	27.6
75 (3 inches)	30	65	F2	1.15E-08	9.83	21.3	27	29.6	31.6	47	86.4
			D5	9.50E-08	5.91	18	22.8	25	26.6	39.7	72.9
			D10	8.50E-08	3.78	15.5	19.6	21.5	22.9	34.2	62.8

North

Hole size (mm)	Pressure (barg)	Temperature (C°)	Weather	Frequency (occ/year)	VCE Scenario (m)						
					New Flammable gas (kg)	0.5 bar	0.35 bar	0.3 bar	0.27 bar	0.15 bar	0.07 bar
5	30	65	F2	1.50E-09	3.40	3	3.7	4	4.3	6.5	12
			D5	1.25E-08	3.00	2.3	3	3.3	3.5	5	9.5
			D10	1.10E-08	12.00	2	2.5	2.8	3	4.4	8
25	30	65	F2	4.25E-09	1.29	10.8	13.7	15	16	23.9	43.9
			D5	3.50E-08	0.75	9	11.4	12.5	13.4	19.9	36.6
			D10	3.00E-08	0.44	7.6	9.6	10.5	11.2	16.7	30.7
75 (3 inches)	30	65	F2	5.75E-09	13.40	23.7	29.9	32.8	35	52.1	95.8
			D5	4.75E-08	8.06	20	25.3	27.7	29.5	44	80.9
			D10	4.25E-08	5.15	17.2	21.7	23.8	25.4	37.9	69.7

Note: For west-east direction is assumed same damage distance, thus the frequency of occurrence is doubled compared to other direction.
For the release point, refer to chapter 5.1 where the release point is reported in the layout.

Section 3 horizontal release ESD

South

Hole size (mm)	Pressure (barg)	Temperature (C°)	Weather	Frequency (occ/year)	VCE Scenario (m)						
					New Flammable gas (kg)	0.5 bar	0.35 bar	0.3 bar	0.27 bar	0.15 bar	0.07 bar
5	30	25	F2	1.25E-08	0.031	3	4	4.2	4.5	6.5	12.5
			D5	1.05E-07	0.015	2.5	3	3.3	3.6	5.5	10
			D10	9.25E-08	0.001	2	2.5	3	3	4.5	8.5
25	30	25	F2	4.25E-08	2.30	12	15	16.5	18	26.5	48
			D5	3.75E-07	1.50	11	14	15.5	16.5	24.5	46
			D10	3.25E-07	1.10	10	13	14	15	22	41
50 (2 inches)	30	25	F2	3.50E-09	9.72	21.2	26.8	29.4	31.4	46.8	86
			D5	3.00E-08	5.79	17.8	22.5	24.6	26.3	39.2	72
			D10	2.50E-08	4.14	15.9	20.1	22.1	23.6	35.1	64.5

East-West

Hole size (mm)	Pressure (barg)	Temperature (C°)	Weather	Frequency (occ/year)	VCE Scenario (m)						
					New Flammable gas (kg)	0.5 bar	0.35 bar	0.3 bar	0.27 bar	0.15 bar	0.07 bar
5	30	25	F2	2.50E-08	0.031	3	4	4.2	4.5	6.5	12.5
			D5	2.10E-07	0.015	2.5	3	3.3	3.6	5.5	10
			D10	1.85E-07	0.001	2	2.5	3	3	4.5	8.5
25	30	25	F2	8.50E-08	0.95	9.8	12.4	13.6	14.5	21.6	39.6
			D5	7.50E-07	0.53	8	10.2	11.2	11.9	17.8	32.6
			D10	6.50E-07	0.38	7.2	9.1	10	10.7	15.9	29.2
50 (2 inches)	30	25	F2	7.00E-09	3.15	14.6	18.5	20.3	21.6	32.2	59.1
			D5	6.00E-08	1.88	12.3	15.5	17	18.2	27	49.8
			D10	5.00E-08	1.34	11	13.9	15	16.3	24.2	44.5

North

Hole size (mm)	Pressure (barg)	Temperature (C°)	Weather	Frequency (occ/year)	VCE Scenario (m)						
					New Flammable gas (kg)	0.5 bar	0.35 bar	0.3 bar	0.27 bar	0.15 bar	0.07 bar
5	30	25	F2	1.25E-08	2.500	3	4	4.2	4.5	6.5	12.5
			D5	1.05E-07	2.000	2.5	3	3.3	3.6	5.5	10
			D10	9.25E-08	12.000	2	2.5	3	3	4.5	8.5
25	30	25	F2	4.25E-08	0.44	7.6	9.6	10.5	11.2	16.7	30.7
			D5	3.75E-07	0.24	6.2	7.8	8.6	9.2	13.6	25.1
			D10	3.25E-07	0.18	5.6	7.1	7.8	8.3	12.4	22.8
50 (2 inches)	30	25	F2	3.50E-09	1.45	11.3	14.3	15.6	16.7	24.8	45.7
			D5	3.00E-08	0.86	9.5	12	13.1	14	20.9	38.4
			D10	2.50E-08	0.62	8.5	10.7	11.8	12.6	18.7	34.4

Note: For west-east direction is assumed same damage distance, thus the frequency of occurrence is doubled compared to other direction.

For the release point, refer to chapter 5.1 where the release point is reported in the layout.

Section 3 horizontal release ESD Failure

South

Hole size (mm)	Pressure (barg)	Temperature (C°)	Weather	Frequency (occ/year)	VCE Scenario (m)						
					New Flammable gas (kg)	0.5 bar	0.35 bar	0.3 bar	0.27 bar	0.15 bar	0.07 bar
5	30	25	F2	1.38E-09	0.031	3	4	4.2	4.5	6.5	12.5
			D5	1.15E-08	0.015	2.5	3	3.3	3.6	5.5	10
			D10	1.03E-08	0.001	2	2.5	3	3	4.5	8.5
25	30	25	F2	4.75E-09	2.30	12	15	16.5	18	26.5	48
			D5	4.00E-08	1.50	11	14	15.5	16.5	24.5	46
			D10	3.50E-08	1.10	10	13	14	15	22	41
50 (2 inches)	30	25	F2	4.00E-10	9.72	21.2	26.8	29.4	31.4	46.8	86
			D5	3.25E-09	5.79	17.8	22.5	24.6	26.3	39.2	72
			D10	3.00E-09	4.14	15.9	20.1	22.1	23.6	35.1	64.5

East-West

Hole size (mm)	Pressure (barg)	Temperature (C°)	Weather	Frequency (occ/year)	VCE Scenario (m)						
					New Flammable gas (kg)	0.5 bar	0.35 bar	0.3 bar	0.27 bar	0.15 bar	0.07 bar
5	30	25	F2	2.75E-09	0.031	3	4	4.2	4.5	6.5	12.5
			D5	2.30E-08	0.015	2.5	3	3.3	3.6	5.5	10
			D10	2.05E-08	0.001	2	2.5	3	3	4.5	8.5
25	30	25	F2	9.50E-09	0.95	9.8	12.4	13.6	14.5	21.6	39.6
			D5	8.00E-08	0.53	8	10.2	11.2	11.9	17.8	32.6
			D10	7.00E-08	0.38	7.2	9.1	10	10.7	15.9	29.2
50 (2 inches)	30	25	F2	8.00E-10	3.15	14.6	18.5	20.3	21.6	32.2	59.1
			D5	6.50E-09	1.88	12.3	15.5	17	18.2	27	49.8
			D10	6.00E-09	1.34	11	13.9	15	16.3	24.2	44.5

North

Hole size (mm)	Pressure (barg)	Temperature (C°)	Weather	Frequency (occ/year)	VCE Scenario (m)						
					New Flammable gas (kg)	0.5 bar	0.35 bar	0.3 bar	0.27 bar	0.15 bar	0.07 bar
5	30	25	F2	1.38E-09	2.500	3	4	4.2	4.5	6.5	12.5
			D5	1.15E-08	2.000	2.5	3	3.3	3.6	5.5	10
			D10	1.03E-08	12.000	2	2.5	3	3	4.5	8.5
25	30	25	F2	4.75E-09	0.44	7.6	9.6	10.5	11.2	16.7	30.7
			D5	4.00E-08	0.24	6.2	7.8	8.6	9.2	13.6	25.1
			D10	3.50E-08	0.18	5.6	7.1	7.8	8.3	12.4	22.8
50 (2 inches)	30	25	F2	4.00E-10	1.45	11.3	14.3	15.6	16.7	24.8	45.7
			D5	3.25E-09	0.86	9.5	12	13.1	14	20.9	38.4
			D10	3.00E-09	0.62	8.5	10.7	11.8	12.6	18.7	34.4

Note: For west-east direction is assumed same damage distance, thus the frequency of occurrence is doubled compared to other direction.

For the release point, refer to chapter 5.1 where the release point is reported in the layout.

Section 3 down release ESD

South

Hole size (mm)	Pressure (barg)	Temperature (C°)	Weather	Frequency (occ/year)	VCE Scenario (m)						
					New Flammable gas (kg)	0.5 bar	0.35 bar	0.3 bar	0.27 bar	0.15 bar	0.07 bar
5	30	25	F2	1.25E-08	0.051	3.5	4.5	5	5.3	8	14
			D5	1.05E-07	0.048	3.6	4.5	5	5.3	8	14.5
			D10	9.25E-08	0.037	3.3	4	4.5	5	7.5	13.5
25	30	25	F2	4.25E-08	2.6	12	15.5	17	18	27	50
			D5	3.75E-07	1.9	12	15	17	18	27	49
			D10	3.25E-07	1.2	10.6	13.4	14.7	15.6	23	42.9
50 (2 inches)	30	25	F2	3.50E-09	15.3	25	31.5	34.5	36.5	54.5	101
			D5	3.00E-08	8.9	20.6	26	28.6	30.5	45.5	83.6
			D10	2.50E-08	5.7	17.8	22.5	24.7	26.3	39.2	72

East-West

Hole size (mm)	Pressure (barg)	Temperature (C°)	Weather	Frequency (occ/year)	VCE Scenario (m)						
					New Flammable gas (kg)	0.5 bar	0.35 bar	0.3 bar	0.27 bar	0.15 bar	0.07 bar
5	30	25	F2	2.50E-08	0.051	3.5	4.5	5	5.3	8	14
			D5	2.10E-07	0.048	3.6	4.5	5	5.3	8	14.5
			D10	1.85E-07	0.037	3.3	4	4.5	5	7.5	13.5
25	30	25	F2	8.50E-08	1.3	10.7	13.7	15	16	23.9	44
			D5	7.50E-07	0.7	8.8	11.2	12.3	13	19.5	35.8
			D10	6.50E-07	0.4	7.3	9.3	10.2	10.8	16.2	29.7
50 (2 inches)	30	25	F2	7.00E-09	5.2	17.2	21.8	23.9	25.5	38	69.9
			D5	6.00E-08	2.9	14.2	17.9	19.7	21	31.3	57.5
			D10	5.00E-08	1.9	12.3	15.6	17.1	18.2	27.2	50

North

Hole size (mm)	Pressure (barg)	Temperature (C°)	Weather	Frequency (occ/year)	VCE Scenario (m)						
					New Flammable gas (kg)	0.5 bar	0.35 bar	0.3 bar	0.27 bar	0.15 bar	0.07 bar
5	30	25	F2	1.25E-08	3.600	3	4	4.2	4.5	6.5	12.5
			D5	1.05E-07	3.300	2.5	3	3.3	3.6	5.5	10
			D10	9.25E-08	12.000	2	2.5	3	3	4.5	8.5
25	30	25	F2	4.25E-08	0.60	8.4	10.6	11.6	12.4	18.5	34
			D5	3.75E-07	0.30	6.7	8.4	9.2	9.9	14.7	27
			D10	3.25E-07	0.17	5.5	7	7.6	8.2	12.2	22.3
50 (2 inches)	30	25	F2	3.50E-09	2.37	13.3	16.8	18.4	19.6	29.3	53.8
			D5	3.00E-08	1.33	11	13.8	15.2	16.2	24.1	44.4
			D10	2.50E-08	0.85	9.4	11.9	13.1	14	20.8	38.2

Note: For west-east direction is assumed same damage distance, thus the frequency of occurrence is doubled compared to other direction.
For the release point, refer to chapter 5.1 where the release point is reported in the layout.

Section 3 down release ESD Failure

South

Hole size (mm)	Pressure (barg)	Temperature (C°)	Weather	Frequency (occ/year)	VCE Scenario (m)						
					New Flammable gas (kg)	0.5 bar	0.35 bar	0.3 bar	0.27 bar	0.15 bar	0.07 bar
5	30	25	F2	1.38E-09	0.051	3.5	4.5	5	5.3	8	14
			D5	1.15E-08	0.048	3.6	4.5	5	5.3	8	14.5
			D10	1.03E-08	0.037	3.3	4	4.5	5	7.5	13.5
25	30	25	F2	4.75E-09	2.6	12	15.5	17	18	27	50
			D5	4.00E-08	1.9	12	15	17	18	27	49
			D10	3.50E-08	1.2	10.6	13.4	14.7	15.6	23	42.9
50 (2 inches)	30	25	F2	4.00E-10	15.3	25	31.5	34.5	36.5	54.5	101
			D5	3.25E-09	8.9	20.6	26	28.6	30.5	45.5	83.6
			D10	3.00E-09	5.7	17.8	22.5	24.7	26.3	39.2	72

East-west

Hole size (mm)	Pressure (barg)	Temperature (C°)	Weather	Frequency (occ/year)	VCE Scenario (m)						
					New Flammable gas (kg)	0.5 bar	0.35 bar	0.3 bar	0.27 bar	0.15 bar	0.07 bar
5	30	25	F2	2.75E-09	0.051	3.5	4.5	5	5.3	8	14
			D5	2.30E-08	0.048	3.6	4.5	5	5.3	8	14.5
			D10	2.05E-08	0.037	3.3	4	4.5	5	7.5	13.5
25	30	25	F2	9.50E-09	1.3	10.7	13.7	15	16	23.9	44
			D5	8.00E-08	0.7	8.8	11.2	12.3	13	19.5	35.8
			D10	7.00E-08	0.4	7.3	9.3	10.2	10.8	16.2	29.7
50 (2 inches)	30	25	F2	8.00E-10	5.2	17.2	21.8	23.9	25.5	38	69.9
			D5	6.50E-09	2.9	14.2	17.9	19.7	21	31.3	57.5
			D10	6.00E-09	1.9	12.3	15.6	17.1	18.2	27.2	50

North

Hole size (mm)	Pressure (barg)	Temperature (C°)	Weather	Frequency (occ/year)	VCE Scenario (m)						
					New Flammable gas (kg)	0.5 bar	0.35 bar	0.3 bar	0.27 bar	0.15 bar	0.07 bar
5	30	25	F2	1.38E-09	3.600	3	4	4.2	4.5	6.5	12.5
			D5	1.15E-08	3.300	2.5	3	3.3	3.6	5.5	10
			D10	1.03E-08	12.000	2	2.5	3	3	4.5	8.5
25	30	25	F2	4.75E-09	0.60	8.4	10.6	11.6	12.4	18.5	34
			D5	4.00E-08	0.30	6.7	8.4	9.2	9.9	14.7	27
			D10	3.50E-08	0.17	5.5	7	7.6	8.2	12.2	22.3
50 (2 inches)	30	25	F2	4.00E-10	2.37	13.3	16.8	18.4	19.6	29.3	53.8
			D5	3.25E-09	1.33	11	13.8	15.2	16.2	24.1	44.4
			D10	3.00E-09	0.85	9.4	11.9	13.1	14	20.8	38.2

Note: For west-east direction is assumed same damage distance, thus the frequency of occurrence is doubled compared to other direction.

For the release point, refer to chapter 5.1 where the release point is reported in the layout.

ATTACHMENT 5

QRA: LSIR FROM LOWER DECK

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LSIR from lower deck



Jet Fire contribution to LSIR



Flash Fire contribution to LSIR



VCE contribution to LSIR

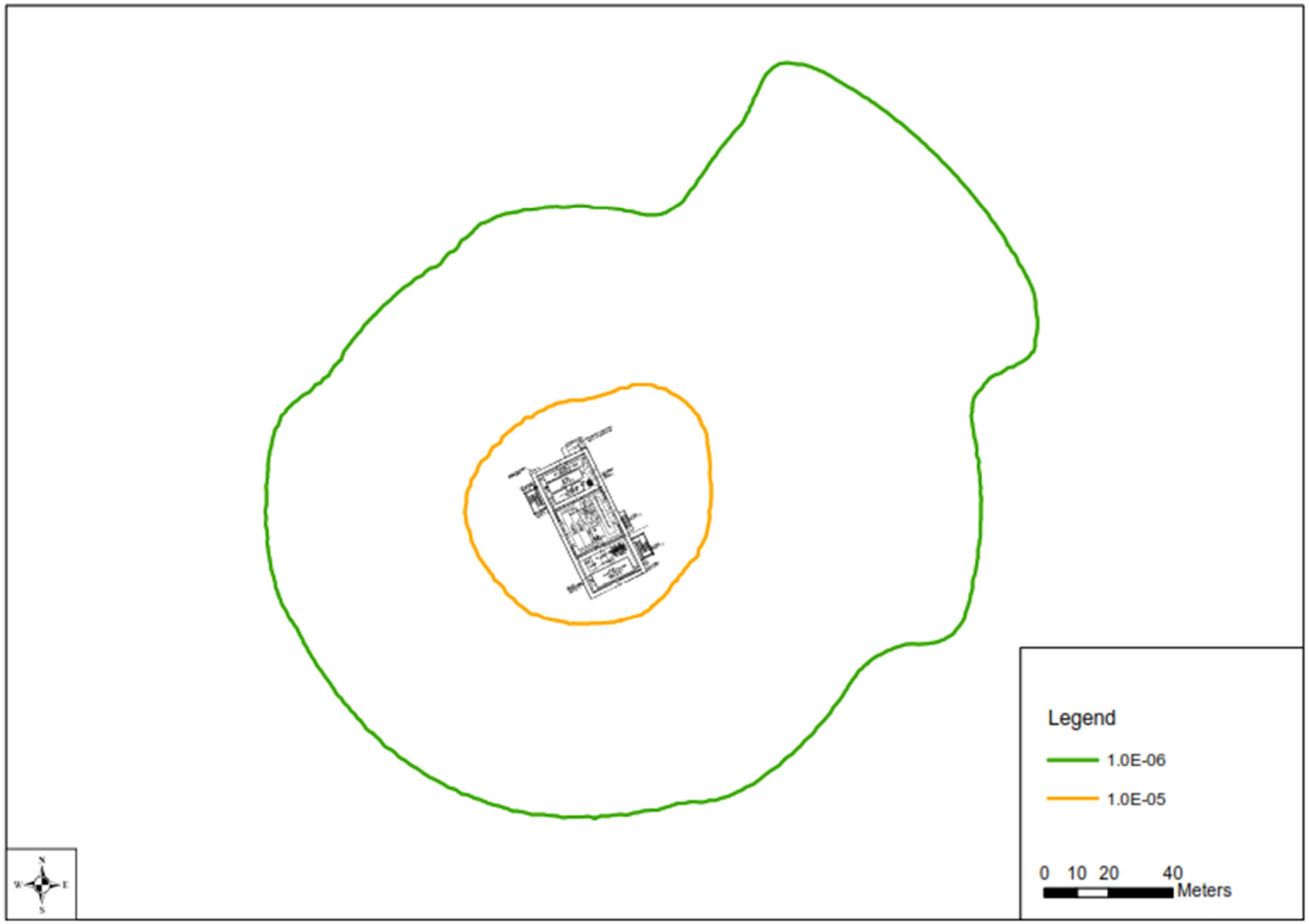


ATTACHMENT 6

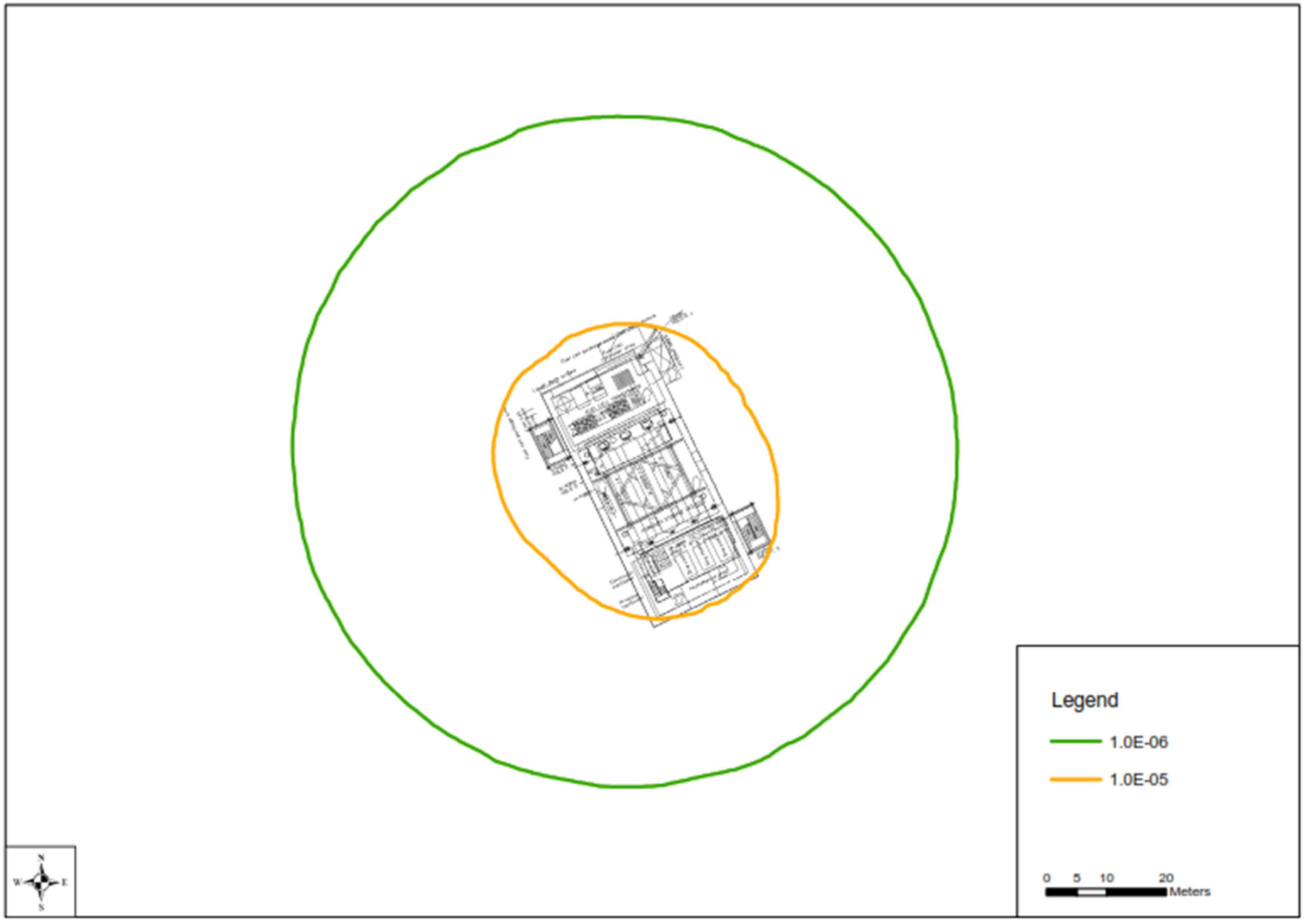
QRA: LSIR FROM UPPER DECK

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LSIR curves from upper deck



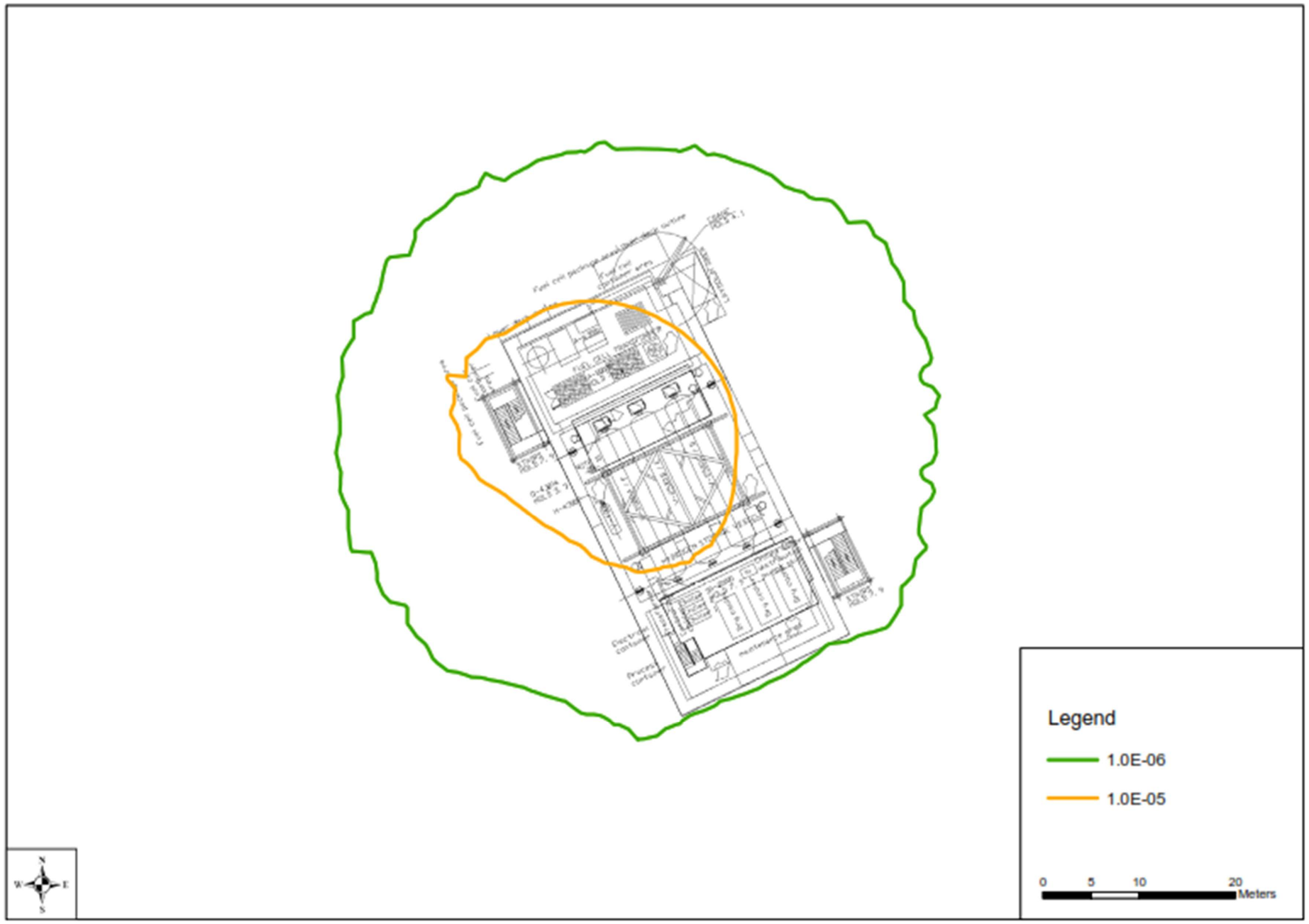
Jet Fire contribution to LSIR



Flash **Fire contribution to LSIR**



VCE contribution to LSIR



ATTACHMENT 7

QRA: ASSUMPTION REGISTER

Note
For completeness, here below is reported an extract of the document "Assumption Register", doc n 123A90-DDL-SAF-LIS-30014 – rev2 for additional information regarding the study methodology.

MAIN REFERENCES

Ref.	Description
1	Risk assessment data directory, document no. IOGP 434_1– 2019 - Process Release Frequency
2	Hydrogen Risk Assessment Models (HyRAM) Version 3.0 Technical Reference Manual, Sandia National Laboratories, United States Department of Energy USA, September 2020
3	Flammable Gases and Liquids and their hazard, United States Environmental Protection Agency, February 1994
4	Review of Methods for Estimating the Overpressure and Impulse Resulting From a Hydrogen Explosion in a Confined-Obstructed Volume, Air liquid R&D, ENSI de Bourges, PRISME institute, 2009
5	Risk assessment data directory, document no. IOGP 434_7 – 2010 - Consequences modelling
6	Risk assessment data directory, document no. IOGP 434_14 – 2013 - Vulnerability of humans
7	Risk assessment data directory, document no. IOGP 434_15 – 2010 - - Vulnerability of plant/structure
8	Guidance on ALARP Decisions in COMAH – UK Health and Safety Executive (UK HSE), SPC/Permissioning/37, 2001
9	DNVGL-OS-A101 - Safety principles and arrangements, 2019
10	ISO 15544:2000 Petroleum and natural gas industries – Offshore production installations – Requirements and guidelines for emergency response, 2021
11	EU DIRECTIVE 2003/10/EC on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (noise) (update with the amendment by Regulation (EU)2019/1243 of 20 June 2019)
12	ISO 3746:2010 "Acoustics, Determination of sound power levels and sound energy levels of noise sources using sound pressure
13	API Standard 521-Pressure-relieving and Depressuring Systems (2020)
14	K559-2254-SE-REP-008 - BLPH - Escape, Evacuation and Rescue Assessment (EERA) (note: study for FEED phase)
15	K559-2254-SE-REP-013-01 - Noise Report (note: study for FEED phase)
16	ISO 9613 Attenuation of sound during propagation outdoors
17	K559-2254-SE-REP-007 - Fire and Explosion Risk Analyses (FERA) (note: study for FEED phase)
18	BLPH_MODEL_FINAL_29-03-23 (3D model of platform)
19	K559-2254-PI-PPL-001 - BLPH Base Load Power Hub Plot Plan (note: study for FEED phase)
20	K559-2254-PR-REP-001 – Process Description (note: study for FEED phase)
21	123A90-DDL-PR-DG-80003//123A90-DDL-PR-DG-80005- PFD

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Ref.	Description
22	K559-2254-PR-PID-001// K559-2254-PR-PID-014-001 – P&ID
23	123A90-DDL-SAF-RE-30046 – HSE Design Philosophy, rev 01, 16/10/2023
24	123A90-DDL-PR-BL-80002 – H&MB, rev 01, 09/11/2023
25	123A90-DDL-OEM-LIS-02012 - Mechanical Handling - Lifting equipment requisition and location list (See HOLD List #1)
26	123A90-DDL-OEM-PRO-02011 - Mechanical Handling - removal & replacement procedures (See HOLD List #1)
27	DNV-RP-F107, 2001 - Risk assessment of pipeline protection
28	K559-2254-PM-PLN-003 – BDEP – Basic Design Engineering Package revision 1
29	123A90-DDL-SAF-RE-30019 - Quantified Risk Assessment (QRA) Report
30	123A90-DDL-SAF-RE-30020 - Fire and Explosion Risk Analys (FERA) report
31	123A90-DDL-SAF-RE-30015 - Evacuation, Escape and Rescue Assessment (EERA) Report
32	123A90-DDL-SAF-RE-30041 - Noise Assessment Study Report

Reference Documents

DEFINITIONS AND ABBREVIATIONS

Definitions

COMPANY or Client (CPY):	Crosswind
EPC CONTRACTOR (CTR):	ROSETTI MARINO S.p.A.
PROJECT:	HOLLANDSE KUST NOORD WIND PARK Project
CONSEQUENCES	The outcome of an event. For the purpose of this project, the outcome is identified in terms of harm to exposed persons and assets.
EVENT	Occurrence or change of a particular set of circumstances.
EVENT TREE	Logical qualitative and quantitative representation of accident sequences, from initial release to final scenarios (fire, explosion, and flammable / toxic gas dispersion).
FAILURE	Damage of equipment which can lead to release of substances from the process.
FERA	Fire and Explosion Risk Assessment. A comprehensive risk evaluation directed to the analysis of the effects of fire and

	explosion scenarios (due to LOCs of hazardous substance handled in an equipment to be installed during project development) on process equipment, structures and buildings.
FIRE	The outcome of combustion of flammable substance released in the atmosphere as a consequence of a LOC, which can produce effects to exposed persons and to process equipment and structure due to thermal radiation.
FLASH FIRE	An accelerated combustion of a vapor cloud without significant overpressure consequences.
FREQUENCY	The estimated number of events per defined unit of time (normally refereed to one-year time).
IRPA	Frequency at which an individual may be expected to sustain lethal levels of harm from the realisation of specified hazards. It is usually taken to be the risk of death and expressed as a risk per year.
JET FIRE	It is a turbulent diffusion flame resulting from the combustion of a fuel continuously released with some significant momentum in a particular direction or directions. Jet fires can arise from releases of gaseous, flashing liquid (two phase) and pure liquid inventories.
LSIR	Risk expressed as likelihood of fatality per year at a particular location on the basis of continuous exposure (24 hours per day, and 365 days per year)
LOC	Loss of Containment. The event associated with the release of a hazardous substance from equipment leading to a potential accident scenario
PARTS COUNT	The counting of any piece of equipment pertaining to a given isolatable section. This task is handled in order to calculate a generic leak frequency value for generic types of cause
POOL FIRE	The fire developed from the ignition of a liquid pool of flammable substances.
QRA	Quantitative Risk Assessment. For the purpose of this study, a comprehensive risk evaluation focused on the identification of the impact to persons (workers and external population) due to effects of accident scenarios due to LOCs of hazardous substance handled in equipment to be installed during project development.
RANDOM LOSS	A loss of containment from piping and equipment due to random causes which leads to a release of a hazardous substance in the environment.

RISK	Combination of frequency and consequence of scenarios. For the purpose of the present project, the risk is evaluated on exposed persons and on project equipment, due to the effects of events caused by LOC of hazardous substances
RISK CONTOUR	A risk contour is the locus of points that geographically describes the location of a specific risk level. This risk will be defined by a pre-determined type of harm (e.g., fatality) at a specific frequency (e.g., 1.0 x 10-6/year).

Table 18 - Definitions

Abbreviations

ALARP	As Low As Reasonably Practicable
BESS	Battery Energy Storage System
BLPH	Base Load Power Hub
DNV	Det Norske Veritas
EERA	Escape, Evacuation and Rescue Assessment
ESDV	Emergency Shut-Down valve
F&G	Fire and Gas
FERA	Fire and Explosion Risk Assessment
H&MB	Heat and Material Balance
HKN	Hollandse Kust Noord
HyRAM	Hydrogen Risk Assessment Model
HSE	Health, Safety and Environment
IOGP	International Association of Oil & Gas Producers
IRPA	Individual Risk Per Annum
LFL	Lower Flammable Limit
LSIR	Location Specific Individual Risk
LOC	Loss Of Containment
NNF	Normally No Flow
P&ID	Piping and Instrumentation Diagram
PFD	Process Flow Diagram
QRA	Quantitative Risk Assessment
SPL	Sound pressure levels
VCE	Vapour Cloud Explosion

Table 19 – Abbreviations

ASSUMPTIONS

The assumptions for studies developed are recorded in a specific format ("Assumption sheet") that is presented below.

Study:	The applicability of the assumption to specific study		
Subject:	A brief description of the assumption for easy searching		
Assumption #	Unique assumption number	**Rev.**	Current revision number
Reference:	Main reference for the assumption		
Description: This section presents the details of the assumption, main references and impact of the assumption on the results of the assessment.			

Table 20 – Assumption sheet template

Study:	QRA, FERA		
Subject:	Isolatable Sections		
Assumption #	1	Rev.	1
Reference:	5, 17, 21, 22,29,30		

On detection of a gas release, it will be considered that the process is automatically shut down and isolated by means of Emergency Isolation Valves and depressurized via blow-down valves whenever applicable; the result of isolation process is the division of the plant in section separated each other and isolated by isolation elements. For this reason, the hazard identification process treats each isolatable section of the plant as a distinct hazard considering its relative inventory, which will be calculated considering process equipment volume and pipe length.

The identification of Isolatable Section will be performed considering project PFDs and P&IDs.

Following assumptions are made for determining isolatable sections.

- An isolatable section is defined as section between shutdown valves and/ or within dead-end like a blind flange, or normally closed valve.
- Each package in the scope of the Crosswind (electrolyser, fuel cell package, BESS) will be considered as a separate section. The studies (e.g QRA, FERA) will includes the risk for these equipment in terms of frequency of occurrence and hazardous scenarios as for vendor information (if available; otherwise, information as for FEED QRA will be considered).

For isolatable section definition, following exclusion will be considered:

- Sections containing non-hazardous material.
- Sections defined as Normally No Flow, make up line, start up lines as there is no hazardous material continuously present inside in normal operation.
- Additionally, pipes in which the flow is not continuous in normal operation are not considered in the definition of the sections.
- Drains, emergency vents are generally, NNF type and will not be considered in inventory analysis or for identifying isolatable sections.

Table 21 – Assumption #1

Study:	QRA, FERA		
Subject:	Failure Case Selection and release diameters		
Assumption #	2	Rev.	1
Reference:	1, 17, 29,30		

Failure Case Selection

Loss of Containment (LoC) events include hydrogen leaks from process equipment and associated piping, due to random causes such as corrosion, impacts etc. or other. The selection of LOC cases takes into consideration the risks associated to process hazards. For similar dangerous substances and similar inventory, the items with more critical operating conditions are preferably selected. On the basis of process condition inside an isolable section one or more LOC will be defined.

Identified LOCs shall be defined in terms of location, material released, quantity released, release conditions, inventory size, temperature, pressure, leak size, leak direction, leak frequency and ignition probability.

Leak diameter

The representative leak hole sizes to be modelled are selected to ensure that the entire range of potential hole size is represented in the modelling. Three leak hole size will be selected, representative for small, medium and full-bore cases.

Generic data for leak frequencies of individual items of process equipment together with the distribution of leak sizes are derived from IOGP report 434-1 2019. In IOGP database, release frequencies for wide range of holes and equipment types are available. Considering that specific failure rates for equipment which handling H_2 with the same grade of accuracy are not available in literature, in the present report IOGP database is selected as representative, even if specific for hydrocarbon process plants. Some examples of IOGP failure rate application for piping are reported below. In the platform, piping shows diameter between 1 and 3 inches. The 2" is the smallest data set available from IOGP, meaning that the release frequencies for other line diameter is derived as per table below.

Release Size	IOGP Hole range diameter (mm)	Selected hole diameter (mm)	1"DIA (25 mm)	1.5"DIA (37.5 mm)	2"DIA (50 mm)	3"DIA (75 mm)
Small hole	3 - 10	5	6.40E-06	6.40E-06	6.40E-06	6.40E-06
Medium hole	10 - 50	25	3.80E-06	2.80E-06	2.80E-06	2.80E-06
Full bore	50 -150	Full bore	--	1.00E-06	1.00E-06	1.00E-06

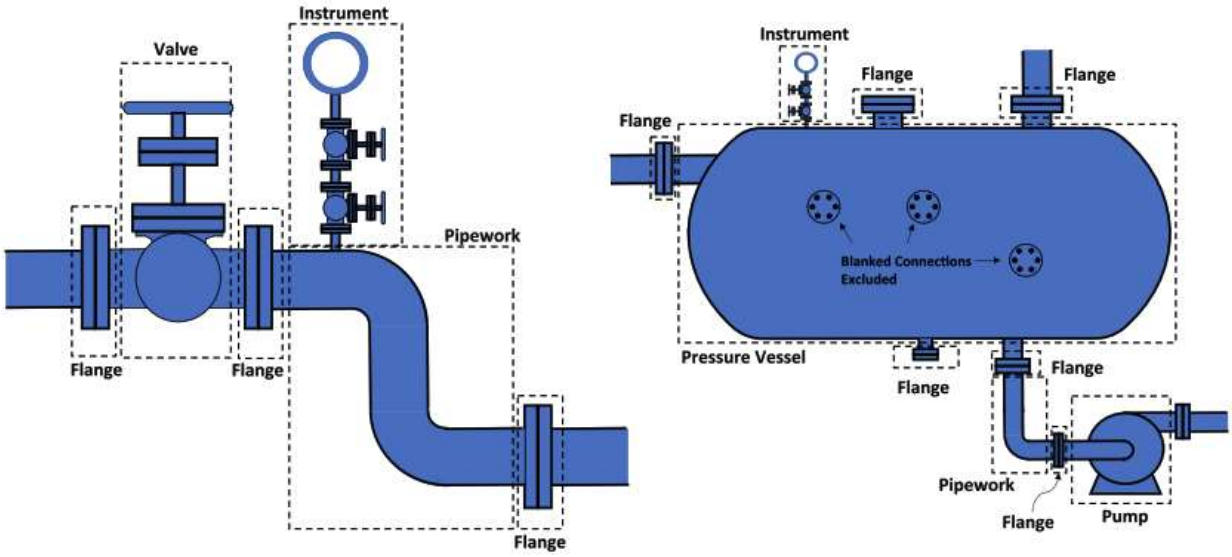
Same approach will be followed for other equipment (e.g valves, flanges..).

Table 22 – Assumption #2

Study:	QRA, FERA		
Subject:	Parts Count & Failure Frequency		
Assumption #	3	Rev.	0
Reference:	1, 17, 22, 29,30		

LOC frequency inside each isolatable section will be calculated by means of "Parts Count" methodology, summing basic frequency associated to each process element present in the isolatable section under analysis (e.g. vessels, reactors, piping, valves, etc.). Necessary information is derived from the available P&IDs together with estimates of line lengths and elevations from plot plans / 3D model.

The estimation of the release frequencies of equipment packages is based on the generic release frequency data and counting rules derived from standard. Example of main equipment identification in the process are reported below.



For example, in part count the scope of valve includes the valve body, stem, and packing but excludes flanges. These flanges shall be counted separately. Normally opened valve assembly may be counted as one valve and two flanged joints; whereas normally closed valve assembly (where only leaks from one side of valve would cause the consequence) may be counted as 1 times of the valve and one flange joint.

Based on P&ID; sample parts count methodology is reported below.

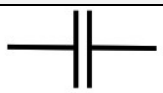
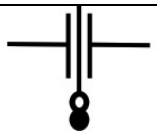
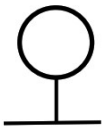
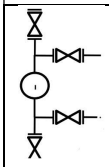
Symbol	Equipment	Part count
	Flange Joint	One flange of the appropriate line size
	Open Spectacle Plate	Two flanges of the appropriate line size
	Any type of valve (including check or non-return valves)	Two flanges and one valve of the appropriate type (actuated / manual) and size
	Instrument	One instrument connection
		

Table 23 – Assumption #3

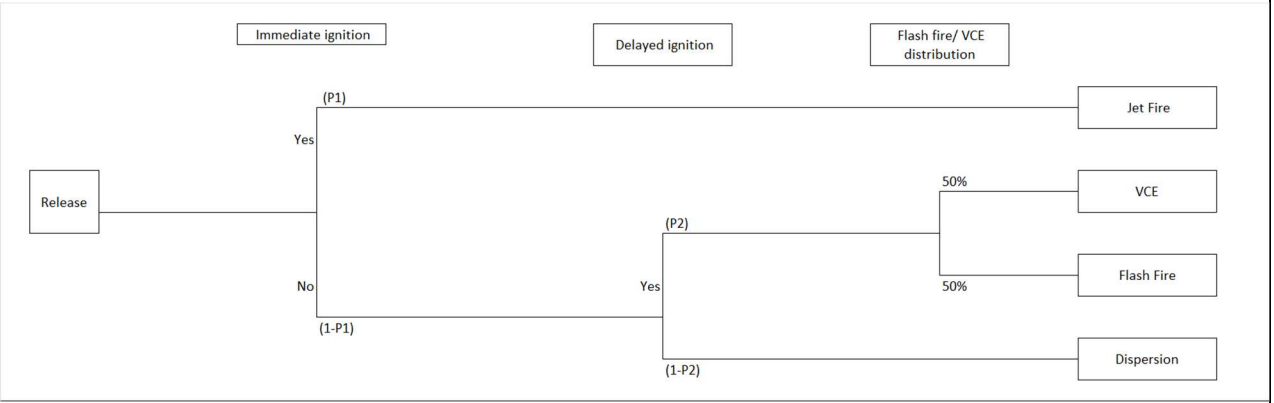
Study:	QRA, FERA		
Subject:	Scenario frequency calculation: event tree analysis		
Assumption #	4	**Rev.**	1
Reference:	3, 17, 29,30		

Scenario types and frequency is depending on the release and its evolution in the environment. In case of release and ignition of flammable gas clouds, following scenarios are expected:

- Jet fire (immediate ignition);
- Flash fire (delayed ignition);
- Confined Vapor Cloud Explosion (delayed ignition);

In order to qualify and quantify all potential outcome scenarios, the "Event Tree" technique is applied. The event tree in case of release of hydrogen is reported below.

Selection of ignition probability follows the criteria reported in assumption 5.



The scenario modelling needs to take into account the probability of failure of detection and isolation system. Additional information regarding event tree which will be used in the report are reported in Assumption 6.

BLEVE (Boiling Liquid Expanding Vapor Explosion) scenario is not applicable considering that are no present in the platform storage vessel containing low boiling liquid or liquefied gases (as LPG).

Table 24 – Assumption #4

Study:	QRA, FERA		
Subject:	Ignition Probability Data and congestion grade		
Assumption #	5	Rev.	1
Reference:	2, 4, 17, 29,30		

Ignition probability

Immediate ignition upon release will result in jet fire (provided sufficient pressure and process inventory exist). If hydrogen gas does not immediately ignite upon release and subsequently accumulates within a congested area, its delayed ignition would result in a flash fire or explosion.

For the release of hydrocarbons several well established ignition probability models exist. For hydrogen particularly in offshore scenarios there is greater uncertainty due to the lack of such studies, however it is reasonable to assume that the likelihood of immediate and delayed ignition is greater than for natural gas due to the low ignition energy required to ignite a hydrogen release. As a reference the Hydrogen Risk Assessment Model (HyRAM) specifies the release rate dependant ignition probabilities given in the table below. The HyRAM is a basic software for conducting risk assessment and consequence modelling for hydrogen infrastructure and transportation systems (Issued by Sandia National Laboratories, USA), and is specific for H_2.

Release rate (kg/s)	Immediate (P1)	Delayed (P2)
< 0.125	0.0080	0.004
0.125 – 6.25	0.0530	0.0270
>= 6.25	0.23	0.12

The delayed ignition is split in 50% of delayed ignitions result in explosion and 50% resulting in flash fire.

Congestion factor

The UVCE scenario consequences will be calculated according to the "TNO Multi -Energy" method. The method, starting from the flammable mass of the substances, determines the expected values of pressure waves around the source of ignition. The intensity of pressure waves is calculated by means of a "Confinement Strength" factor, which is calculated on basis of confinement strength of the area where the flammable gas clouds is foreseen. It is demonstrated that a higher confinement grade will increase the overpressure associated to the UVCE. Calculation of Confinement Strength is based on a set of criteria connected to following elements, based on criteria provided by reference technical documentation [4];

- value of ignition energy of selected substances (a lower value ignition energy will determine higher susceptibility to ignition and increase the potential effects of explosion);
- obstacle density (a higher obstacle density will create conditions for gas cloud accumulation and increase the potential effects of explosion);
- confinement level (a higher confinement level will create conditions for gas cloud accumulation and increase the potential effects of explosion).

According to the standard, the selected confinement grade is calculated as per below table.

Element	Configuration on present study
Ignition energy	Low
Obstacle density	High
Confinement	Existing
Suggested Value	Range 5-7
Selected Value	7

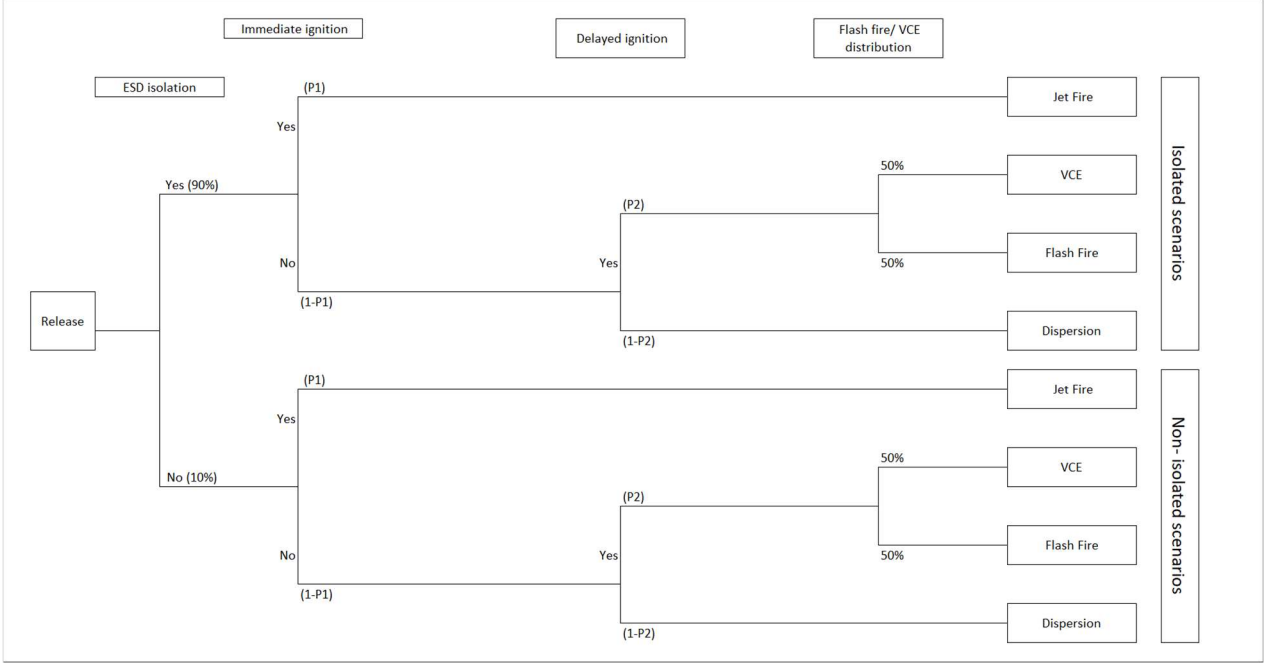
According to the above table, the selected confinement grade is considered equal to 7 (conservative value).

Table 25 – Assumption #5

Study:	QRA, FERA		
Subject:	ESD failure and Scenario duration		
Assumption #	6	Rev.	1
Reference:	17, 29,30		

The isolation can be performed automatically by the protection system (ESD), which is assumed 90% reliable, considering that will be maintained and tested in appropriate manner, thus the probability of failure on demand is very low (considering also the lifetime of platform, equal to 2 years).

The event tree which considers the probability of failure of ESD, which will be used in the QRA/FERA development, is reported below.



If a leakage is successfully detected and isolated, the minimum inventory released will be restricted by the isolatable section inventory.

Leak duration is a parameter with a high level of uncertainties.

Release duration is calculated as a sum of the following time intervals:

Scenario duration= Time for detection + Time for isolation + Time for emptying the circuit

Time for detection

The rapidity of detection of a leak of a flammable substance is related to the extent of the release itself but also to the capacity of the detection systems available in the unit.

Time for isolation

Once the leak is identified the isolatable section can be isolated by closing the on-off valves by the intervention of F&G system. The time for the intervention is limited to the required time to close the valves, which show diameter less than 3 inches. Considering that a typical valve closure velocity is 2 second for inch, the isolation time is in the order of some seconds.

Time for emptying the circuit

Emptying of the isolatable section is function of dimension of the release hole and the hold up of the isolatable section.

In conclusion, in case of effective intervention of ESD system, the total release time for each hole diameter in the table below is summarized.

Type of release	Detection/Isolation (minutes)	Emptying
Small release	10	Depending on hold up of the section and release rate from the hole (calculated via Phast software, considering the dynamic flow rate)
Medium hole	5	
Full bore	1	

In case of ineffective intervention of ESD system, the scenarios will be not-isolated for each release hole, and the duration is assumed higher that 10 minutes (which is the threshold for escalation effects, see assumption 7).

Table 26 – Assumption #6

Study:	QRA, FERA		
Subject:	Scenario consequences calculation and reference threshold for QRA / FERA		
Assumption #	7	Rev.	1
Reference:	5, 6,7, 13, 17, 24, 29,30		

Scenario consequence modelling

The scenario consequences will be modelled with the package Phast released by DNV (8.9 latest revision available), in order to assess the spatial distribution of physical effects of scenarios. Operating pressure and temperature and composition of the hazardous fluid will be selected from H&M Balance project documentation. For gas releases the pressure in the system, and hence the release rate, could slowly decrease following isolation, resulting in a time dependent release. As a conservative approach, the calculated initial release rate is assumed constant over the release duration for such scenarios; the scenarios consequences will be evaluated at time = 0, where the release flow rate shows the maximum value. The orientation of the release is an important factor because it will define the orientation of jet fires and their impact. The orientation of release will be modelled as follows:

- horizontal non-impinged for jet fire, in order to maximize damage distances scenarios.
- horizontal (50 % of probability) and down impingement (50 % of probability) for flammable gas dispersion (FF and explosion), in order to maximize damage distances scenarios.

Reference thresholds for QRA

This paragraph provides information on the vulnerability of humans.

Jet fire exposure:

The values for humans' fatality are reported below:

- 37.5 kW/m^2: Probability of human lethality: 100%
- 12.5 kW/m^2: Probability of human lethality: 30%
- 4.73 kW/m^2: Probability of human lethality: 3%

Flash fire exposure:

The values for humans' fatality are reported below:

- LFL: Probability of human lethality: 100%
- LFL/2: Probability of human lethality: 50%

Overpressure exposure:

The values for humans' fatality are reported below:

- 0.5 bar: Probability of human lethality: 100%
- 0.3 bar: Probability of human lethality: 50%

Reference threshold for FERA

This paragraph provides information on the effects of fire and explosion on asset and structure.

Jet fire exposure:

The 37.5 kW/m^2 represent the threshold which unprotected steel will reach thermal stress temperatures that can cause failure. Anyway, for determination of escalation effect it is required to calculate the time which the target is involved in such critical thermal radiation. According to generally adopted exclusion criteria related to the duration of fire scenarios, a possible escalation effect can be expected in case of exposure to jet fire from more than 10 minutes.

For the determination of probability of escalation, a dedicated iso-damage contours will be calculated as the sum of all jet fire scenarios which duration equal or higher than 10 minutes.

Overpressure exposure:

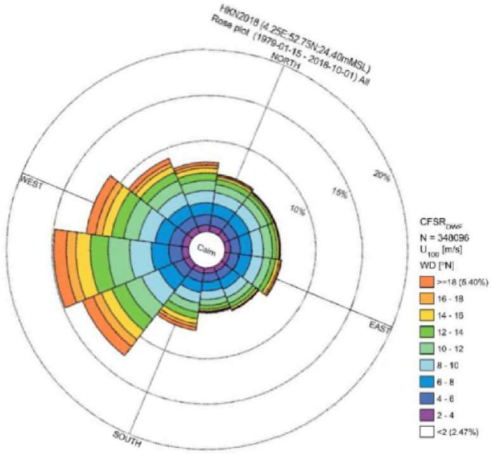
The values for vulnerability to explosion for asset and structure are reported in the tables below.

Overpressure (bar)	Effect on asset/structure
0.35	Collapse of steel girder framed buildings
0.27	Frameless, self-framing steel panel building demolished
0.15	Partial collapse of roofs and walls of buildings.
0.07	Large and small windows usually shattered; occasional damage to windows frame.

Table 27 – Assumption #7

Study:	QRA, FERA		
Subject:	Weather condition		
Assumption #	8	Rev.	1
Reference:	17, 28, 29,30		

Project wind distribution are reported below.



Modelling of physical effects of each scenario will be carried out with reference to n. 3 representative meteorological cases, on the basis of wind percentages distribution:

- wind speed 2 m/s and Pasquil stability Factor "F" for approx. 6 % of time (this weather condition including, as a conservative approach, also 2,5% of "calm condition" of wind lower than 2 m/s;
- wind speed 5 m/s and Pasquil stability Factor "D" for approx. 50 % of time (value corresponding to blue wind speeds in the figure);
- wind speed 10 m/s and Pasquil stability Factor "D" for approx. 44 % of time (value corresponding to green and orange wind speeds in the figure).

The risk will be also calculated taking into consideration the distribution of wind directions according to the wind rose. Additional weather data for consequences simulation are reported below:

- Ambient temperature (nom) (°C) : 10.5°C
- Relative humidity (%): 83
- Solar Radiation (kW/m^2): 0.5
- Surface Roughness: 0.11

Table 28 – Assumption #8

Study:	QRA		
Subject:	QRA Risk recombination and acceptability criteria		
Assumption #	9	Rev.	0
Reference:	8, 29		

Risk recombination

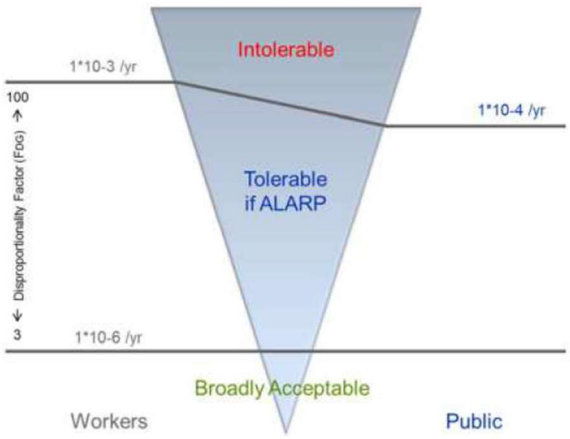
The Location Specific Individual Risk (LSIR) is the expected frequency of death of a hypothetical person assumed to be continuously present at a specific location. It is usually expressed as a risk of death per year and presented in form of risk contours. The risk exposure is calculated for all identified hazards and each contribution is summed to provide the overall risk for the area of the installation. The main steps for risk contours calculation are reported below:

- frequency calculation of the hazardous scenario (e.g., flash fire, jet fire events);
- calculation of consequence of each scenario (in terms of thermal flux or flammable gas cloud extension or overpressure);
- assessment of fatality probability for each scenario consequences;
- geo-referencing of each scenario in the plant layout;
- contour plot calculation by definition of a squared grid around the plant.

Calculations will be performed by application of a dedicated ArcGis 9.3 model for geographical data management.

Acceptability criteria

Reference IRPA (Individual Risk Per Annum) risk acceptability thresholds are indicated in the following figure. People distribution and manning level will be based on project information, considering that platform is unmanned, and people presence is limited only to maintenance activities.



This approach is related to the identification of three risk regions (unacceptable, ALARP and broadly acceptable), to which is assigned different frequency values for unacceptable risk threshold. Reference Individual Risk acceptability thresholds are indicated in the following table.

LOCATION	IRPA (fatality/ year)		
	Risk region: Unacceptable	Risk region: ALARP	Risk region: Broadly acceptable
Platform area	> 1 x 10-03	1 x 10-03 ≥ IR ≤ 1 x 10-06	IR < 1 x 10-06

Table 29 – Assumption #9

Study:	FERA		
Subject:	FERA Risk recombination and acceptability criteria		
Assumption #	10	Rev.	0
Reference:	9, 17,30		

Risk recombination

The iso-damage contours plots are defined on basis of all the identified scenarios, each one characterized by its frequency value and damage distances. Calculation of the risk at a specific geographical location for a risk type (overpressure, fire), is equal to the sum of the selected threshold frequency of occurrence at that point, posed cumulatively by all other scenario (with the same threshold) from other LOC identified within the plant. The main steps for risk contours calculation are reported below:

- frequency calculation of the hazardous scenario (overpressure, jet fire1 events);
- calculation of consequence of each scenario (in terms of thermal flux or overpressure);
- geo-referencing of each scenario in the plant layout;
- contour plot calculation by definition of a squared grid around the plant.

Calculations have been performed by application of a dedicated ArcGis 9.3 model for geographical data management. The software provides the sub-division of the overall complex by means of a specific grid. In each position (x,y) of the grid, the total frequency is calculated as composition (numerical sum) of the frequencies of impact of the single impact scenario.

Acceptability criteria

A Fire and Explosion Risk Analysis (FERA) will be performed in order to evaluate the risk of possible escalation of the initial scenario (e.g. Jet Fire, explosion) in a complex accident scenario, involving severe damage in a secondary equipment with loss of containment and propagation of the hazard scenario in multiple plant units.

This method marks the 1E-04 occurrence per year threshold as the maximum tolerable for asset/structure involved in a fire or explosion scenario [9].

This approach requires the elaboration of dedicated iso-contour plots, where all jet fire and explosion scenarios frequencies are summed in each point of the area under investigation. The method requires to ensure that there are no incidents which, alone or when summed, fall just below the 1E-04 occ./year cut-off threshold.

[1] For jet fire iso-damage contours, only scenario with duration which allows escalation effect will be considered.

The acceptability criteria are reported below: • the frequency of iso-damage contours representing the exposure of a thermal radiation (calculated as a sum of thermal radiation from jet fires) of 37.5 kW/m^2 in a target shall be less than 1E-04 occ./year; • the frequency of iso-damage contours representing the exposure of an overpressure threshold of 0.3, 0.14, 0.07 bar (each considered separately) in target shall be less than 1E-04 occ./year.

Table 30 – Assumption #10

Study:	EERA		
Subject:	Estimated travel time		
Assumption #	11	Rev.	0
Reference:	10, 14, 31		

The estimated travel time along any escape ways will be calculated using the typical speeds summarized below.

Route	Time (m/s)
Walkways	1.0
Staircase	0.8
Ladders	0.3
Man-rider winch (Also used for winching down to liferaft)	0.2

Table 31 – Assumption #11

Study:	Noise Study		
Subject:	Methodology and Mathematical model		
Assumption #	12	Rev.	0
Reference:	15, 16, 32		

The noise impact assessment methodology will include the following steps:

- Creation of the model input data:
  - definition of flat model of the terrain and assign water propagation data,
  - definition of calculation area
  - creation of a three-dimensional grid of calculation limited to perimeter;
  - identification and characterization of the noise sources,
  - creation of a three-dimensional model of installation including all the noise sources;
- calculation of values of sound pressure levels (SPL) in the study area using the simulation model including all sources, on the entire noise study area, outside of containers and equipment cabinets.
- analysis of results and comparison with the limit values identified for the project.

The mathematical model that will be used will be SoundPLAN 7.3 released by Braunstein + Berndt GmbH / SoundPLAN International LLC, an engineering services and software company headquartered in Germany. SoundPLAN is an advanced program designed to simulate the acoustical behaviour of any arbitrary enclosed volume, any open space or a combination of both.

SoundPLAN models the physics of acoustical propagation, including specular and diffuse reflections against physical boundaries, wall adsorption and air adsorption, diffraction across screens and transmission through walls.

The calculation results will be shown by acoustic pressure maps by the "maps graph" application of the software. The simulation of industrial noise source will be performed applying ISO 9613 noise propagation standard.

Table 32 – Assumption #12

Study:	Noise Study		
Subject:	Sources		
Assumption #	13	Rev.	0
Reference:	12, 15, 32		

Starting from the available project documents (i.e. equipment list), the list of the noise sources will be characterized according to following main information:

- Noise source name/description
- Project coordinates (x,y,z) refer to layout reference point 1-A ,
- Sound power levels [dB(A)].

The Sound Power Level for each source will be calculated by the sound pressure level data or derived from other similar project, from vendors end /or specific databases.

Equipment noise levels and spectra used in the model will be based on equipment datasheet, or according to field measurement experience for similar design/capacity equipment and estimated for level based upon their maximum anticipated operational duty at normal operating conditions.

The definition of the total Sound Power Level (Lw) will be carried out considering the:

- Enveloping surface dimension of each noise source, where the enveloping surface is the minimum surface, which contains the noise source itself and it is determined by the examination of the Unit plot plans.
- Sound Pressure Level (Lp) referred to 1 meter distance from each noise source, determined by relevant noise equipment datasheet and project specifications.

In order to obtain the Sound Power Level (Lw) of each noise source starting from the Sound Pressure Level (SPL) of the noise source, the calculation will be conduct according to the UNI EN ISO3746 "Acoustics, Determination of sound power level of noise sources - Survey Method".

Table 33 – Assumption #13

Study:	Noise Study		
Subject:	Evaluation Grid		
Assumption #	14	**Rev.**	1
Reference:	15,28, 32		

The computing grid will be created starting from the elevation of the study area and setting a mesh size of 1 m x 1 m. It allows the model to build the noise contours by interpolating values of sound pressure calculated at each node of the grid.

In order to consider the noise levels at each deck of installation, multiple grids will be created, one for each deck. Each deck simulation considers all the noise sources of the installation area.

The software will be settings with the following parameters:

- Grid size: 1.0 m;
- Calculation height: 1.5 m above each deck level;
- Number of reflections: 3.

The environmental data introduced in the simulation software are the following:

- Temperature: 10.5°C,
- Humidity condition: 83%,
- Atmospheric pressure: 1013.3 mbar,
- Ground factor G: 0.0 (corresponding to hard ground such as asphalt, water or industrial site).

Table 34 – Assumption #14

Study:	Noise Study		
Subject:	Noise limit		
Assumption #	15	Rev.	0
Reference:	11, 15, 32		

As BLPH has been designed with a relatively short operational life and is planned to be operationally un-manned, only having maintenance operatives aboard for commissioning, essential maintenance and for de-commissioning. The requirements for noise control have therefore been focused on ensuring that any maintenance operatives attending the plant are safe and that noise exposure levels will be compliant with the EU Directive 2003/10/EC – Noise which requires that noise control measures shall be included at the planning and design phases of new facilities and a noise limit of 85 dBA applies to any work area which cannot be restricted to access during normal operations.

The general work area noise limit is 85 dB(A). The area noise level limits defined therein shall apply as the maximum sound pressure level at any location within a working area, but not closer than 1 m to equipment and other noisy installations. Where the area noise limit of 85 dB(A) is unfeasible, the limit of 90 dB(A) shall apply. The individual employee's daily noise exposure Leq,8h (dB(A)) shall be lower than 85 dB(A) (equivalent to the exposure reported in the following table).

Exposure Time	Noise LevelLAeq [dB(A)]
24 hours	80
16 hours	82
12 hours	83
10 hours	84
8 hours	85
4 hours	88
2 hours	91
1 hour	94
30 minutes	97
15 minutes	100

Limits applicable for operation condition only and not for start-up, shut down, emergency or any other unusual condition. In any case the sound pressure level in the work area shall never exceed 110 dB (A). These limits will be considered as a reference basis for the evaluation of noise compatibility within all areas identifiable as a working environment, outside of containers and equipment cabinets.

Table 35 – Assumption #15

Study:	Dropped Object study		
Subject:	Dropped Object scope and main data		
Assumption #	16	Rev.	0
Reference:	25 ,26, 27, 32		

The objective of the Dropped Object Study is to assess the potential to drop lifted objects during normal operations and maintenance activities of the platform, and to assess the expected impact energy over potentially vulnerable areas.

After dropping, the object might hit the platform leading to possible damage to process equipment, to the decks' structure and/or to injury/fatality of workers.

The analysis of impact on the platform will be based on international standard based on the location of critical equipment handling dangerous substances and on the distribution of workers (considering that the platform is designed as unmanned, and the presence of working personnel is limited to the maintenance activities).

The study will be based on information reported in the equipment list; the typology and the frequency of lifting activities will be based on information reported in the handling study.

Table 36 – Assumption #16