Base Load Power Hub (BLPH)

Fire and Explosion Risk Analysis (FERA) report

Document Number: 123A90-DDL-SAF-LIS-30020

Document Class: 1

Rev.	Date	Description	Prepared	Reviewed	Approved
04	29/11/2024	Accepted for Construction (AFC)	G. Giani	C. Caracciolo	D. Lo Sterzo
03	26/09/2024	Accepted for Construction (AFC)	G. Giani	C. Caracciolo	D. Lo Sterzo
02	24/05/2024	Accepted for Construction (AFC)	G. Giani	C. Caracciolo	D. Lo Sterzo
01	15/03/2024	Issue for Acceptance (IFA)	G. Giani	C. Caracciolo	D. Lo Sterzo
00	15/02/2024	Issue for Acceptance (IFA)	G. Giani	C. Caracciolo	D. Lo Sterzo

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Revision / Change Log

Rev.	Description
00	Issue for Acceptance (IFA)
01	Issue for Acceptance (IFA)
02	Accepted for Construction (AFC)
03	Accepted for Construction (AFC)
04	Accepted for Construction (AFC)

HOLDS LIST

No.	Description
1	
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1 INTRODUCTION

1.1 PROJECT OVERVIEW

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

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

1.1.1 Project Location

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

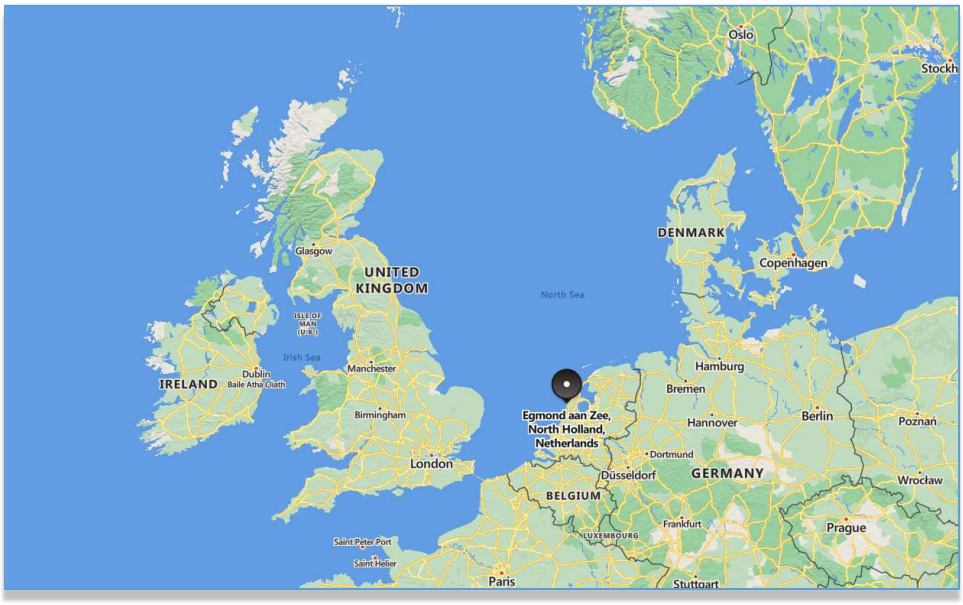


Figure 1 HOLLANDSE KUST NOORD WIND PARK Location Map

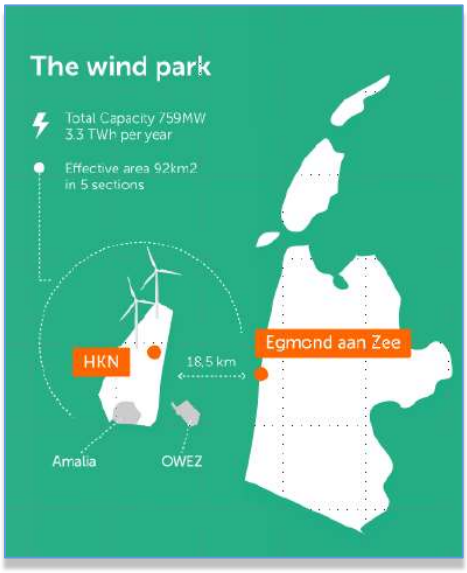


Figure 2 - Wind Park Details

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

1.1.2 Project Concept

All components included in the BLPH will be integrated onshore on a 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.

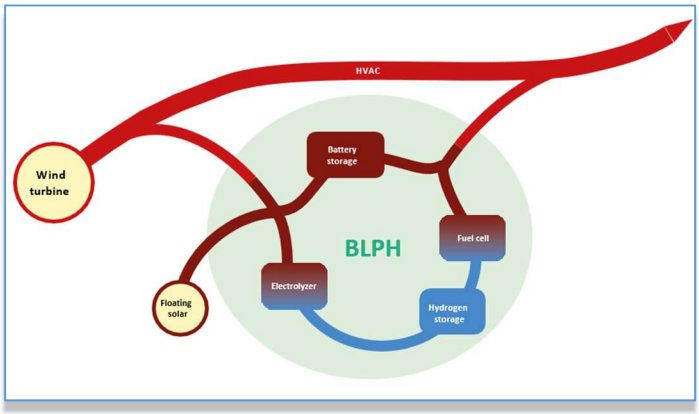


Figure 3 – BLPH Concept

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.

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2 EXECUTIVE SUMMARY

This document has the purpose of detailing the results of the Fire and Explosion Risk Assessment (FERA) 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. 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 escalation;
- to evaluate the fire escalation scenarios in detail and suggest suitable risk reduction measures.

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-GL. 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 FERA study are reported below.

- Jet Fire.

  there are no areas in the platform in which the thermal radiation threshold contours of 37.5 kW/m^2 from jet fire is equal to or above 1.0E-04 per year. The impact of jet fire scenarios on equipment is lower than target frequency and can be classified as tolerable .

- Explosion

  there are no areas in the platform in which the explosion threshold contours of 0.35, 0.27, 0.15 and 0.07 bar are equal to or above 1.0E-04 per year, thus the risk from VCE is considered tolerable .

Following actions are recommended:

- In order to reduce the escalation risk from section 2 (storage section) it is suggest to reduce the total hold up involved in the hazardous scenarios. At the present, all vessels are considered aligned, and

in case of release, about 1200 kg are potentially involved in the release. It is recommended to define the logics of line-up and closure of each vessel automatically during normal operation.

This action will significantly reduce the total amount of H_2 involved in a critical scenario, leading to the decrease of scenario duration and the risk of escalation.

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	123A90-PML-PM-TQ-00045_TQ REPLY Automated Extinguishing Systems for Contractor Supplied Containers 12/10/2023
11	Packages FERA assessment rev 1.0

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.
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).
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.

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.
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 tolerable.
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

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2.2.2 Abbreviations

BESS	Battery Energy Storage System
BLPH	Base Load Power Hub
BMS	Battery Management System
CPI	Company Provided Item
ESD	Emergency Shut-Down
ETA	Event Tree Analysis
F&G	Fire and Gas
FERA	Fire and Explosion Risk Assessment
H&MB	Heat and Material Balance
HKN	Hollandse Kust Noord
HSE	Health, Safety and Environment
IOGP	International Association of Oil & Gas Producers
LFL	Lower Flammable Limit
LSIR	Location Specific Individual Risk
LOC	Loss Of Containment
NNF	Normally No Flow
P&ID	Piping and Instrumentation Diagram
PFP	Passive Fire Protection
PFD	Process Flow Diagram
SDV	Shut Down Valve
VCE	Vapour Cloud Explosion
WTG	Wind Turbine Generator

Table 3 - Abbreviations

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3 STRUCTURE OF THE REPORT

The Report is structured in the following parts:

- FERA summary report, which includes:
  - Introduction to the project and scope of present FERA,
  - 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 escalation and VCE risk in the platform
  - 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: FERA hazard risk contours: Jet Fire envelope.
  - Attachment 6: FERA hazard risk contours: VCE envelope.
  - Attachment 7: Extract of the document "Assumption Register", doc n 123A90-DDL-SAF-LIS-30014 – rev2

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4 RISK ANALYSIS

The FERA 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 (pressure and temperature), 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 plant 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].

Conservatively, the development of this document does not take into account the effect of blowdown.

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

4.1 HAZARD IDENTIFICATION AND FAILURE CASE DEFINITION

The FERA 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 [11].

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 [11]; main results in term of frequencies of occurrence and damage distances are summarized in the present chapter.

Electrolyser

A parts count on P&ID has been performed on the electrolyser package in order to calculate large, medium and small release frequencies.
For consequences simulations, a stoichiometric hydrogen/air cloud of 44 m^3 in the container (100% of the free space filled with H_2 cloud) was considered for large hole and a gas cloud of 22 m^3 in the container (50% of the free space filled with H_2 cloud) was considered for medium and small holes.

Additional scenario of internal explosion of electrolyser package due to complete membrane failure for the 8 stacks is considered.
Results of frequency and consequences simulation are reported in **Attachment 4B**.

Fuel cell

A parts count on P&ID has been performed on the fuel cell package in order to calculate large, medium and small release frequencies.
For consequences simulations, a stoichiometric hydrogen/air cloud of 44 m^3 in the container (100% of the free space filled with H_2 cloud) was considered for large hole and a gas cloud of 22 m^3 in the container (50% of the free space filled with H_2 cloud) was considered for medium and small holes.
Results of frequency and consequences simulation are reported in **Attachment 4B**.

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 package can be 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

Section	LOC cases		Small release (occ/year)	Medium release (occ/year)	Full bore (occ/year)	
			5mm	25mm	Diameter mm	Frequency
	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, which is a flammable substance, shall produce a fire that can be configured as:

- Jet fire (in case of early 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, ignition probability and probability of failure of ESD system. In terms of frequency, the ESD system is assumed 90% reliable, meaning that a "not-isolated scenario" has 10% probability of occurrence following a LOC.

In case of effective intervention of ESD system ("isolated scenarios"), the total duration of the damage scenarios is calculated as sum of:

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. It is assumed different time to detection,

depending on the hole diameter (higher time for small release, which lead to small flammable gas cloud, and an early detection for medium and full bore release, due to higher gas clouds).

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 not higher 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. Time for emptying is calculated via Phast software, considering the dynamic flow rate.

In conclusion, in case of effective intervention of ESD system, the total release time for each hole diameter in the table below is summarized. The hold up of each isolatable section, as well as the duration of each scenario, are reported in the chapter 5.1.

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	

Table 8 – Scenario duration

In the contrary, 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 valve, and is assumed, for each LOC, a scenario duration higher than 10 minutes and included in the escalation analysis.

The identification of the different event tree types is described in **Attachment 3**, where is also reported the findings of the event tree analysis applied to each selected LOC.

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 frequency for avoid potential damage to the equipment in terms of fire and explosion exposure.

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 4.

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 Iso-damage contours

The risk from FERA is expressed by calculation of dedicated iso-damage contours plots showing the risk for fire and for overpressure for each threshold considered separately.

The 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 platform. The main steps for risk contours calculation are reported below:

- frequency calculation of the hazardous scenario (e.g. jet fire / explosion 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.

4.3.2 FERA acceptability criteria

A Fire and Explosion Risk Analysis (FERA) was 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.

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.

The acceptability criteria are reported below:

- the frequency of iso-damage contours representing the exposure of a thermal radiation for more than 10 minutes (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 0.35, 0.27, 0.15, 0.07 bar (each considered separately) in target shall be less than 1E-04 occ./year.

5 RESULTS

FERA hazard frequency contours are presented in this section showing the frequency of exposure to different effect levels, each characterized with different consequences on equipment.

Specific contours associated with each typology of scenario are elaborated:

- Iso-contours plot of 37.5 kW/m^2 for thermal radiation from Jet Fire (**Attachment 7**);
- Iso-contours plot of 0.35, 0.27, 0,15, and 0.07 barg risk for overpressure scenario showing the significative damage to buildings/structure (**Attachment 8**).

5.1 RISK FROM JET FIRE

The 37.5 kW/m^2 represent the threshold which unprotected steel will reach thermal stress temperatures that can cause failure, if exposed to a jet fire scenarios from more than 10 minutes. According to Assumption register [1], only jet fire scenarios with expected duration higher than 10 minutes need to be considered during risk recombination in order to calculate the risk of escalation in the area.

5.1.1 Selection of jet fire for escalation

In the present report, two type of jet fire are considered:

- "non isolated scenarios " (meaning failure of ESD system), which shows duration > 10 minutes from each release hole diameter;
- "isolated scenarios", (meaning effective intervention of ESD system), which shows duration depending on hole diameter and total hold up of the isolatable section.

Jet fire scenarios from non-isolated case.

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, meaning that all jet fire scenarios are considered for escalation, as per below table.

LOC cases		Release hole	Total (min)	Jet fire for Escalation
1.1	Release from electrolyser outlet piping to storage section	5mm	>10	YES
		25mm	>10	YES

LOC cases		Release hole	Total (min)	Jet fire for Escalation
2.1	Release from storage connection piping (1.5 inches)	5mm	>10	YES
		25mm	>10	YES
		Full bore (1.5 inches)	>10	YES
2.2	Release from BDV connecting piping on top of storage vessel (3 inches)	5mm	>10	YES
		25mm	>10	YES
		Full bore (3 inches)	>10	YES
3.1	Release from vessels outlet piping to fuel cell package	5mm	>10	YES
		25mm	>10	YES
		Full bore (2 inches)	>10	YES

Table 9- "Non isolated" scenario duration

Jet fire scenarios from isolated case.

In this case, the total release time from each hole diameter in equal to the time for detection and isolation (which is different for each hole range, as reported [1]) and the emptying time (which is depending on hold up of the section and release rate from the hole)[1].

Considering that the piping shows, for all isolatable section, low volume (due to low piping length and diameter), the contribution of piping to the total hold up of the section is negligible for all section. In the contrary, in the isolatable section 2, the presence of six hydrogen storage vessels lead to the increase of hold up.

The emptying time for isolatable section 1 and 3 is negligible compared to detection and isolation time, while for isolatable section 2 the emptying will be higher than 10 minutes, for each release diameter, considering the hold up of the section (about 1200kg).

The jet fire duration for isolated cases in the table below are summarized.

[1] The emptying time is calculated via Phast software considering the dynamic flow rate staring from the hold up of the isolated section.

LOC cases		Release hole	Jet Fire for Escalation			Jet fire for Escalation
			Detection and isolation (min)	Time to emptying (sec)	Total (min)	
1.1	Release from electrolyser outlet piping to storage section	5mm	10	15	>10	YES
		25mm/ Full bore	2	1	<10	NO
2.1	Release from storage connection piping (1.5 inches)	5mm	10	14000 (233 min)	>10	YES
		25mm	2	6160 (102 min)	>10	YES
		Full bore (1.5 inches)	1	2738 (45 min)	>10	YES
2.2	Release from BDV connecting piping on top of storage vessel (3 inches)	5mm	10	14000 (233 min)	>10	YES
		25mm	2	6160 (102 min)	>10	YES
		Full bore (3 inches)	1	663	>10	YES
3.1	Release from vessels outlet piping to fuel cell package	5mm	10	60	>10	YES
		25mm	2	2	<10	NO
		Full bore (2 inches)	1	1	<10	NO

Table 10 – Isolated scenarios duration

Jet fire scenarios for FERA calculation

In conclusion, in the table below the jet fire for FERA calculation for isolated and not isolated scenarios are summarized.

LOC cases		Release hole	Jet fire for Escalation	
			ESD intervention (90% probability)	ESD failure (10% probability)
1.1	Release from electrolyser outlet piping to storage section	5mm	YES	YES
		25mm/ Full bore	NO	YES
2.1	Release from storage connection piping (1.5 inches)	5mm	YES	YES
		25mm	YES	YES
		Full bore (1.5 inches)	YES	YES
2.2	Release from BDV connecting piping on top of storage vessel (3 inches)	5mm	YES	YES
		25mm	YES	YES
		Full bore (3 inches)	YES	YES
3.1	Release from vessels outlet piping to fuel cell package	5mm	YES	YES
		25mm	NO	YES
		Full bore (2 inches)	NO	YES

Table 11 – Jet fire for escalation (duration >10 minutes)

As already mentioned, the not-isolated scenarios show lower frequency of occurrence compared to isolated scenario, considering that the ESD system is assumed 90% reliable. In attachment 3 the frequency of occurrence of both scenarios are reported.

5.1.2 Jet fire consequences analysis

According to assumption register, jet fire consequences calculation is performed at time =0, where the release flow rate shows the highest value, in order to maximize the damage distances. Note that, for risk resummation, these damage distances are considered constant for all the duration of the scenario, even if, according to the process condition, the flow rate and associated consequences will progressively decrease due to decrease of total hold up of the section. For completeness, in Attachment 4 the flow rates at different time are reported.

Jet fire from 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 and the potential for escalation, in case of ESD intervention, is limited to the 5 mm release (which is assumed with duration > 10minutes). The frequency of occurrence of this scenario is between 1.1E-06 and 1.3E-07 (depending on wind distribution) with damage distance of 37.5kW/m^2 equal to 3.6 meters.

In case of failure of ESD, both the 5 mm and 25 mm have scenario duration higher than 10 minutes and will be part of escalation analysis. For this case, the jet fire probability is between 1.2E-07 and 1.5E-08 occ/year for 5 mm case and between 5.9E-08 and 4.9E-07 for 25 mm case. Note that, compared to ESD intervention, the frequency of not-isolated scenarios is lower (ESD probability of failure is assume equal to 10%). For 25 mm cases, the damage distance of 37.5kW/m^2 is equal to 16.6 meters. 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.

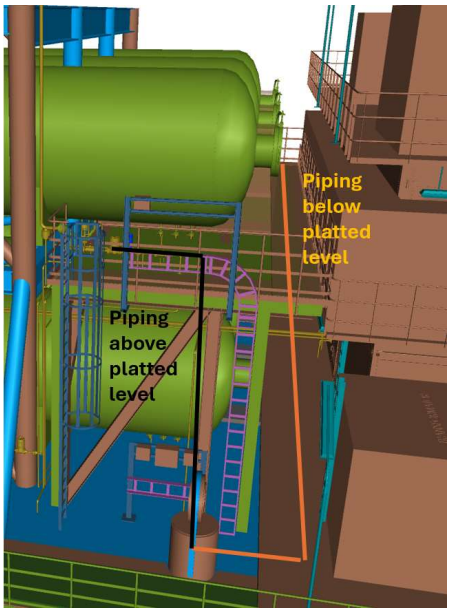


Figure 4 – Section 1 piping routing

In the following figure is reported the calculated damage distances on piping route.

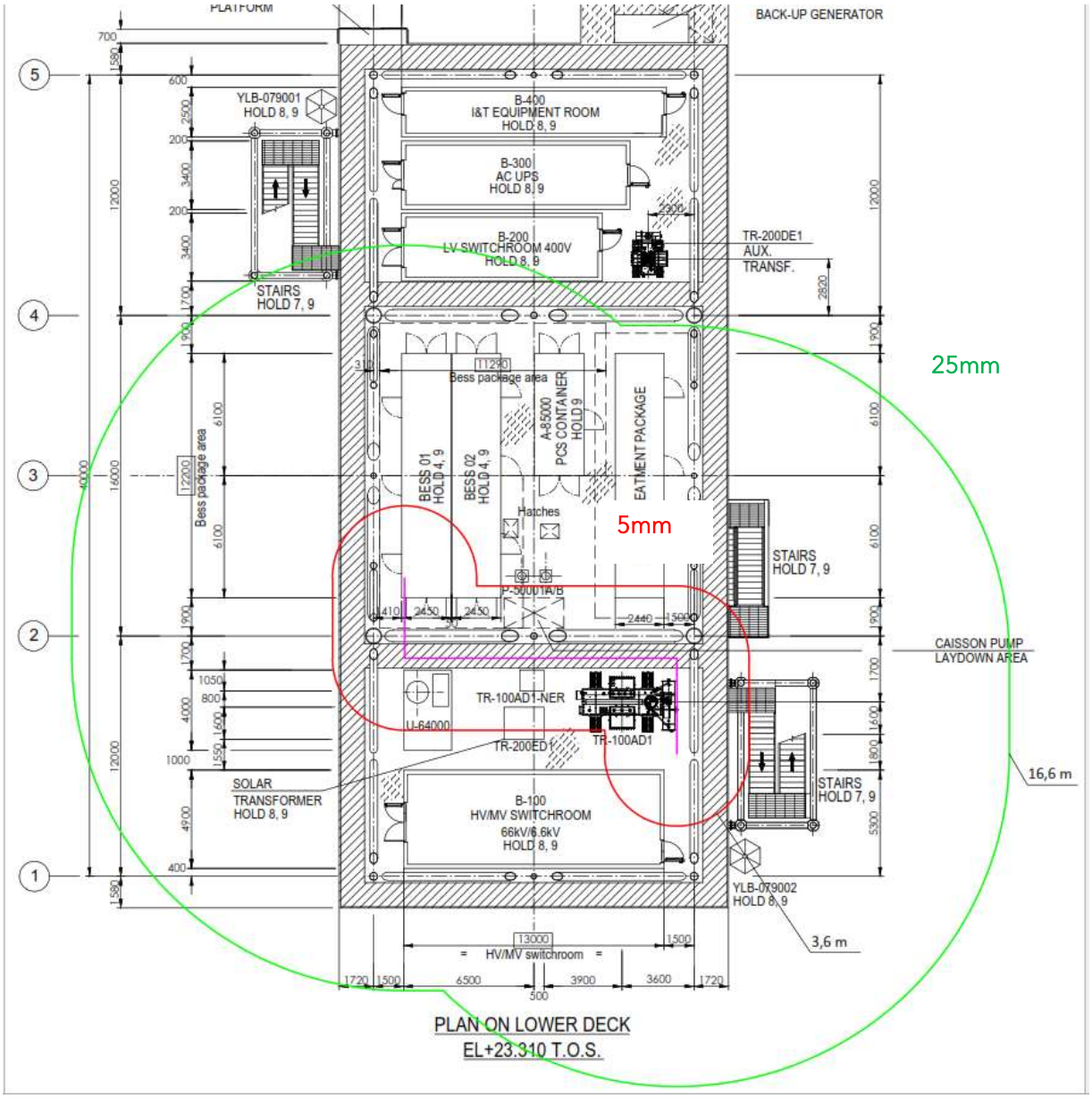


Figure 5 – Section 1 scenario consequences (37.5 kW/m²)

On the basis of calculated damage distances and piping route, following conclusions are applicable:

- For both the release hole, the jet fire is located below a plated level, and the involvement of storage vessel is limited only to the part of piping above plated level (about 15 meters) connecting the 25-SDV-001 valve.

- On the basis of damage distances of jet fire, the 5 mm involves only the nearest storage vessel; in the contrary, the 25 mm can potentially, involves all the storage vessels (even if, according to the layout, a "shielding effect" can be expected, at least for the vessel located in the opposite side from the release).

- Regarding lower deck, it is possible the involvement of BESS cabinets from 5 mm scenario; for 25 mm, the potential target, in addition to BESS are the water treatment package and B-100 switch room. However, the BESS and other package are inside a container, meaning that the escalation, that although possible, should be considered unlikely.

- On the basis of frequency of occurrence of isolated and not-isolated scenarios, the expected risk for escalation from this section is very low. The resummation of the risk from lower level (section 1 and section 3) is reported in figure 17.

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 hold up of the section includes the hold up of all vessels and piping piping (about 1400 kg), meaning that, both isolated and not-isolated scenarios show duration higher than 10 minutes and will be part of escalation analysis. For this case, the jet fire probability (as sum of isolated and not-isolated scenarios) is between 2.2E-05 and 2.7E-06 occ/year for 5 mm case; between 8.8E-05 and 1.0E-05 for 25 mm case and between 9.1E-06 and 1.1E-06 for 37.5 mm case. The damage distance of 37.5kW/m^2 is equal to 3.6 meters for 5mm, 16.6 meters for 25 mm and 24 for 37.5 mm case. In the following figure is reported (in a simplified way) the main location of the piping in the 3D model. 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.

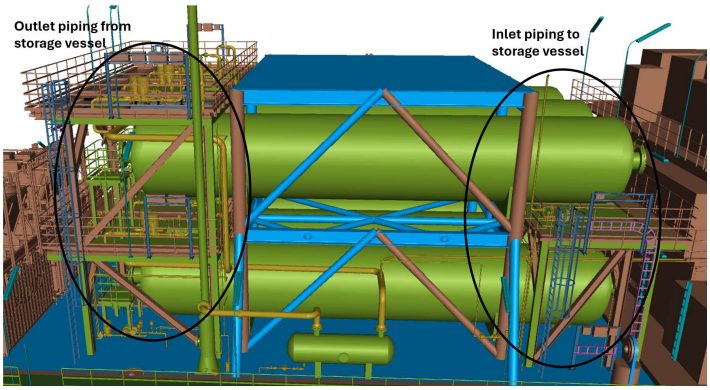


Figure 6 – Section 2 LOC 2.1 piping location

In the following figure is reported the calculated damage distances on piping route.

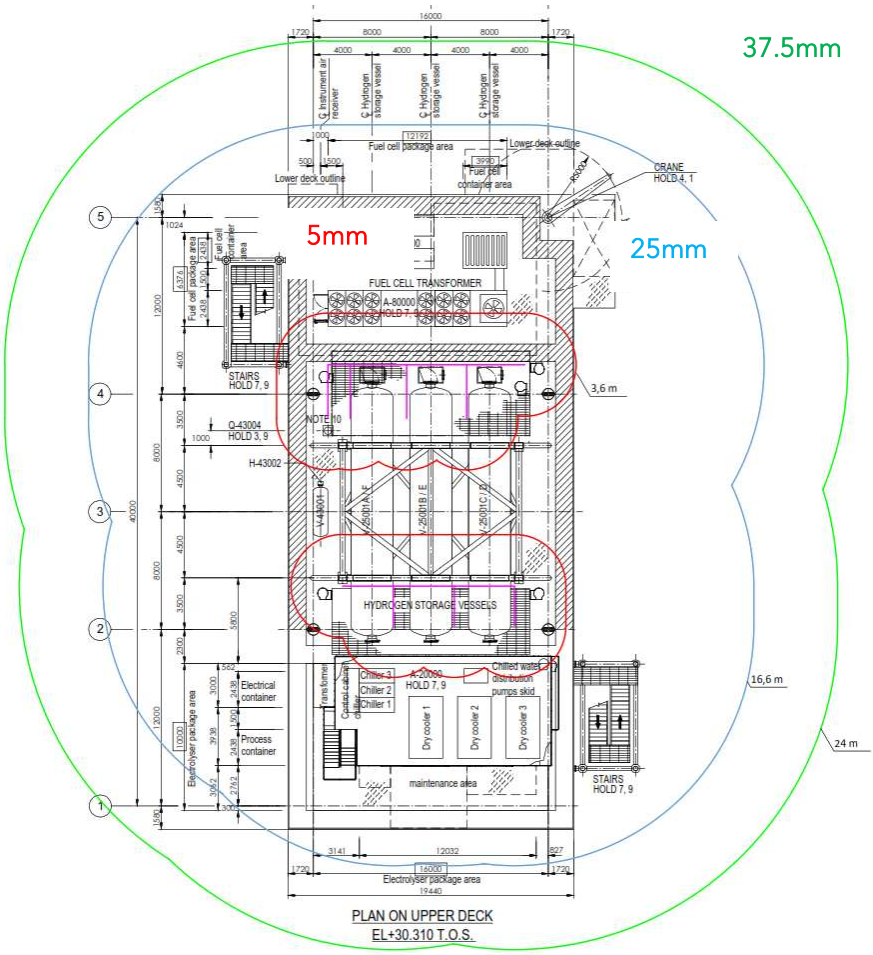


Figure 7 – Section 2 LOC 2.1 scenarios consequences (37.5 kW/m²)

On the basis of calculated damage distances and piping route, following conclusions are applicable:

- All jet fire show impact on storage vessel. For 5 mm case, the nearest storage vessel to the release point will be the target, in the contrary, for 25 and 37.5 mm release, all vessel can be potentially involved in critical thermal radiation.
- On the basis of release point, also the A-8000 package (Fuel cell) and A-2000 electrolyzer package) can be target of all release holes.
- 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. Anyway, a possible impact on lower deck is still possible if the jet fire duration will be very long.

However, the BESS and other package are inside a container, meaning that the escalation, that although possible, should be considered unlikely.

- On the basis of damage distance and duration of isolated and not-isolated scenarios, the escalation risk need to be assessed, even if the frequency of occurrence is lower than the target frequency of 1.0E-04 occ/year. The resummation of the risk from upper level is reported in figure 18.

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. The hold up of the section includes the hold up of all vessels (about 1200 kg), meaning that, both isolated and not-isolated scenarios show duration higher than 10 minutes and will be part of escalation analysis.

For this case, the jet fire probability (as sum of isolated and not-isolated scenarios) is between 3.6E-06 and 4.9E-07 occ/year for 5 mm case; between 1.1E-05 and 1.3E-06 for 25 mm case and between 2.2E-06 and 1.9E-05 for 75 mm case. The damage distance of 37.5kW/m^2 is equal to 3.6 meters for 5mm, 16.6 meters for 25 mm and 45.5 for 75 mm case.

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.

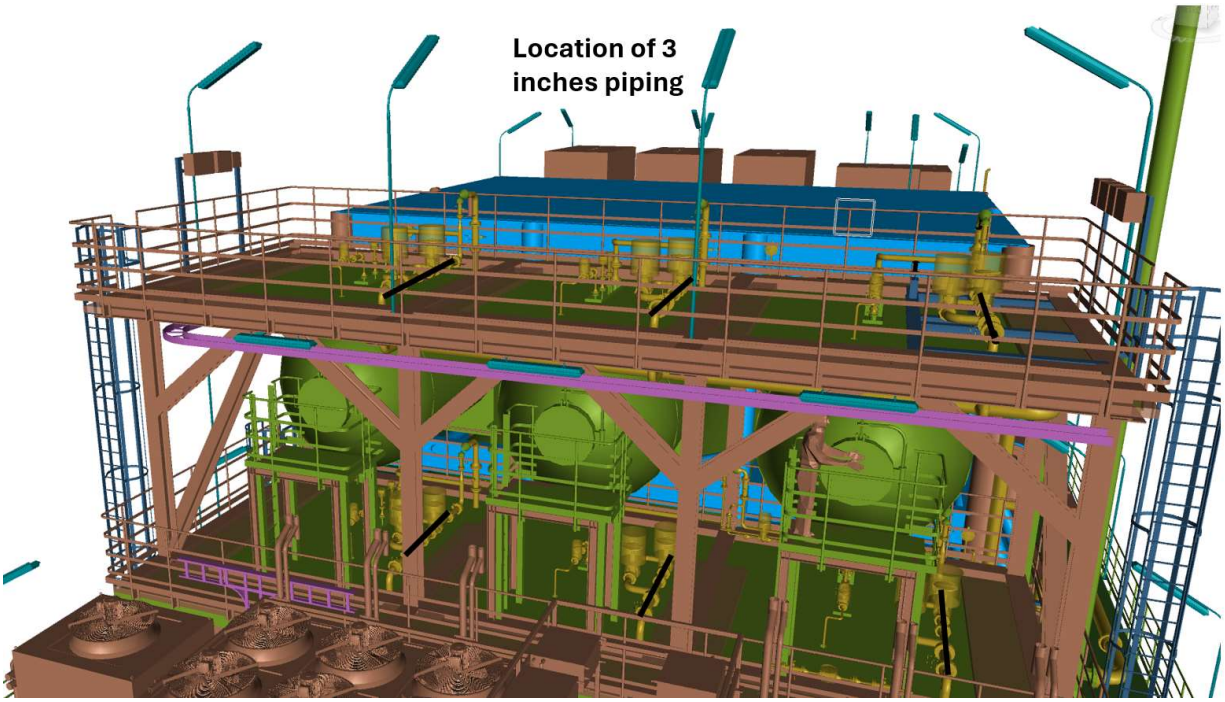


Figure 8 – Section 2 LOC 2.2 piping routing

In the following figure is reported the calculated damage distances on piping route.

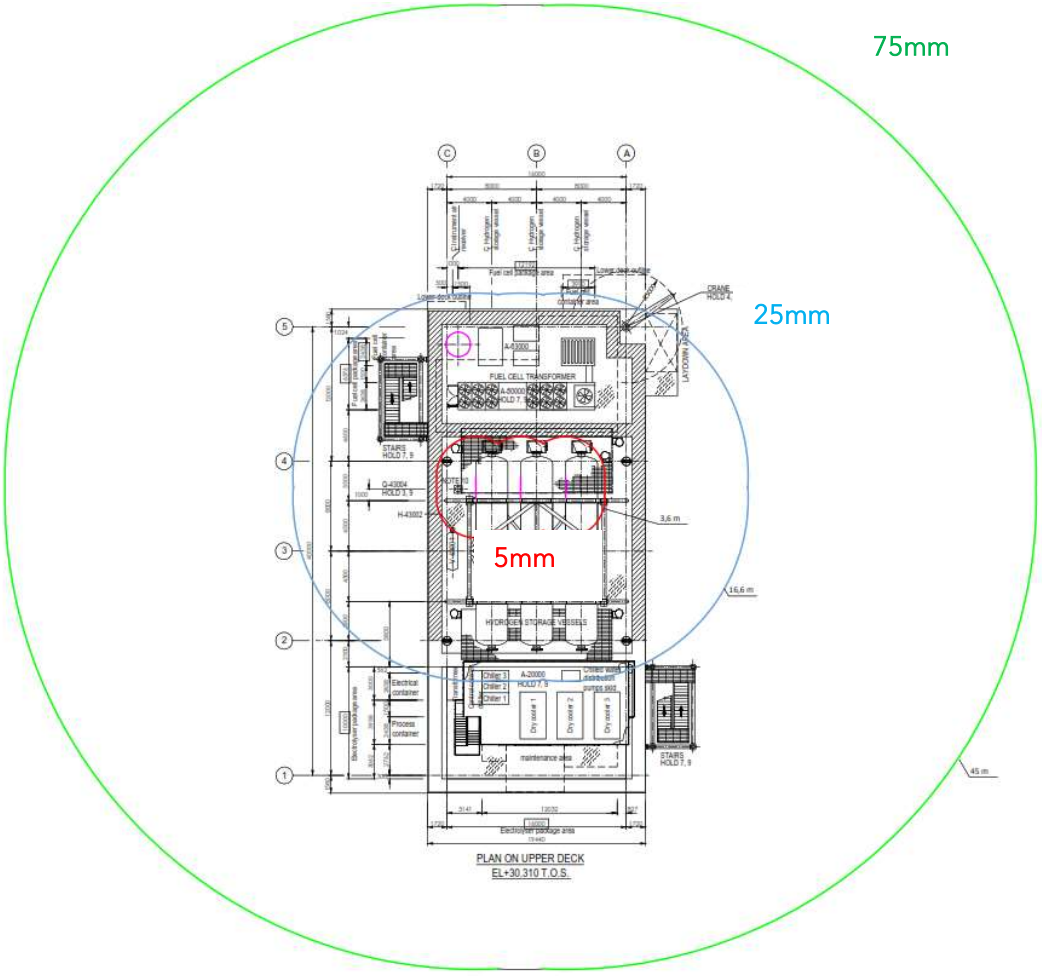


Figure 9 – Section 2 LOC 2.2 scenarios consequences (37.5 kW/m²)

On the basis of calculated damage distances and piping route, following conclusions are applicable:

- In case of release from the piping located in the platform between the storage vessel (height +4 meters from upper level deck), an impact on storage vessel is expected for all the release holes, potentially involving also the A-8000 package (Fuel cell) and A-2000 electrolyzer package). In the contrary, in case of release from the upper platform (heigh +8 from upper level deck), considering damage distance at the height of targets, no impact in A-8000 and A-2000 package is expected. In addition, the exposure to the storage vessel is limited by the presence of plated structures.

- Regarding lower deck, considering the presence of a plated area and storage vessel, the thermal radiation will be limited, meaning that the escalation, that although possible, should be considered unlikely.

- On the basis of damage distance and duration of isolated and not-isolated scenarios, the escalation risk needs to be assessed, even if the frequency of occurrence is well lower than the target frequency of 1.0E-04 occ/year. The resummation of the risk from upper level is reported in figure 18.

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 and the potential for escalation, in case of ESD intervention, is limited to the 5 mm release (which is assumed with duration > 10minutes). The frequency of occurrence of this scenario is between 3.3E-06 and 4.0E-07 (depending on wind distribution) with damage distance of 37.5kW/m^2 equal to 3.6 meters.

In case of failure of ESD, both the 5 mm, 25 mm and 50 mm have scenario duration higher than 10 minutes and will be part of escalation analysis. For this case, the jet fire probability is between 3.3E-07 and 4.5E-08 occ/year for 5 mm case; between 1.6E-07 and 1.3E-06 for 25 mm case and between 1.1E-07 and 9.6E-08 for 50 mm case. Note that, compared to ESD intervention, the frequency of not-isolated scenarios is lower (ESD probability of failure is assumed equal to 10%). The damage distance of 37.5kW/m^2 is equal to 17.5 meters for 25 mm and 32.5 for 50 mm case.

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.

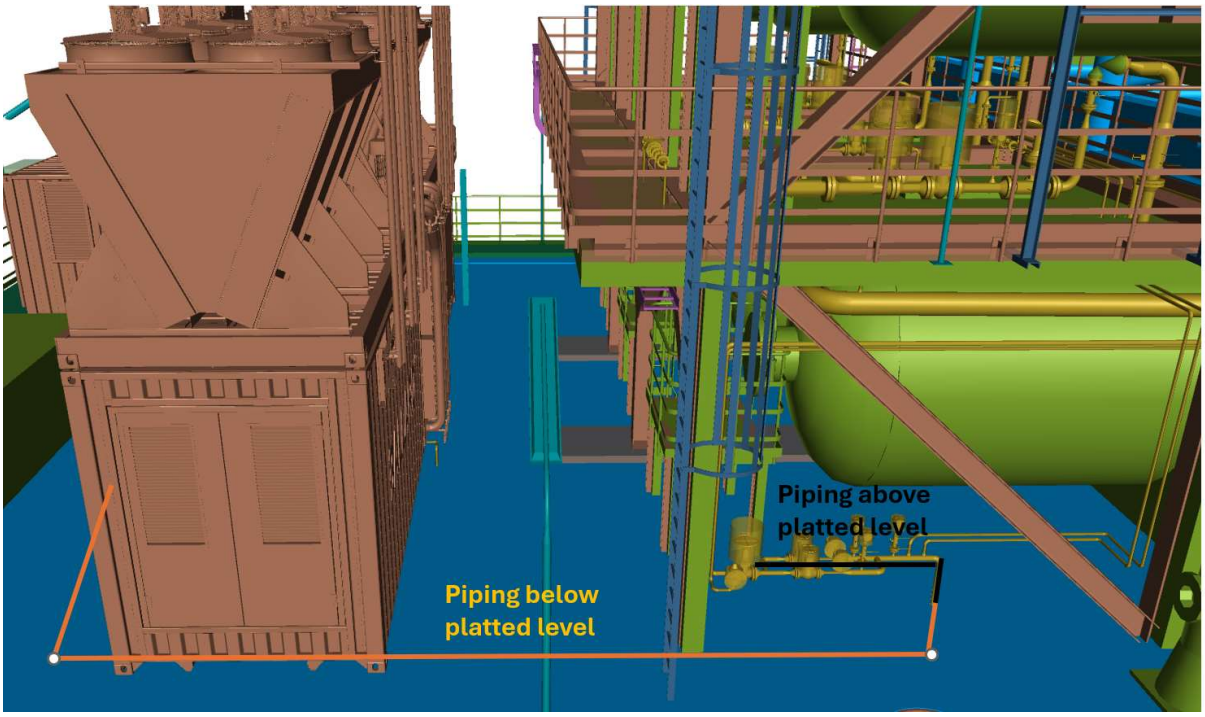


Figure 10 – Section 3 piping routing

In the following figure is reported the calculated damage distances on piping route.

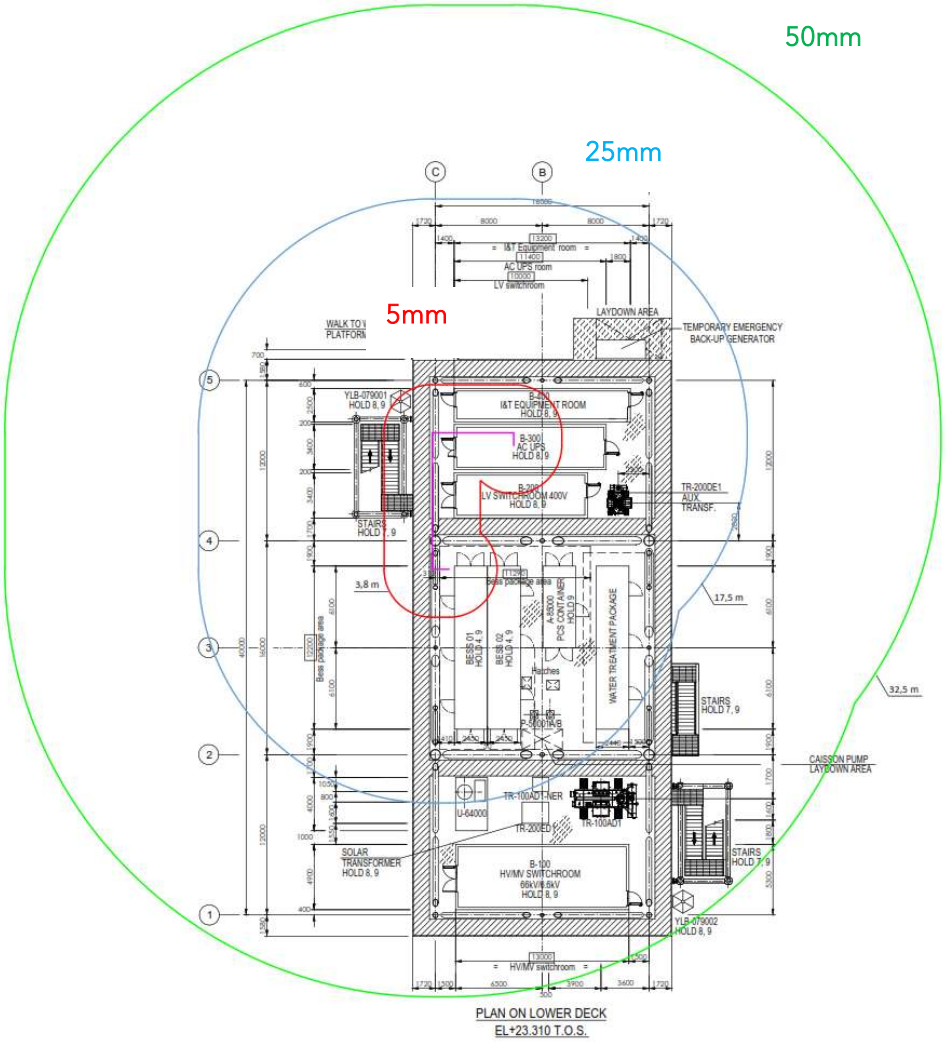


Figure 11 – Section 3 scenario consequences (37.5 kW/m²)

On the basis of calculated damage distances and piping route, following conclusions are applicable:

- For all the release hole, the jet fire is located below a plated level, and the involvement of storage vessel is limited only to the part of piping above plated level (about 3.5 meters).
- On the basis of damage distances of jet fire, the 5 mm involves only the nearest storage vessel; in the contrary, the 25 mm and 50mm can potentially, involves all the storage vessels (even if, according

to the layout, a "shielding effect" can be expected, at least for the vessel located in the opposite side from the release).

- Regarding lower deck, it is possible the involvement of BESS cabinets, and B-200 (LV switch room), B-300 (AC UPS), B-400 (I&T room) from 5 mm scenario; for 25 mm, the potential target, in addition to 5 mm included also A-8500 PCS container and water treatment package, and the 50 includes also the B-100 HV/MV switchroom. However, the BESS and other package are inside a container, meaning that the escalation, that although possible, should be considered unlikely.

- On the basis of frequency of occurrence of isolated and not-isolated scenarios, the expected risk for escalation from this section is very low. The resummation of the risk from lower level (section 1 and section 3) is reported in figure 17.

5.1.3 Risk of escalation

The calculation of iso-damage risk contours of 37.5 kW/m^2 from jet fire is reported in **Attachment 5**. The iso-damage curves are elaborated on the basis of consideration as for chapter 5.1.2. regarding Jet fire location on platform.

The iso-damage contours plots of 37.5 kW/m^2 are calculated as a sum of all the identified scenarios (with adequate time for escalation), each one characterized by its frequency value and damage distances. Calculation of the risk at a specific geographical location for a risk type, 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 platform. The main steps for risk contours calculation are reported below:

- frequency calculation of the hazardous scenario and identification of duration of each scenario;
- calculation of consequence of each scenario (in terms of thermal flux);
- 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.

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 iso-damage contours reports:

- in figure 17 the combination of jet fire in the lower deck (section 1 and 3);
- in figure 18 the combination of jet fire in the upper deck (section 2).
- in Location of the platform that receive a thermal radiation heat flux of 37.5 kW/m2 for at least 10 minutes with likelihood of 1.0E-04 per year or above will be identified as location that require passive fire protection.

Escalation risk from lower deck

In figure 17 (refer to Attachment 5) the combination of jet fire in the lower deck are reported. As for chapter 5.1.1, the risk in this section is mainly due to the isolatable section 1 and 3. The risk values in this area are well below the target frequency of 1.0E-04 per year. The higher value of risk, about 5.0E-07, is located near the isolatable section 3, as expected considering the presence of 3 release hole and damage distance. The escalation risk for main equipment/cabinets are reported in the table below.

Area	Frequency of occurrence (occ/year)
BESS cabinets	5.0E-07
Water treatment package	4.0E-07
B-100 (switch room)	1.3E-07
B-200 (LV switch room)	5.0E-07
B-300 (AC UPS)	5.0E-07
B-400 (I&T room)	5.0E-07
A-8500 PCS container	4.5E-07
Secondary Muster point	3.5E-07

Table 12 – Escalation risk from lower deck

Escalation risk from upper deck

In figure 18 (refer to Attachment 5) the combination of jet fire in the upper deck are reported. As for chapter 5.1.1, the risk in this section is due to the isolatable section 2 (LOC 2.1 and 2.2). For this section, considering the hold up of six storage vessels, both isolated and not-isolated scenarios show jet fire duration higher than 10 minutes; in addition, the number of equipment and piping length determine higher frequency of occurrence of jet fire. Anyway, the risk values in this area are below the target frequency of 1.0E-04 per year. The higher value of risk, about 3.4E-05, is located near the storage vessel, due to the contribution of jet fire from LOC 2.1 and 2.2. In particular, the LOC 2.2 shows the highest jet fire frequency of occurrence and

damage distance compared to other section due to 3inches for full bore rupture and expected ignition probability. The escalation risk for main equipment/cabinets are reported in the table below.

Area	Frequency of occurrence (occ/year)
A-8000 package (Fuel cell)	2.3E-05
A-2000 (electrolyzer package)	1.6E-05
Hydrogen storage vessels	3.4E-05

Table 13 – Escalation risk from upper deck

Regarding the impact on lower deck from jet fire located in upper 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. Anyway, a possible impact on lower deck is still possible if the jet fire duration will be very long. However, the BESS and other package are inside a container, meaning that the escalation, that although possible, should be considered unlikely. In order to assess this scenario, in the figure 18 was elaborated the risk calculation considering, as a conservative approach, the contribution of all jet fire scenarios.

Jet Fire risk inside CPIs

According to CW information [11], a jet fire risk is expected for electrolyzer and fuel cell package, due to random release of H_2 during package operation (on the basis of design of containers, the fire risk is limited to the internal area of the containers). On the basis of expected damage distances and containers dimension, it possible to calculate, with a coarse but conservative assumption, that the fire risk inside the containers is equal to the resummation of jet fire from small, medium and large release (it is assumed that jet fires cover the entire area of the container). The results of resummation are reported below.

Area	Frequency of occurrence (occ/year)
A-2000 electrolyzer package	2.5E-05
A-8000 package (Fuel cell)	1.6E-07

Table 14 – Jet fire risk on CPIs

These values represent the risk from jet fire generated inside the containers. According to acceptability criteria, the risk is below the target threshold of 1.0E-04 occ/year, and the risk is classified as tolerable .

Note that the risk is lower than the target criteria even if is summed the contribution of other isolatable sections on such cabinets (e.g. values on table 13): 4.1E-05 occ/year for electrolyzer package and 2.3E-05 occ/year for Fuel cell..

5.2 RISK FROM VCE

In Attachment 6 are reported the hazard frequency contours of overpressures of 0.35, 0.27, 0.15, and 0.07 bar. The resummation follows same methodology for escalation risk calculation, briefly described below.

The iso-damage contours plots of each threshold are calculated as a sum 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, 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 platform. The main steps for risk contours calculation are reported below:

- frequency calculation of the hazardous scenario;
- calculation of consequence of each scenario (in terms of 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. In terms of risk calculation, the VCE consequences is considered as a circle near the release point. The consequences of explosion are calculated with a congestion factor equal to 7. For explosion calculation, all the scenarios are included in the resummation (are included also scenario with duration lower than 10 minutes). 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).

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. 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.

Detailed calculation of consequences and frequency of occurrence, for each direction, is reported in Attachment 4C. Explosion from CPIs are also included in calculation, as for damage distance and frequency of occurrence of Attachment 4B.

The resummation was elaborated considering the contribution of each section (lower deck and upper deck) for the damage threshold of 0.35 and 0.27 bar due to very severe damage to the mechanical integrity of the whole platform.

For the damage threshold of 0.15 and 0.7 bar, the resummation was performed for separately for lower deck and upper deck, considering than no severe impact is expected to the structural element of the platform

and the presence of plated deck is considered a positive separation for the gas cloud to migrate between the two platform decks.

In the table below is reported the maximum value of risk calculated for the platform, for each threshold.

VCE threshold (bar)	Frequency of occurrence (occ/year)
0.35	6.8E-05
0.27	8.9E-05
0.15 (upper deck)	8.7E-05
0.15 (lower deck)	2.8E-05
0.07 (upper deck)	9.4E-05
0.07 (lower deck)	3.1E-05

Table 15 – VCE escalation risk in the platform

As expected, the decrease of overpressure threshold determines an increase of damage distances of the scenarios, leading to increase of possible overlapping of scenarios and the final frequency of occurrence of exposure in the platform. The risk from electrolyser and BESS package are in the order of 1.0E-05 occ/year, meaning that the explosion risk for such packages is a significant contribution to the total risk.

Anyway, for each threshold there are no areas in the platform in which the overpressure contours are equal or above 1E-04 occ/year; therefore, there are no areas in which the risk is classified as unacceptable.

6 CONCLUSIONS AND RECOMMENDATIONS

6.1 FERA CONCLUSIONS

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

- there are no areas in the platform in which the thermal radiation threshold contours of 37.5 kW/m^2 from jet fire is equal to or above 1.0E-04 per year. The impact of jet fire scenarios on equipment is lower than target frequency and can be classified as tolerable .
- there are no areas in the platform in which the explosion threshold contours of 0.35, 0.27, 0.15 and 0.07 bar are equal to or above 1.0E-04 per year, thus the risk from VCE is considered tolerable .

6.2 RECOMMENDATIONS

On basis of the present FERA study results, only one recommendation has been raised. Its implementation allows a general improvement on project documentation, but no design impact is expected.

Ref. #	Description	Responsible
1	In order to reduce the escalation risk from section 2 (storage section) it is suggest to reduce the total hold up involved in the hazardous scenarios. At the present, all vessels are considered aligned, and in case of release, about 1200 kg are potentially involved in the release. It is recommended to define the logics of line-up and closure of each vessel automatically during normal operation. This action will significantly reduce the total amount of H_2 involved in a critical scenario, leading to the decrease of scenario duration and the risk of escalation.	Rosetti Marino

Table 16 – Recommendations

ATTACHMENT 1

ISOLATABLE SECTIONS ON P&ID

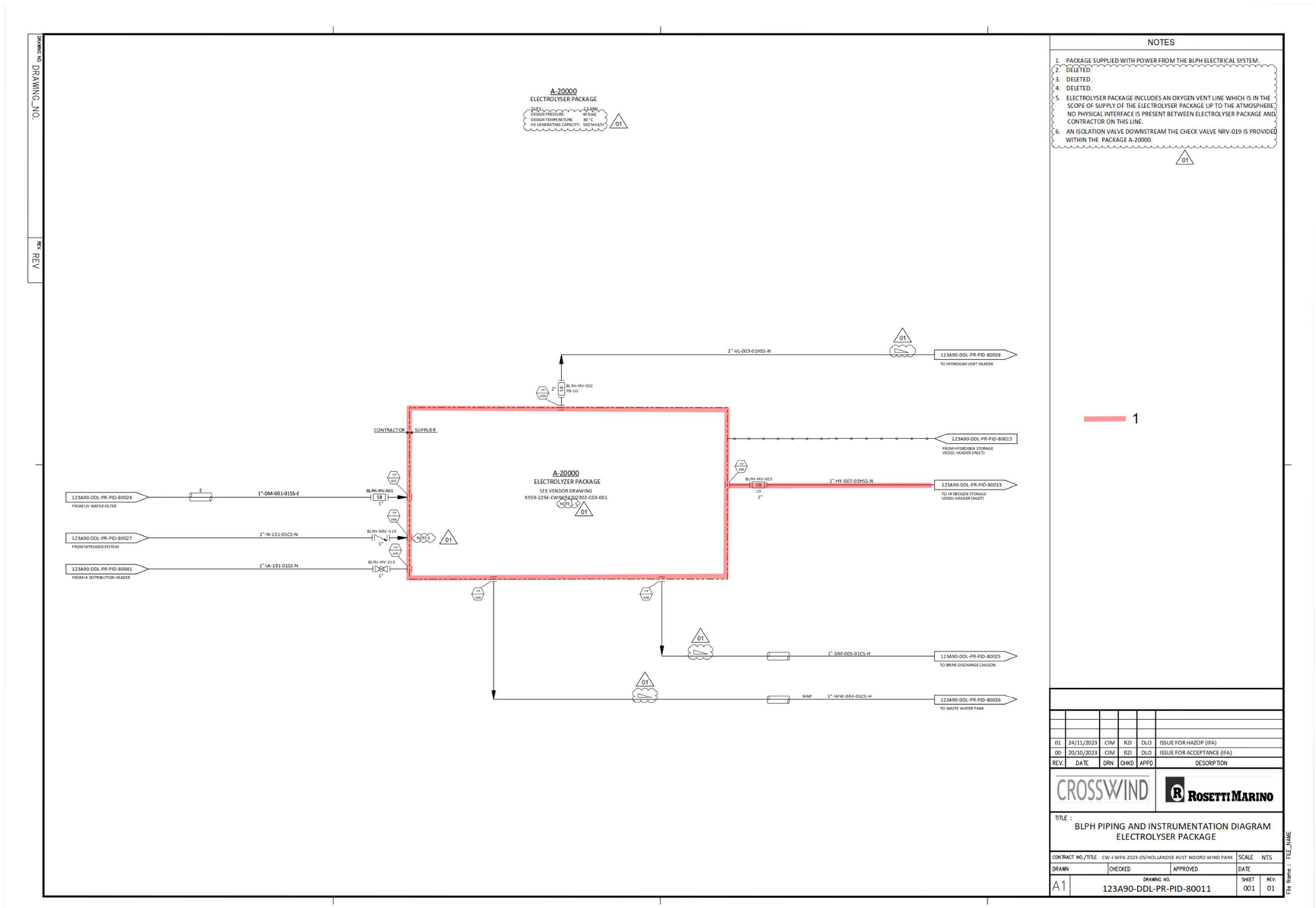


Figure 12 – P&ID isolatable section 1

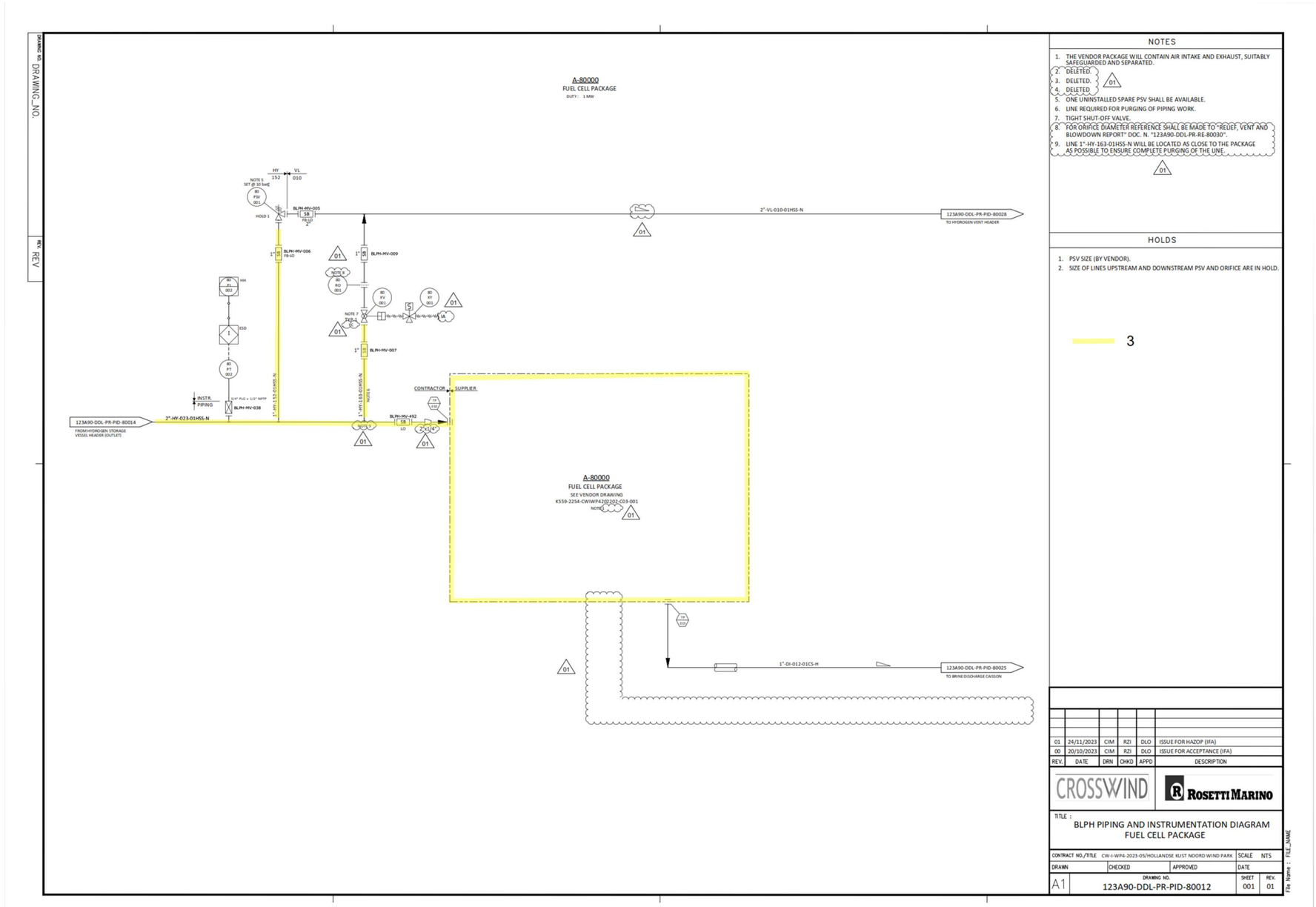


Figure 13 – P&ID isolatable section 3

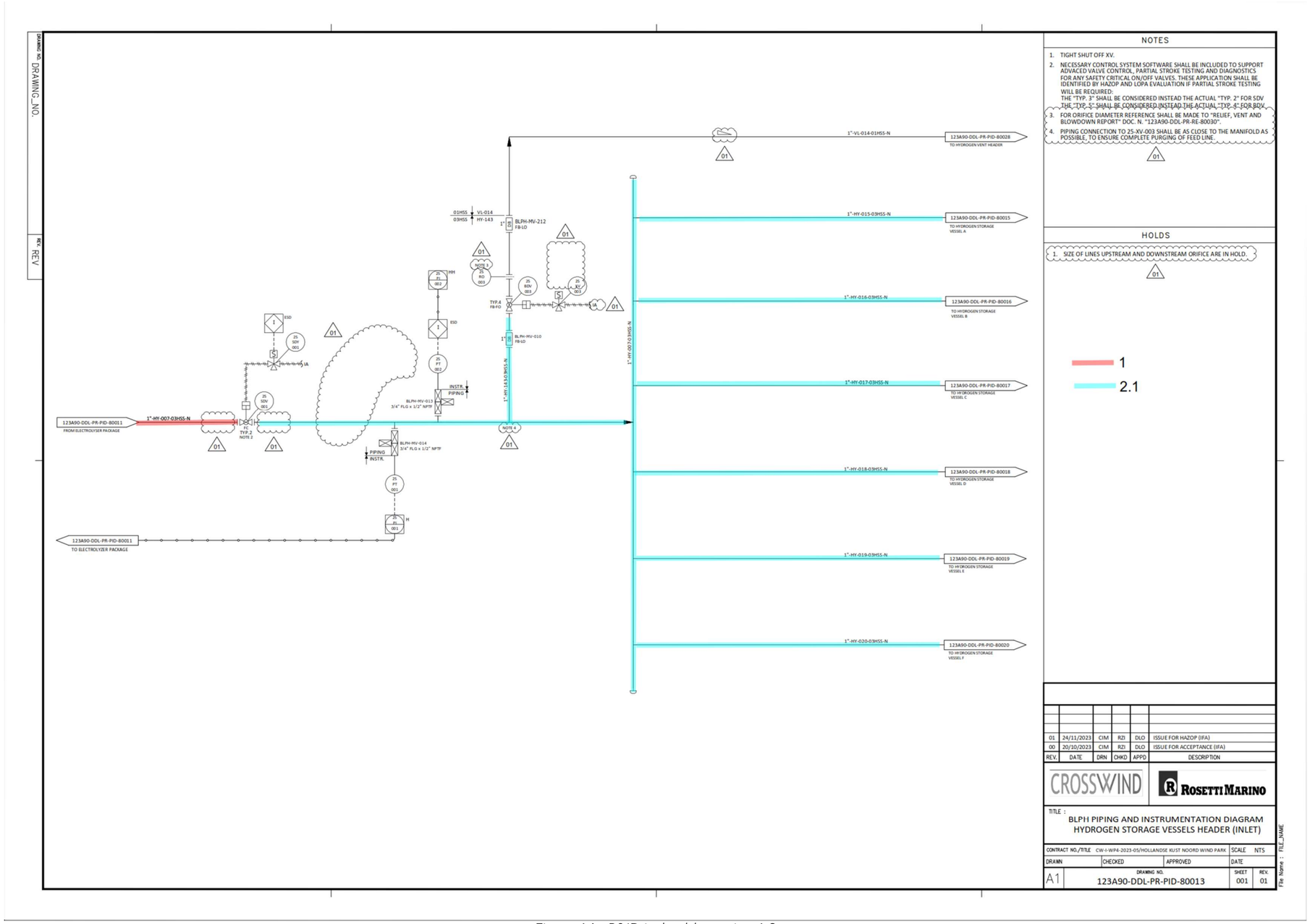


Figure 14 – P&ID isolatable section 1,2

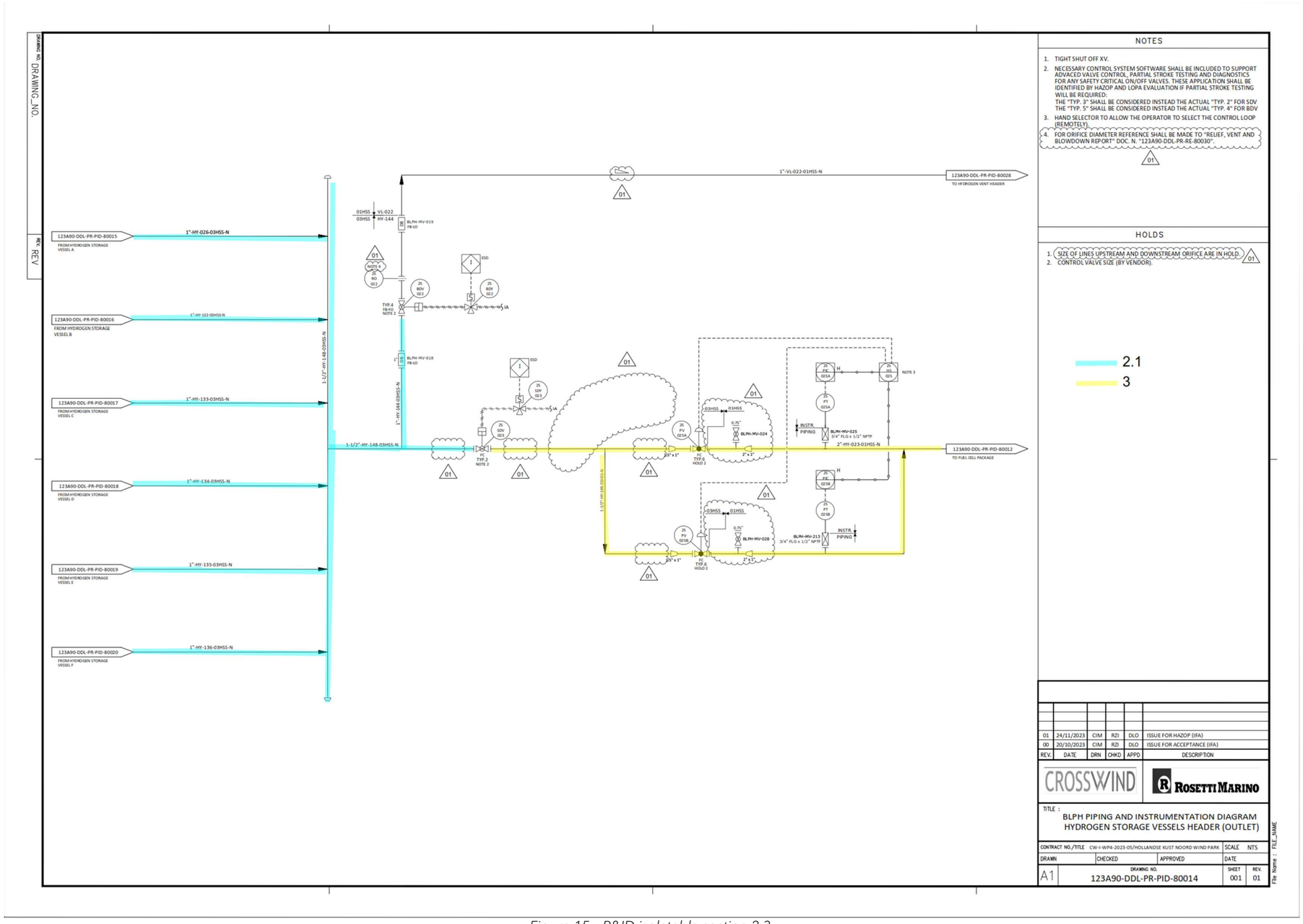


Figure 15 – P&ID isolatable section 2,3

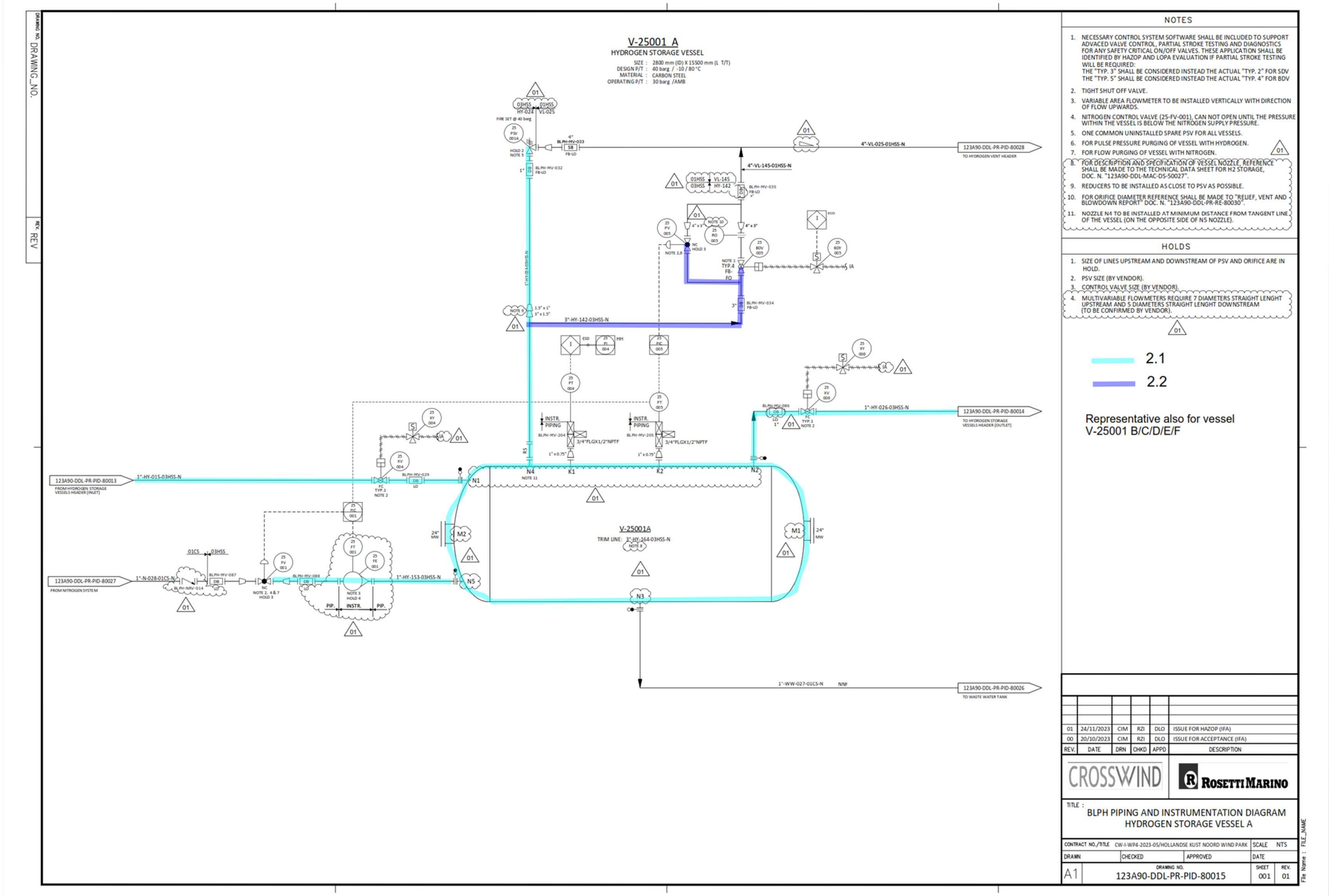


Figure 16 – P&ID isolatable section 2

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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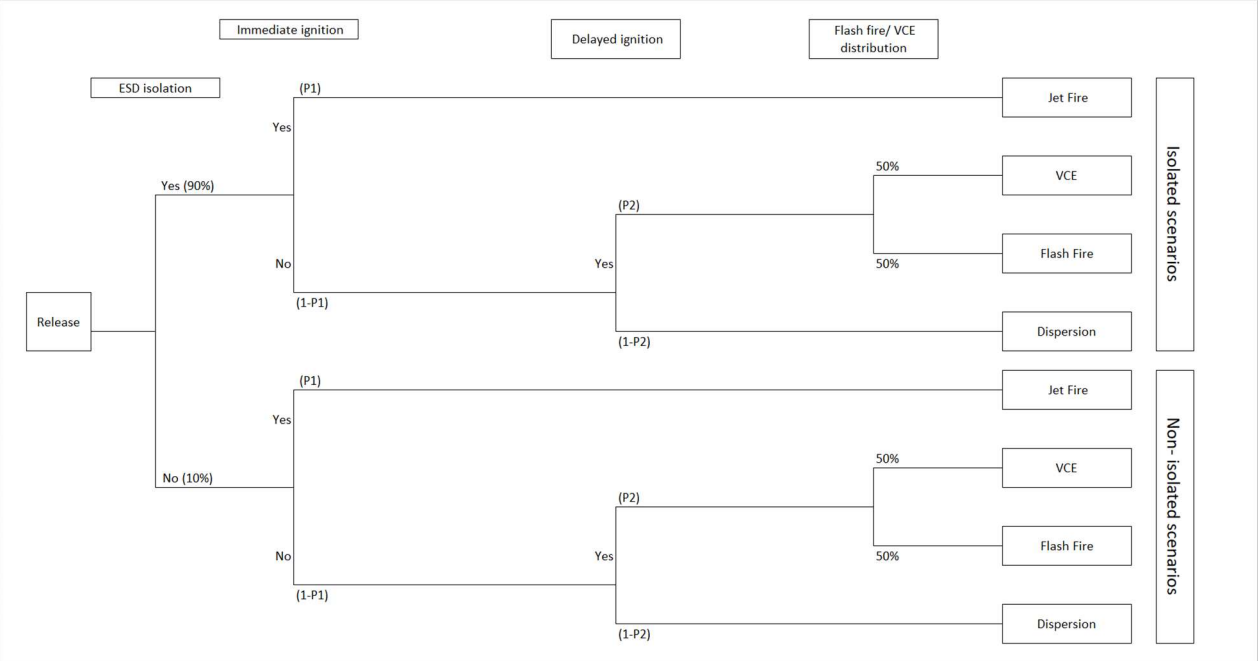
ATTACHMENT 3
EVENT TREE ANALYSIS

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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)



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

Section 1

ESD in operation

Hole size (mm)	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)	Jet fire duration (>10 min)	Probability	Frequency (occ./year)	Probability	Frequency (occ./year)	Probability	Frequency (occ./year)	Probability	Frequency (occ./year)
5	3.0E-04	F2	0.03	7.2E-03	1.3E-07	YES	8.9E-04	1.6E-08	8.9E-04	1.6E-08	8.9E-04	1.6E-08	8.9E-04	1.6E-08
		D5	0.03	7.2E-03	1.1E-06	YES	8.9E-04	1.4E-07	8.9E-04	1.4E-07	8.9E-04	1.4E-07	8.9E-04	1.4E-07
		D10	0.03	7.2E-03	9.6E-07	YES	8.9E-04	1.2E-07	8.9E-04	1.2E-07	8.9E-04	1.2E-07	8.9E-04	1.2E-07
25	1.8E-04	F2	0.76	4.7E-02	5.3E-07	NO	5.7E-03	6.4E-08	5.7E-03	6.4E-08	5.7E-03	6.4E-08	5.7E-03	6.4E-08
		D5	0.76	4.7E-02	4.4E-06	NO	5.7E-03	5.3E-07	5.7E-03	5.3E-07	5.7E-03	5.3E-07	5.7E-03	5.3E-07
		D10	0.76	4.7E-02	3.9E-06	NO	5.7E-03	4.7E-07	5.7E-03	4.7E-07	5.7E-03	4.7E-07	5.7E-03	4.7E-07

Note:
"Probability" column considers the combination of probability for ESD failure and the ignition probability (P1, P2) as for relevant scenario, on the basis of event tree.
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.
Detailed Jet fire duration is reported in the table of consequence evaluation.

ESD failure

Hole size (mm)	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)	Jet fire duration (>10 min)	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-04	1.5E-08	YES	9.9E-05	1.8E-09	9.9E-05	1.8E-09	9.9E-05	1.8E-09	9.9E-05	1.8E-09
		D5	0.03	8.0E-04	1.2E-07	YES	9.9E-05	1.5E-08	9.9E-05	1.5E-08	9.9E-05	1.5E-08	9.9E-05	1.5E-08
		D10	0.03	8.0E-04	1.1E-07	YES	9.9E-05	1.3E-08	9.9E-05	1.3E-08	9.9E-05	1.3E-08	9.9E-05	1.3E-08
25	1.8E-04	F2	0.76	5.3E-03	5.9E-08	YES	6.4E-04	7.1E-09	6.4E-04	7.1E-09	6.4E-04	7.1E-09	6.4E-04	7.1E-09
		D5	0.76	5.3E-03	4.9E-07	YES	6.4E-04	5.9E-08	6.4E-04	5.9E-08	6.4E-04	5.9E-08	6.4E-04	5.9E-08
		D10	0.76	5.3E-03	4.3E-07	YES	6.4E-04	5.2E-08	6.4E-04	5.2E-08	6.4E-04	5.2E-08	6.4E-04	5.2E-08

Jet fire for escalation

In the table below are reported the calculation of frequency of occurrence for jet fire for escalation analysis: only jet fire with duration higher than 10 minutes is required.

Hole size (mm)	Frequency LOC	Weather	Jet Fire(occ./year)		
			Isolated scenario	Not-isolated scenario	Escalation Jet fire
5	3.0E-04	F2	1.3E-07	1.5E-08	**1.4E-07**
		D5	1.1E-06	1.2E-07	**1.2E-06**
		D10	9.6E-07	1.1E-07	**1.0E-06**
25	1.8E-04	F2	Not applicable	5.9E-08	**5.9E-08**
		D5		4.9E-07	**4.9E-07**
		D10		4.3E-07	**4.3E-07**

Section 2 LOC 2.1

ESD in operation

Hole size (mm)	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)	Jet fire duration (>10 min)	Probability	Frequency (occ./year)	Probability	Frequency (occ./year)	Probability	Frequency (occ./year)	Probability	Frequency (occ./year)
5	5.6E-03	F2	0.03	7.2E-03	2.4E-06	YES	8.9E-04	3.0E-07	8.9E-04	3.0E-07	8.9E-04	3.0E-07	8.9E-04	3.0E-07
		D5	0.03	7.2E-03	2.0E-05	YES	8.9E-04	2.5E-06	8.9E-04	2.5E-06	8.9E-04	2.5E-06	8.9E-04	2.5E-06
		D10	0.03	7.2E-03	1.8E-05	YES	8.9E-04	2.2E-06	8.9E-04	2.2E-06	8.9E-04	2.2E-06	8.9E-04	2.2E-06
25	3.3E-03	F2	0.76	4.8E-02	9.4E-06	YES	5.8E-03	1.1E-06	5.8E-03	1.1E-06	5.8E-03	1.1E-06	5.8E-03	1.1E-06
		D5	0.76	4.8E-02	7.9E-05	YES	5.8E-03	9.5E-06	5.8E-03	9.5E-06	5.8E-03	9.5E-06	5.8E-03	9.5E-06
		D10	0.76	4.8E-02	6.9E-05	YES	5.8E-03	8.4E-06	5.8E-03	8.4E-06	5.8E-03	8.4E-06	5.8E-03	8.4E-06
37.5 (1.5 inches)	3.4E-04	F2	1.70	4.8E-02	9.8E-07	YES	5.8E-03	1.2E-07	5.8E-03	1.2E-07	5.8E-03	1.2E-07	5.8E-03	1.2E-07
		D5	1.70	4.8E-02	8.2E-06	YES	5.8E-03	9.8E-07	5.8E-03	9.8E-07	5.8E-03	9.8E-07	5.8E-03	9.8E-07
		D10	1.70	4.8E-02	7.2E-06	YES	5.8E-03	8.7E-07	5.8E-03	8.7E-07	5.8E-03	8.7E-07	5.8E-03	8.7E-07

Note:
"Probability" column considers the combination of probability for ESD failure and the ignition probability (P1, P2) as for relevant scenario, on the basis of event tree.
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.
Detailed Jet fire duration is reported in the table of consequence evaluation.

ESD failure

Hole size (mm)	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)	Jet fire duration (>10 min)	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-04	2.7E-07	YES	9.9E-05	3.4E-08	9.9E-05	3.4E-08	9.9E-05	3.4E-08	9.9E-05	3.4E-08
		D5	0.03	8.0E-04	2.3E-06	YES	9.9E-05	2.8E-07	9.9E-05	2.8E-07	9.9E-05	2.8E-07	9.9E-05	2.8E-07
		D10	0.03	8.0E-04	2.0E-06	YES	9.9E-05	2.5E-07	9.9E-05	2.5E-07	9.9E-05	2.5E-07	9.9E-05	2.5E-07
25	3.3E-03	F2	0.76	5.3E-03	1.0E-06	YES	6.4E-04	1.3E-07	6.4E-04	1.3E-07	6.4E-04	1.3E-07	6.4E-04	1.3E-07
		D5	0.76	5.3E-03	8.7E-06	YES	6.4E-04	1.1E-06	6.4E-04	1.1E-06	6.4E-04	1.1E-06	6.4E-04	1.1E-06
		D10	0.76	5.3E-03	7.7E-06	YES	6.4E-04	9.3E-07	6.4E-04	9.3E-07	6.4E-04	9.3E-07	6.4E-04	9.3E-07
37.5 (1.5 inches)	3.4E-04	F2	1.70	5.3E-03	1.1E-07	YES	6.4E-04	1.3E-08	6.4E-04	1.3E-08	6.4E-04	1.3E-08	6.4E-04	1.3E-08
		D5	1.70	5.3E-03	9.1E-07	YES	6.4E-04	1.1E-07	6.4E-04	1.1E-07	6.4E-04	1.1E-07	6.4E-04	1.1E-07
		D10	1.70	5.3E-03	8.0E-07	YES	6.4E-04	9.6E-08	6.4E-04	9.6E-08	6.4E-04	9.6E-08	6.4E-04	9.6E-08

Jet fire for escalation

In the table below are reported the calculation of frequency of occurrence for jet fire for escalation analysis: only jet fire with duration higher than 10 minutes is required.

Hole size (mm)	Frequency LOC	Weather	Jet Fire		
			Isolated scenario	Not-isolated scenario	Escalation Jet fire
5	5.6E-03	F2	2.4E-06	2.7E-07	**2.7E-06**
		D5	2.0E-05	2.3E-06	**2.2E-05**
		D10	1.8E-05	2.0E-06	**2.0E-05**
25	3.3E-03	F2	9.4E-06	1.0E-06	**1.0E-05**
		D5	7.9E-05	8.7E-06	**8.8E-05**
		D10	6.9E-05	7.7E-06	**7.7E-05**
37.5 (1.5 inches)	3.4E-04	F2	9.8E-07	1.1E-07	**1.1E-06**
		D5	8.2E-06	9.1E-07	**9.1E-06**
		D10	7.2E-06	8.0E-07	**8.0E-06**

Section 2 LOC 2.2

ESD in operation

Hole size (mm)	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)	Jet fire duration (>10 min)	Probability	Frequency (occ./year)	Probability	Frequency (occ./year)	Probability	Frequency (occ./year)	Probability	Frequency (occ./year)
5	1.0E-03	F2	3.0E-02	7.2E-03	4.4E-07	YES	8.9E-04	5.4E-08	8.9E-04	5.4E-08	8.9E-04	5.4E-08	8.9E-04	5.4E-08
		D5	3.0E-02	7.2E-03	3.6E-06	YES	8.9E-04	4.5E-07	8.9E-04	4.5E-07	8.9E-04	4.5E-07	8.9E-04	4.5E-07
		D10	3.0E-02	7.2E-03	3.2E-06	YES	8.9E-04	4.0E-07	8.9E-04	4.0E-07	8.9E-04	4.0E-07	8.9E-04	4.0E-07
25	4.3E-04	F2	7.6E-01	4.8E-02	1.2E-06	YES	5.8E-03	1.5E-07	5.8E-03	1.5E-07	5.8E-03	1.5E-07	5.8E-03	1.5E-07
		D5	7.6E-01	4.8E-02	1.0E-05	YES	5.8E-03	1.2E-06	5.8E-03	1.2E-06	5.8E-03	1.2E-06	5.8E-03	1.2E-06
		D10	7.6E-01	4.8E-02	9.1E-06	YES	5.8E-03	1.1E-06	5.8E-03	1.1E-06	5.8E-03	1.1E-06	5.8E-03	1.1E-06
75 (3 inches)	1.7E-04	F2	7.1E+00	2.1E-01	2.0E-06	YES	2.1E-02	2.1E-07	2.1E-02	2.1E-07	2.1E-02	2.1E-07	2.1E-02	2.1E-07
		D5	7.1E+00	2.1E-01	1.7E-05	YES	2.1E-02	1.7E-06	2.1E-02	1.7E-06	2.1E-02	1.7E-06	2.1E-02	1.7E-06
		D10	7.1E+00	2.1E-01	1.5E-05	YES	2.1E-02	1.5E-06	2.1E-02	1.5E-06	2.1E-02	1.5E-06	2.1E-02	1.5E-06

Note:
"Probability" column considers the combination of probability for ESD failure and the ignition probability (P1, P2) as for relevant scenario, on the basis of event tree.
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.
Detailed Jet fire duration is reported in the table of consequence evaluation.

ESD failure

Hole size (mm)	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)	Jet fire duration (>10 min)	Probability	Frequency (occ./year)	Probability	Frequency (occ./year)	Probability	Frequency (occ./year)	Probability	Frequency (occ./year)
5	1.0E-03	F2	3.0E-02	8.0E-04	4.8E-08	YES	9.9E-05	6.0E-09	9.9E-05	6.0E-09	9.9E-05	6.0E-09	9.9E-05	6.0E-09
		D5	3.0E-02	8.0E-04	4.0E-07	YES	9.9E-05	5.0E-08	9.9E-05	5.0E-08	9.9E-05	5.0E-08	9.9E-05	5.0E-08
		D10	3.0E-02	8.0E-04	3.6E-07	YES	9.9E-05	4.4E-08	9.9E-05	4.4E-08	9.9E-05	4.4E-08	9.9E-05	4.4E-08
25	4.3E-04	F2	7.6E-01	5.3E-03	1.4E-07	YES	6.4E-04	1.7E-08	6.4E-04	1.7E-08	6.4E-04	1.7E-08	6.4E-04	1.7E-08
		D5	7.6E-01	5.3E-03	1.2E-06	YES	6.4E-04	1.4E-07	6.4E-04	1.4E-07	6.4E-04	1.4E-07	6.4E-04	1.4E-07
		D10	7.6E-01	5.3E-03	1.0E-06	YES	6.4E-04	1.2E-07	6.4E-04	1.2E-07	6.4E-04	1.2E-07	6.4E-04	1.2E-07
75 (3 inches)	1.7E-04	F2	7.1E+00	2.3E-02	2.3E-07	YES	2.3E-03	2.3E-08	2.3E-03	2.3E-08	2.3E-03	2.3E-08	2.3E-03	2.3E-08
		D5	7.1E+00	2.3E-02	1.9E-06	YES	2.3E-03	1.9E-07	2.3E-03	1.9E-07	2.3E-03	1.9E-07	2.3E-03	1.9E-07
		D10	7.1E+00	2.3E-02	1.7E-06	YES	2.3E-03	1.7E-07	2.3E-03	1.7E-07	2.3E-03	1.7E-07	2.3E-03	1.7E-07

Jet fire for escalation

In the table below are reported the calculation of frequency of occurrence for jet fire for escalation analysis: only jet fire with duration higher than 10 minutes is required.

Hole size (mm)	Frequency LOC	Weather	Jet Fire		
			Isolated scenario	Not-isolated scenario	Escalation Jet fire
5	1.0E-03	F2	4.4E-07	4.8E-08	**4.9E-07**
		D5	3.6E-06	4.0E-07	**4.0E-06**
		D10	3.2E-06	3.6E-07	**3.6E-06**
25	4.3E-04	F2	1.2E-06	1.4E-07	**1.3E-06**
		D5	1.0E-05	1.2E-06	**1.1E-05**
		D10	9.1E-06	1.0E-06	**1.0E-05**
75 (3 inches)	1.7E-04	F2	2.0E-06	2.3E-07	**2.2E-06**
		D5	1.7E-05	1.9E-06	**1.9E-05**
		D10	1.5E-05	1.7E-06	**1.7E-05**

Section 3

ESD in operation

Hole size (mm)	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)	Jet fire duration (>10 min)	Probability	Frequency (occ./year)	Probability	Frequency (occ./year)	Probability	Frequency (occ./year)	Probability	Frequency (occ./year)
5	9.3E-04	F2	0.03	7.2E-03	4.0E-07	YES	8.9E-04	5.0E-08	8.9E-04	5.0E-08	8.9E-04	5.0E-08	8.9E-04	5.0E-08
		D5	0.03	7.2E-03	3.3E-06	YES	8.9E-04	4.2E-07	8.9E-04	4.2E-07	8.9E-04	4.2E-07	8.9E-04	4.2E-07
		D10	0.03	7.2E-03	2.9E-06	YES	8.9E-04	3.7E-07	8.9E-04	3.7E-07	8.9E-04	3.7E-07	8.9E-04	3.7E-07
25	5.0E-04	F2	0.80	4.8E-02	1.4E-06	NO	5.8E-03	1.7E-07	5.8E-03	1.7E-07	5.8E-03	1.7E-07	5.8E-03	1.7E-07
		D5	0.80	4.8E-02	1.2E-05	NO	5.8E-03	1.5E-06	5.8E-03	1.5E-06	5.8E-03	1.5E-06	5.8E-03	1.5E-06
		D10	0.80	4.8E-02	1.1E-05	NO	5.8E-03	1.3E-06	5.8E-03	1.3E-06	5.8E-03	1.3E-06	5.8E-03	1.3E-06
50 (2 inches)	4.1E-05	F2	3.2	4.8E-02	1.2E-07	NO	5.8E-03	1.4E-08	5.8E-03	1.4E-08	5.8E-03	1.4E-08	5.8E-03	1.4E-08
		D5	3.2	4.8E-02	9.8E-07	NO	5.8E-03	1.2E-07	5.8E-03	1.2E-07	5.8E-03	1.2E-07	5.8E-03	1.2E-07
		D10	3.2	4.8E-02	8.7E-07	NO	5.8E-03	1.0E-07	5.8E-03	1.0E-07	5.8E-03	1.0E-07	5.8E-03	1.0E-07

Note:
"Probability" column considers the combination of probability for ESD failure and the ignition probability (P1, P2) as for relevant scenario, on the basis of event tree.
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.
Detailed Jet fire duration is reported in the table of consequence evaluation.

ESD failure

Hole size (mm)	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)	Jet fire duration (>10 min)	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-04	4.5E-08	YES	9.9E-05	5.5E-09	9.9E-05	5.5E-09	9.9E-05	5.5E-09	9.9E-05	5.5E-09
		D5	0.03	8.0E-04	3.7E-07	YES	9.9E-05	4.6E-08	9.9E-05	4.6E-08	9.9E-05	4.6E-08	9.9E-05	4.6E-08
		D10	0.03	8.0E-04	3.3E-07	YES	9.9E-05	4.1E-08	9.9E-05	4.1E-08	9.9E-05	4.1E-08	9.9E-05	4.1E-08
25	5.0E-04	F2	0.80	5.3E-03	1.6E-07	YES	6.4E-04	1.9E-08	6.4E-04	1.9E-08	6.4E-04	1.9E-08	6.4E-04	1.9E-08
		D5	0.80	5.3E-03	1.3E-06	YES	6.4E-04	1.6E-07	6.4E-04	1.6E-07	6.4E-04	1.6E-07	6.4E-04	1.6E-07
		D10	0.80	5.3E-03	1.2E-06	YES	6.4E-04	1.4E-07	6.4E-04	1.4E-07	6.4E-04	1.4E-07	6.4E-04	1.4E-07
50 (2 inches)	4.1E-05	F2	3.2	5.3E-03	1.3E-08	YES	6.4E-04	1.6E-09	6.4E-04	1.6E-09	6.4E-04	1.6E-09	6.4E-04	1.6E-09
		D5	3.2	5.3E-03	1.1E-07	YES	6.4E-04	1.3E-08	6.4E-04	1.3E-08	6.4E-04	1.3E-08	6.4E-04	1.3E-08
		D10	3.2	5.3E-03	9.6E-08	YES	6.4E-04	1.2E-08	6.4E-04	1.2E-08	6.4E-04	1.2E-08	6.4E-04	1.2E-08

Jet fire for escalation

In the table below are reported the calculation of frequency of occurrence for jet fire for escalation analysis: only jet fire with duration higher than 10 minutes is required.

Hole size (mm)	Frequency LOC	Weather	Jet Fire		
			Isolated scenario	Not-isolated scenario	Escalation Jet fire
5	9.3E-04	F2	4.0E-07	4.5E-08	**4.5E-07**
		D5	3.3E-06	3.7E-07	**3.7E-06**
		D10	2.9E-06	3.3E-07	**3.2E-06**
25	5.0E-04	F2	Not Applicable	1.6E-07	**1.6E-07**
		D5		1.3E-06	**1.3E-06**
		D10		1.2E-06	**1.2E-06**
50 (2 inches)	4.1E-05	F2		1.3E-08	**1.3E-08**
		D5		1.1E-07	**1.1E-07**
		D10		9.6E-08	**9.6E-08**

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)						
						Jet Length (m)	100 kW/m2	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	615	3.5	3.4	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	3.5	3.4	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	3.5	3.4	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	15.3	14.5	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	15.3	14.5	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	15.3	14.5	16.6	20.5	27.0	32.5	59.0	0.95	9.7	12.0	13.5	14.5	21.5	49.5

Note: release time is referred to isolated cases.
The damage distances for VCE scenarios are calculated considering the involvement of all released mass in the explosion. For FERA 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

Note: The damage distances for VCE scenarios are calculated considering the involvement of all released mass in the explosion. For FERA 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)	100 kW/m2	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	3.4	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	3.4	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	3.4	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	14.5	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	14.5	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	14.5	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	20.8	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	20.8	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	20.8	24.0	30.0	39.5	49.5	79.5	3.0	14.5	18.0	20.0	21.5	32.0	58.0

Note: release time is referred to isolated cases.
The damage distances for VCE scenarios are calculated considering the involvement of all released mass in the explosion. For FERA 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

Note: The damage distances for VCE scenarios are calculated considering the involvement of all released mass in the explosion. For FERA 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)	100 kW/m2	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	3.4	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	3.4	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	3.4	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	14.5	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	14.5	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	14.5	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	39.0	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	39.0	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	39.0	45.5	57.5	76.5	88.0	123.0	20.2	27.0	34.0	37.5	40.0	60.0	110.0

Note: release time is referred to isolated cases.
The damage distances for VCE scenarios are calculated considering the involvement of all released mass in the explosion. For FERA 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

Note: The damage distances for VCE scenarios are calculated considering the involvement of all released mass in the explosion. For FERA 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)	100 kW/m2	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	3.5	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	3.5	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	3.5	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	15.0	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	15.0	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	15.0	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	27.8	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	27.8	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	27.8	32.5	40.5	53.5	67.0	99.0	7.5	19.0	24.0	26.0	28.0	42.0	78.0

Note: release time is referred to isolated cases.
The damage distances for VCE scenarios are calculated considering the involvement of all released mass in the explosion. For FERA 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

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

Mass flow rate at different time

In the following table the release flow rate at different time is reported (considering the ESD intervention and the hold-up available in the isolatable section).

LOC cases		Release hole	Release flow rate (kg/s)		
			t=0 sec	t=10 min	Note
1.1	Release from electrolyser outlet piping to storage section	5mm	0.03	0.03	
		25mm/ Full bore	0.76	Not applicable	
2.1	Release from storage connection piping (1.5 inches)	5mm	0.03	0.03	
		25mm	0.76	0.6	
		Full bore (1.5 inches)	1.7	0.7	
2.2	Release from BDV connecting piping on top of storage vessel (3 inches)	5mm	0.03	0.03	
		25mm	0.76	0.6	
		Full bore (3 inches)	7.06	0.24	
3.1	Release from vessels outlet piping to fuel cell package	5mm	0.03	0.03	
		25mm	0.80	Not applicable	
		Full bore (2 inches)	3.2	Not applicable	

Note:
For 5 mm cases, considering that the detection and isolation time is equal to 10 minutes, it is assumed that from t= 0 up to t=10 min, the flow rate is the same. After the isolation, considering that the hold up of piping is negligible for isolatable section 1 and 3, the release flow rate decreases rapidly, in the order of some seconds (refer to above tables regarding duration of jet fires), meaning that the release rate at 10 minutes from these holes are not applicable for 25 and FB cases. Instead, for isolatable section 2, considering the hold up of six vessels, the release duration is more than 10 minutes for each hole and a flow rate is reported in the table. As for the table, there are lower flow rates compared to the initial flow rates, meaning that the risk calculated is very conservative (resummation of scenarios with consequences calculated at t=0).

In case of not isolated scenario, it is assumed the same release flow rate as initial time (t=0).

ATTACHMENT 4 B

LOCS AND SCENARIOS (CPIs PACKAGE)

Electrolyser

Random release

Release hole	Jet Fire scenario (m)				VCE Scenario (m)				
	Frequency of occurrence	37.5 kW/m2	12.5 kW/m2	4.73 kW/m2	Frequency of occurrence	0.35 bar	0.27 bar	0.15 bar	0.07 bar
Small	4.8E-07	3.6	4.4	5.5	2.4E-07	12	15	23	41
Medium	1.1E-05	16.6	20.5	27.0	5.5E-06	12	15	23	41
Large	1.4E-05	16.6	20.5	27.0	7.6E-06	15	19	28	51

Note: According to documentation [11] Jet fire damage distances is assumed equal to jet fire consequences of section 1 (Electrolyser).

Internal explosion

Internal explosion Scenario (m)				
Frequency of occurrence	0.35 bar	0.27 bar	0.15 bar	0.07 bar
1.0E-05	13	16	25	55

Fuel cell

Random release

Release hole	Jet Fire scenario (m)				VCE Scenario (m)				
	Frequency of occurrence	37.5 kW/m2	12.5 kW/m2	4.73 kW/m2	Frequency of occurrence	0.35 bar	0.27 bar	0.15 bar	0.07 bar
Small	4.8E-09	3.8	4.5	5.7	2.4E-09	12	15	23	41
Medium	2.0E-07	17.5	21.5	28.0	1.0E-07	12	15	23	41
Large	2.8E-07	32.5	40.5	53.5	1.4E-07	15	19	28	51

Note: According to documentation [11] Jet fire damage distances is assumed equal to section 3 (Fuel cell)

BESS

BESS TR explosion Scenario (m)				
Frequency of occurrence	0.35 bar	0.27 bar	0.15 bar	0.07 bar
1.0E-05	5.2	6.9	13	28

ATTACHMENT 4 C
DETAILED ANALYSIS OF EXPLOSION SCENARIOS WITHIN PLATFORM BOUNDARY

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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 5.1.2, 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 5.1.2, 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 5.1.2, 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 5.1.2, 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 5.1.2, 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 5.1.2, 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 5.1.2, 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 5.1.2, 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 5.1.2, 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 5.1.2, 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 5.1.2, 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 5.1.2, 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 5.1.2, 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 5.1.2, 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 5.1.2, 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 5.1.2, where the release point is reported in the layout.

ATTACHMENT 5

FERA: JET FIRE ENVELOPE

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37.5 kW/m² from Jet fire (>10 minutes) lower floor



Figure 17 – 37.5 kW/m² from Jet fire (>10 minutes) lower floor iso-damage contour

37,5 kW/m² from Jet fire (>10 minutes) upper floor

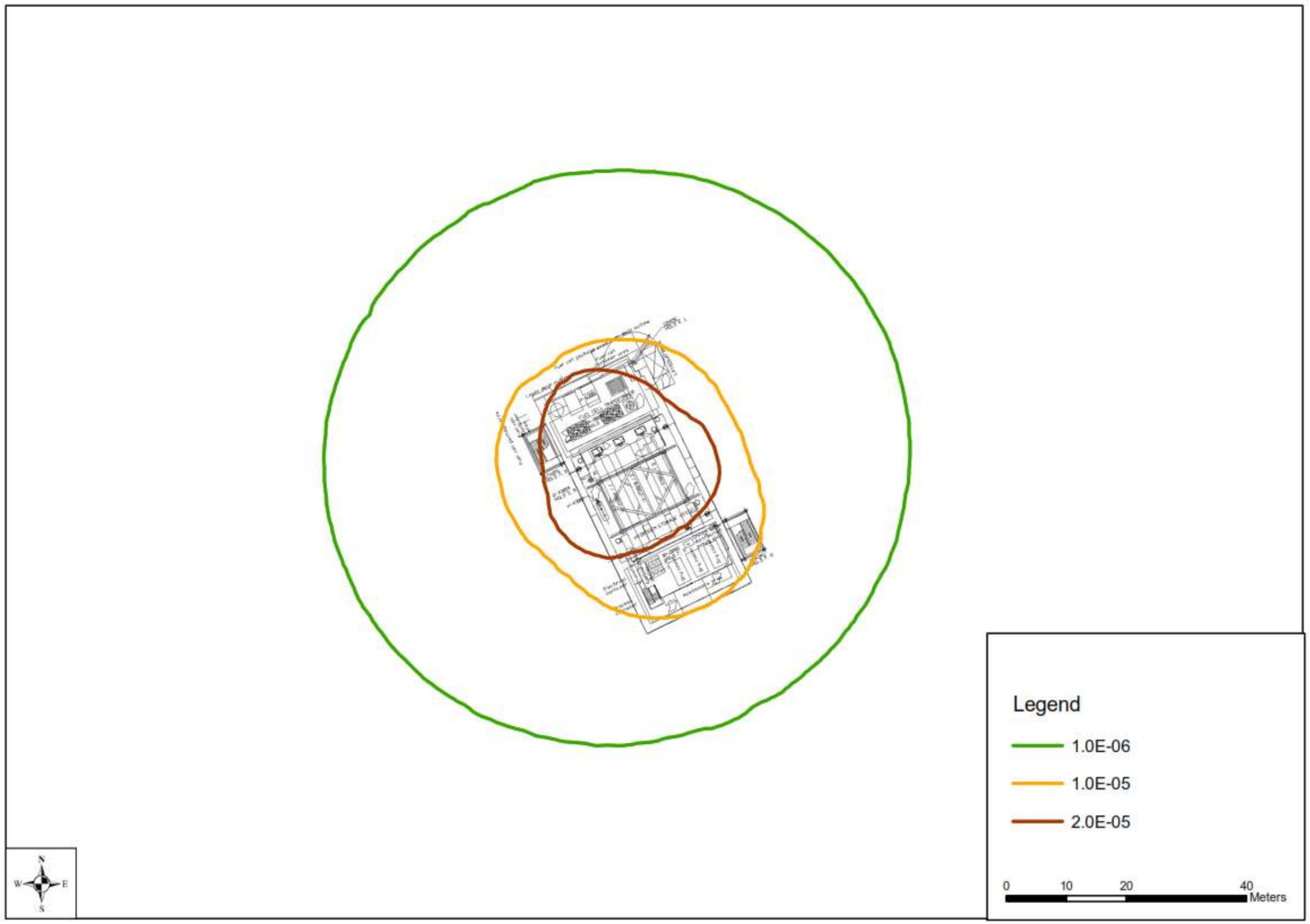


Figure 18 – 37.5 kW/m² from Jet fire (>10 minutes) upper floor iso-damage contour

ATTACHMENT 6

FERA: VCE ENVELOPE

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0.35 bar overpressure iso-damage contour



Figure 19 – 0.35 bar overpressure iso-damage contour

0.27 bar overpressure iso-damage contour



Figure 20 – 0.27 bar overpressure iso-damage contour

0.15 bar overpressure iso-damage contour: upper deck

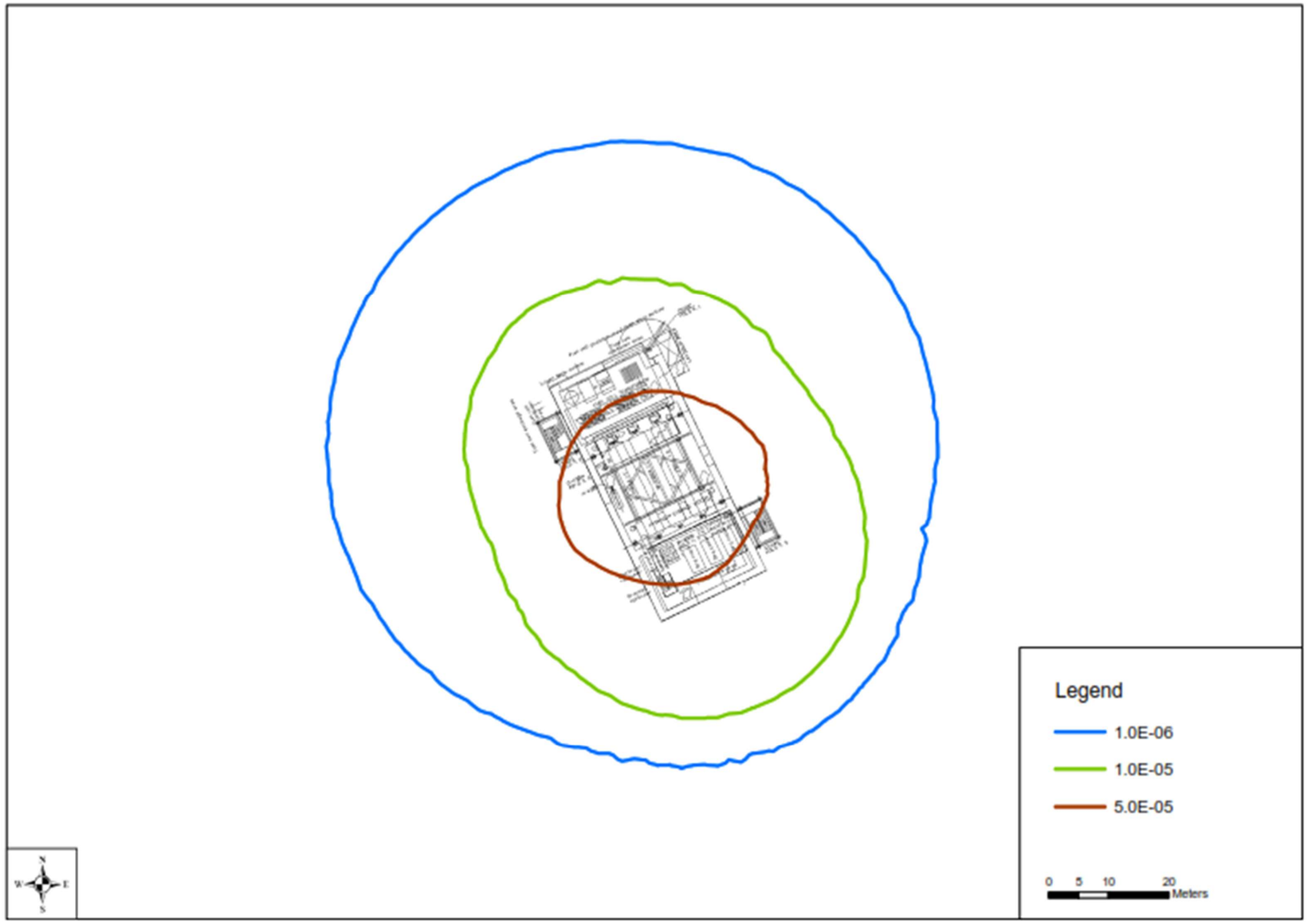


Figure 21 – 0.15 bar overpressure iso-damage contour (upper deck)

0.15 bar overpressure iso-damage contour: lower deck

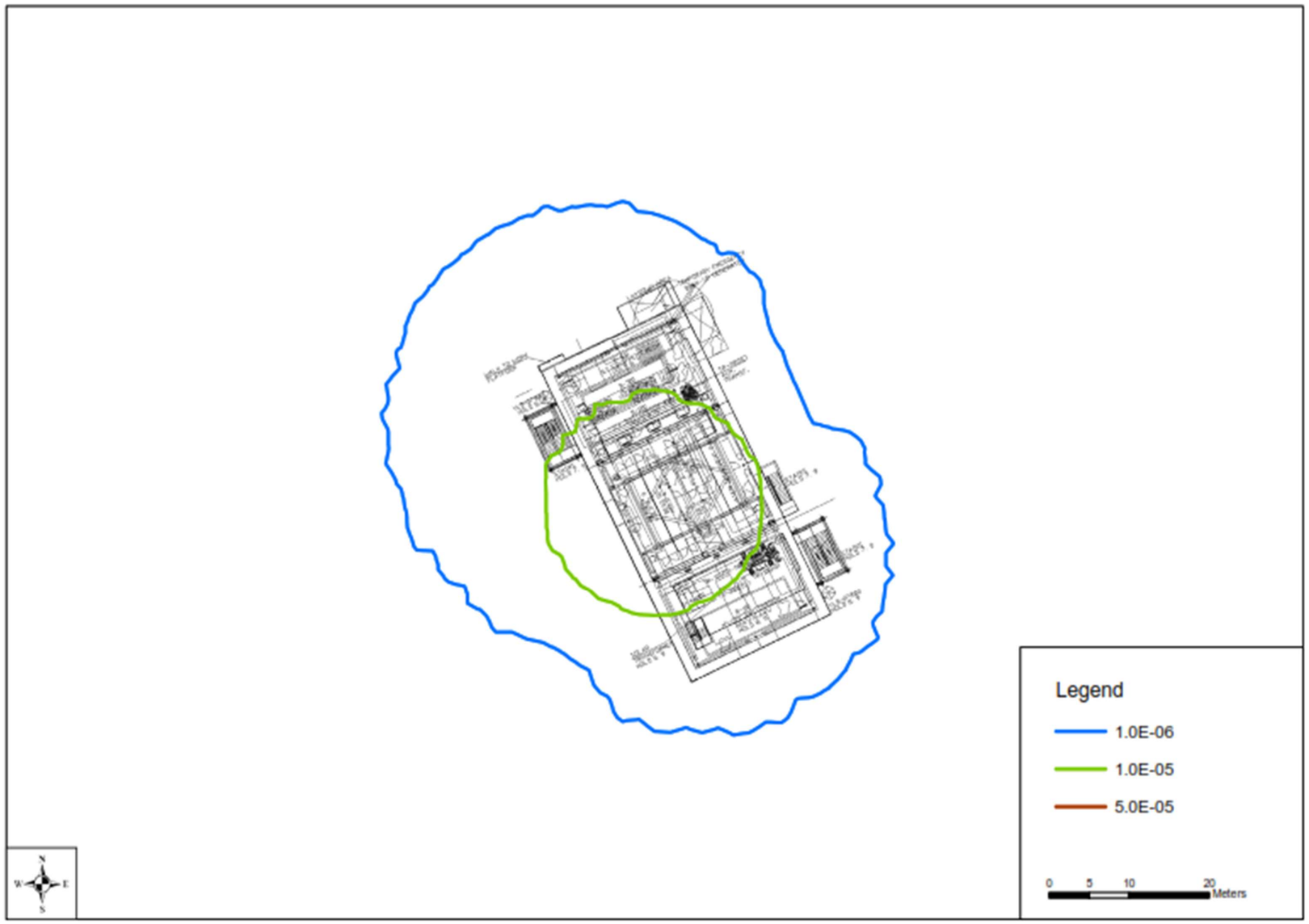


Figure 22 – 0.15 bar overpressure iso-damage contour (lower deck)

0.07 bar overpressure iso-damage contour: upper deck

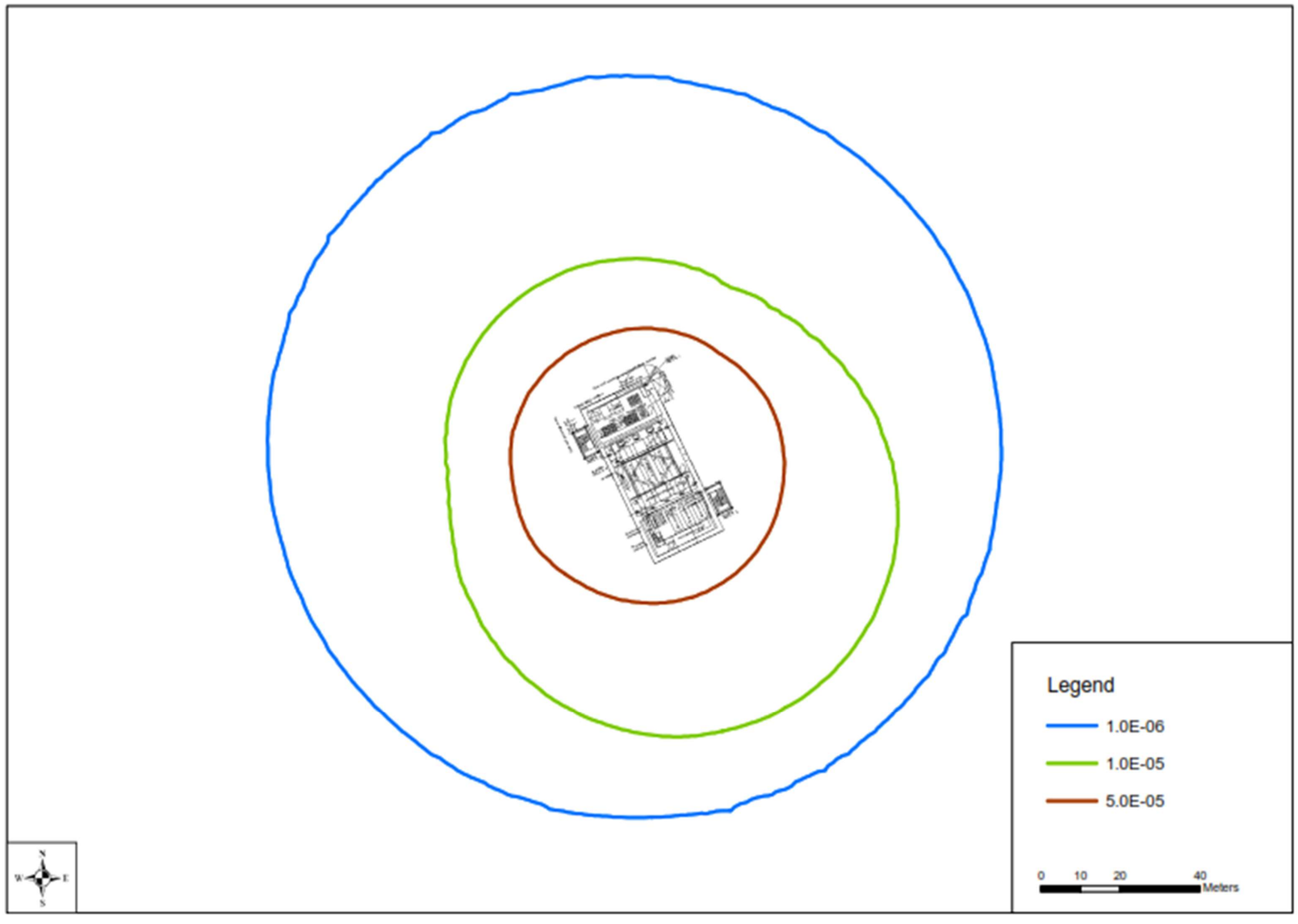


Figure 23 – 0.07 bar overpressure iso-damage contour (upper deck)

0.07 bar overpressure iso-damage contour: lower deck

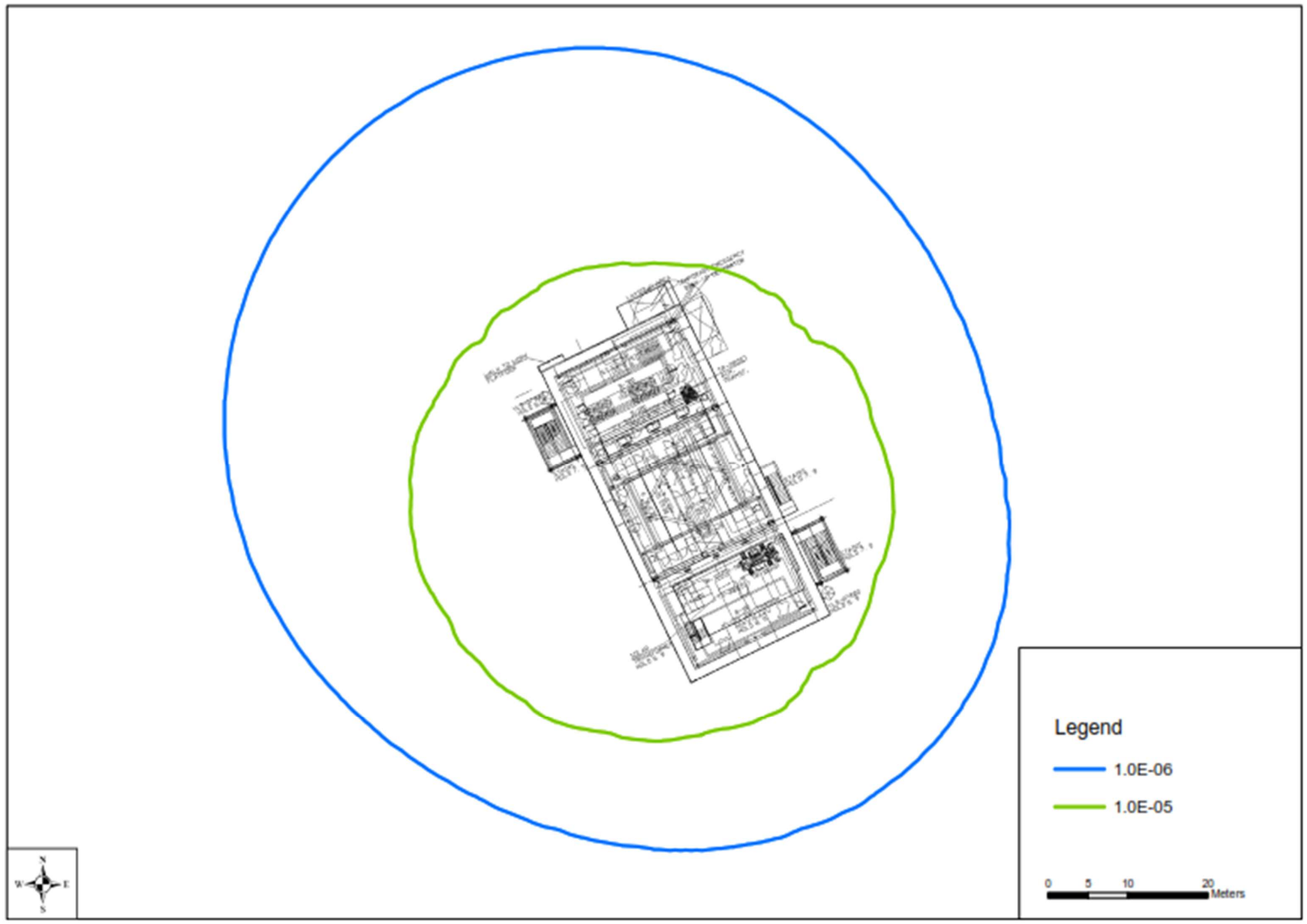


Figure 24 – 0.07 bar overpressure iso-damage contour (lower deck)

ATTACHMENT 7

FERA: 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

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 Desing 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

Table 17 - 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.

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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

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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

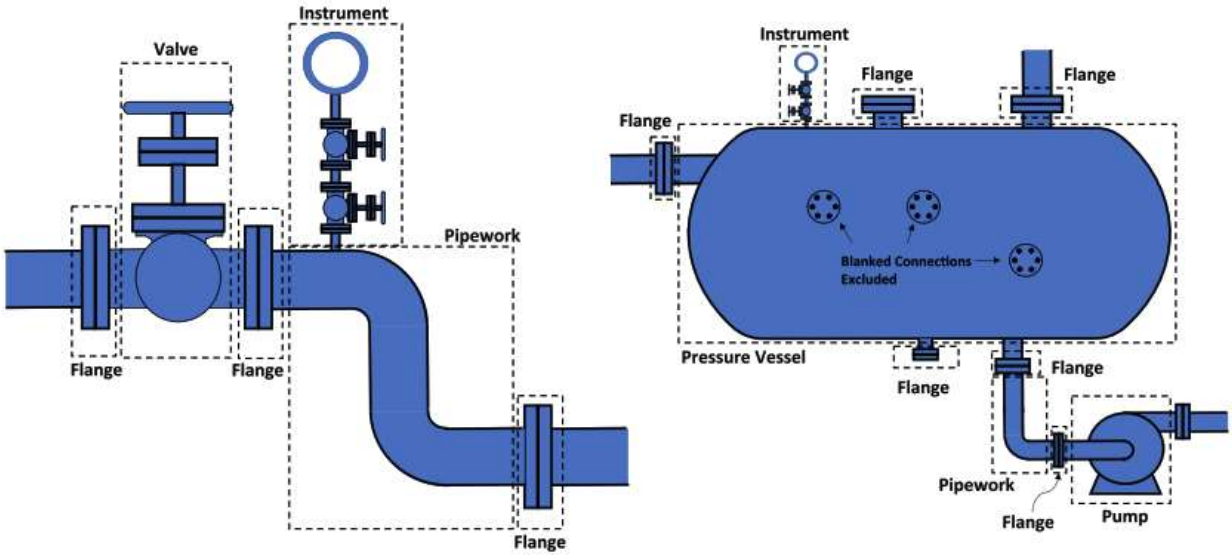
Same approach will be followed for other equipment (e.g valves, flanges..).

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.

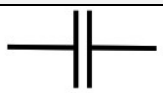
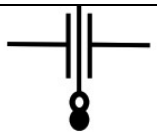
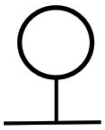
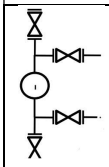
Symbol	Equipment	Part count
	Flange Joint	One flange of the appropriate line size
	Open Spectacle Plate	Two flanges of the appropriate line size
	Any type of valve (including check or non-return valves)	Two flanges and one valve of the appropriate type (actuated / manual) and size
	Instrument	One instrument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

Table 23 – Assumption #3

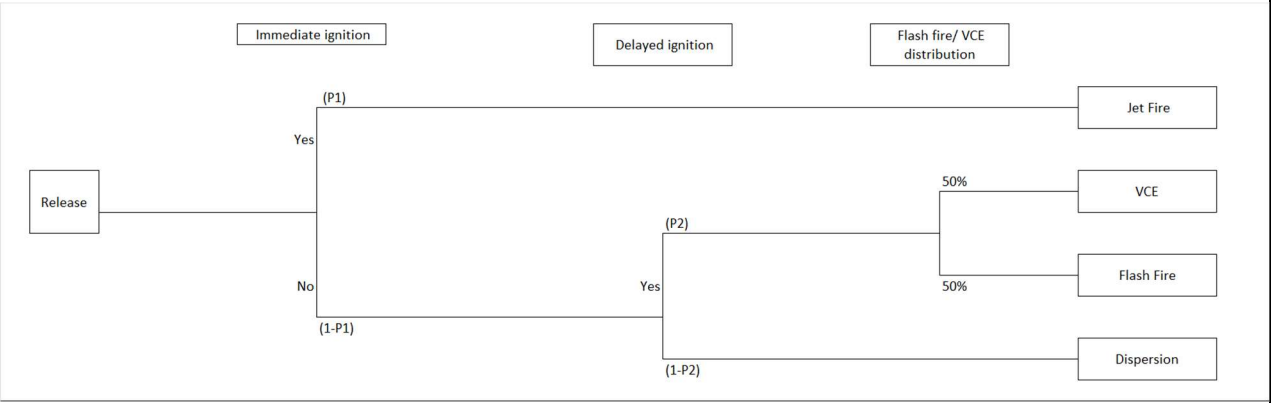
Study:	QRA, FERA		
Subject:	Scenario frequency calculation: event tree analysis		
Assumption #	4	Rev.	1
Reference:	3, 17, 29,30		

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

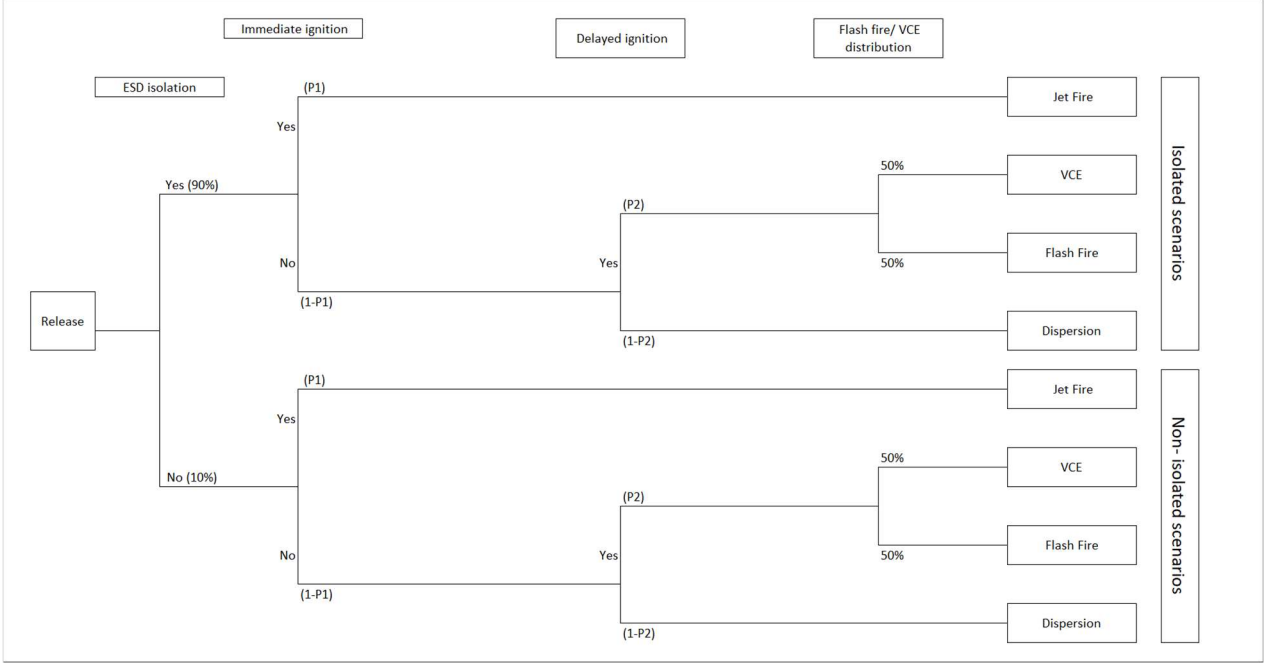
According to the above table, the selected confinement grade is considered equal to 7 (conservative value).

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:

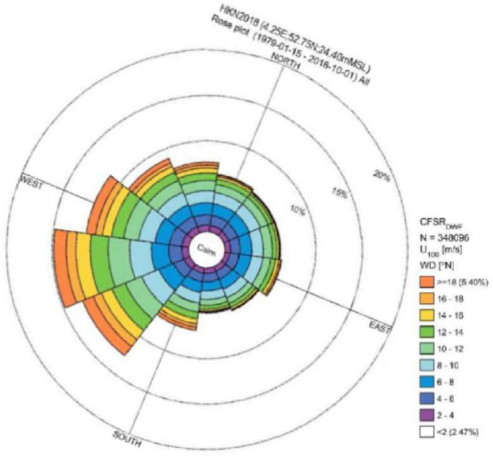
The values for vulnerability to explosion for asset and structure are reported in the tables below.

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

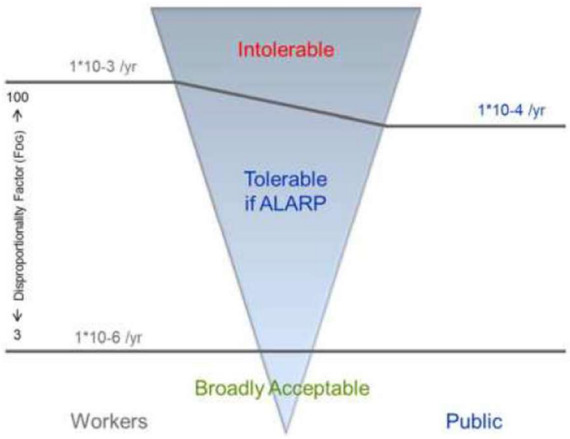
The Location Specific Individual Risk (LSIR) is the expected frequency of death of a hypothetical person assumed to be continuously present at a specific location. It is usually expressed as a risk of death per year and presented in form of risk contours. The risk exposure is calculated for all identified 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 fire2 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.

[2] 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