1 PROJECT DESCRIPTION

According to the available information, Diamond Gas International intends to develop a FSRU based LNG import terminal at Port Qasim. The terminal will receive, re-gasify and transport re-gasified LNG (i.e. natural gas) via pipeline to a delivery point onshore.

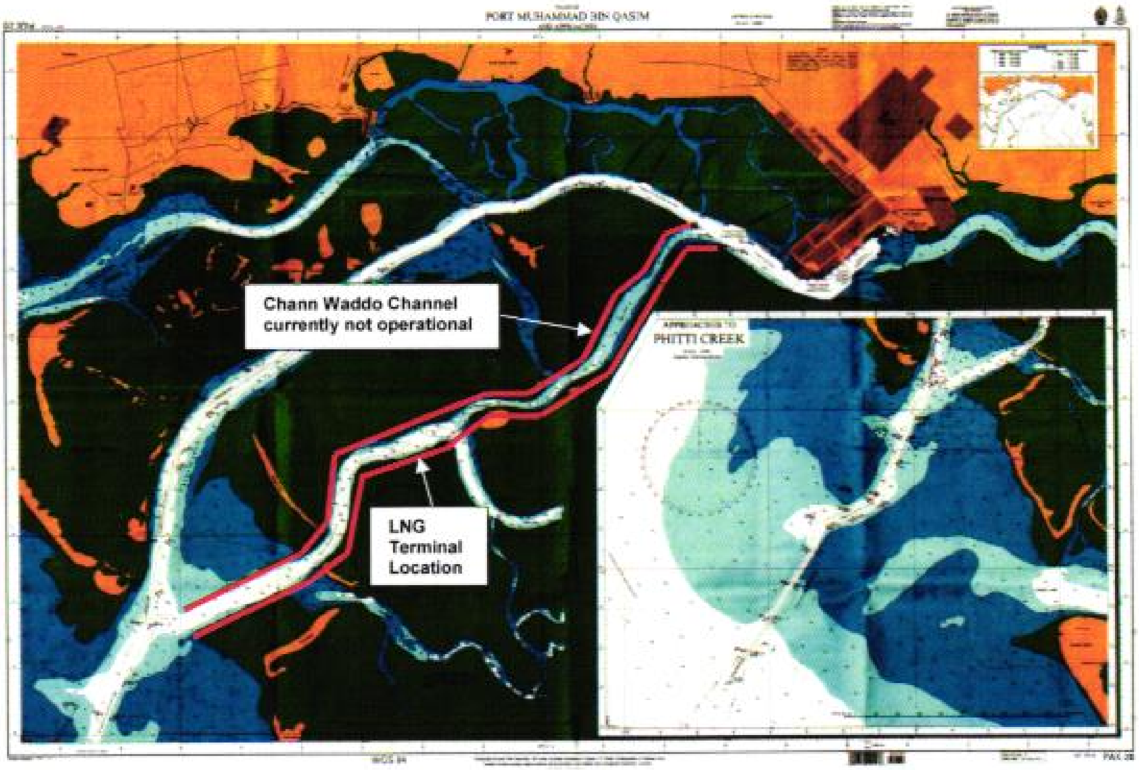

Figure 1.1: Port Qasim LNG Terminal Site

The LNG import terminal will be located at Port Qasim, in Chann Waddo Channel that currently is not in operation. Presently, the LNG carrier traffic is fully managed through the Main Channel for both entrance and exit manoeuvers due to the fact that it is the only one in operation.

2 SCOPE OF THE DOCUMENT

The scope of the present document is to represent the all the necessary inputs, assumptions and data that will be used for the development of the present project.

In the subsequent sections of this document the followings are described:

- ✓ Quantative Risk Analysis (QRA):
  - Main Assumptions and Methodologies;
- ✓ Navigation Study
  - Review of applicable industry standards and practice;
  - Methodology
  - Simulation tool;
  - Metocean data;
  - Analysis assumptions;
  - Preliminary runs table

This document has been updated in accordance with the main assumptions shared and agreed with the Client during the videoconference held on 9th July 2018 (Ref.[13]).

3 QUANTITATIVE RISK ANALYSIS

3.1 MAIN ASSUMPTIONS AND METODOLOGY

The QRA will be developed through the following steps:

- ✓ Hazards Identification;
- ✓ Frequency Assessment;
- ✓ Consequences Assessment;
- ✓ Risk Assessment.

In the following, for each step of QRA a brief description, together with the list of assumptions applied for the step are detailed.

3.1.1 Hazard Identification

Potential hazards sources and related Major Accident Hazards (MAH) will be identified by means of results of HAZID analysis performed for the LNG Terminal. Particularly, potential hazards sources will be identified between the following categories:

- ✓ NG release from process equipment (battery limits are considered the loading arms and HIPPS at ORF, both included);
- ✓ LNG/NG release from LNG Carriers (due to ship collision, wrong manoeuvers);
- ✓ LNG/NG release from Jetty due to ship collision;
- ✓ Others.

3.1.2 Frequency Assessment

Evaluation of frequency of occurrence of LNG release events identified during step 1 will be performed by means of Ref.[1] for the calculation of release frequencies from process equipment. Typical release diameters will be adopted (e.g., 5, 25, 100 and 250 mm);

Ship traffic data along the channels and DNV-RP-F107 (Ref.[2]), together with the results of Manoeuvring Study, will be combined and used in order to evaluate frequency of occurrence of potential accident as ship-ship, ship-jetty collisions, ship-sea bottom collisions.

Since marine traffic data from PQA are currently not available, RINA will consider traffic data of the Main Channel even if it is a very conservative since actually Chann Waddo Channel is not operational.

Once release frequencies are calculated, final scenarios frequencies (e.g., Jet/Pool Fire, Flash Fire and Explosion) will be calculated by means of Event Tree Analysis. The ignition probabilities will be evaluated according to IP-UKOOA Report (Ref.[3]) as detailed in the following:

Ignition probability will be calculated considering the correlation provided by IP-UKOOA. Particularly, for LNG Systems the dedicated correlations "Small Plant Gas LPG", "Large Plant Gas LPG" and "Large Plant Confined Gas LNG" are provided. In addition to these correlations (applicable for gas releases), for liquid releases the correlation "Large Plant Liquid" will be applied, if required.

The share ratio between Early and Delayed Ignition of 30:70 will be applied, as suggested by IP-UKOOA.

Explosion will be considered possible only in case of flammable cloud with an associated flammable mass higher than 100 kg reaching a congested area. If explosion is possible, a share of 50:50 will be adopted between Flash Fire and Explosion.

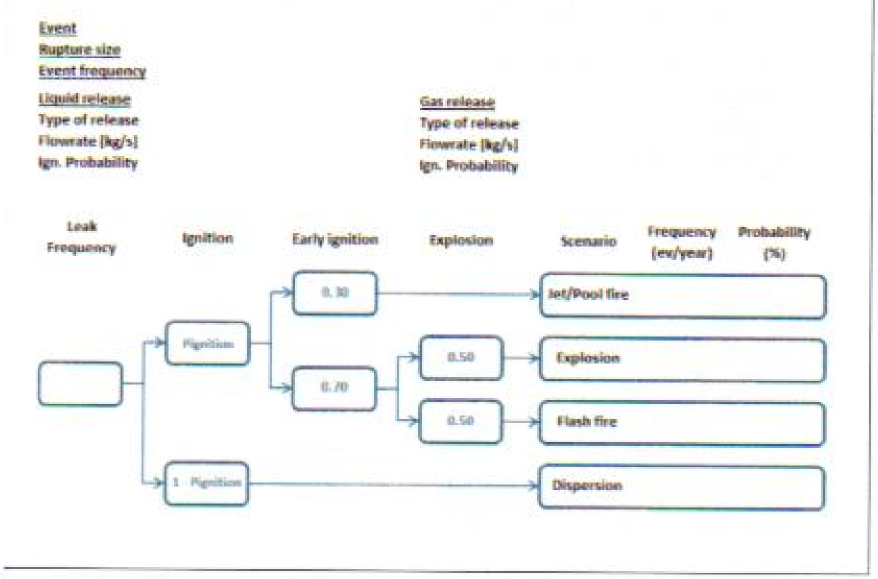

Figure 3.1: Typical Event Tree

3.1.3 Consequences Assessment

Consequences simulation will be performed by means of DNV Phast 7 (Ref.[4]) considering LNG as a stream of 100% methane. Process conditions (e.g., temperature and pressure of each stream) will be taken from PFD.

Release directions will be selected case by case, in order to conservatively maximize the effects of the considered scenario.

In addition, distances results will be calculated considering the initial (peak) flow rate since damage for personnel is usually determined by what happens in the initial 10-20 seconds of the event. Initial peak low rate will be limited to the 150% of the operating flowrate for flow-controlled process streams (e.g. pump discharge line, flow control valve line etc.).

The main results of consequences analysis will be expressed in terms of length of flame (with respect to jet fire), pool diameter (with respect to pool fire) and distances at which the threshold values of radiations, flammable concentrations and overpressure are reached. For the explosions simulations, if any, the TNO Multi-energy Method embedded in Phast 7 will be considered.

The following thresholds, based on international standards, (Italian regulation, Decree 9/5/2001, Minimum requirements for land use planning in areas potentially affected by Major Risks Plants) will be considered representative for each hazardous scenario:

Table 3.1: Scenarios thresholds

Damage thresholds for people and equipment		Damage level			
		Multiple Fatalities	One fatality	Major/ permanent injury	Slight injuries
Accidental Scenario	Pool Fire/Jet Fire	12.5 kW/m2	7 kW/m2	5 kW/m2	3 kW/m2
	Flash-fire	LFL	1/2 LFL	-	-
	Explosion	0.3 bar	0.14 bar	0.07 bar	0.03 bar

Two weather conditions will be considered (namely, 2F and 5D representing nightly and daily conditions) and the environmental conditions will be set as follows:

- ✓ Ambient Temperature: 27°C;
- ✓ Relative Humidity: 50%;
- ✓ Solar radiation: 0.8 kW/m2.

Maps of consequences distances will be provided on plant layout showing the extension of potential fire scenarios in the area around plant location.

3.1.4 Risk Assessment

Risk assessment of each MAH will be performed by means of Individual Risk (IRPA) calculation, considering the following operator distribution along the Plant.

Table 3.2: Operator distribution

Operator distribution		
Location	**Number of people**	**Duration of presence**
FSRU	32	24/7, 365 d/y
LNG Carrier	30	6 times/month
Control Room	2	Semi-unmanned. Operator will be not present 24/7, 365 d/y. He will be present for short period of time for monitoring and control only.

Data proposed in Table 3.2 have been agreed with Client as per information provided by email dated 10th July 2018.

LSIR (Location Specific Individual Risk) map will be also include in order to provide an estimation of risk associated to third parties and public.
Individual risk acceptability criteria will be based on HSE UK tolerability criteria, as shown in the following figure.

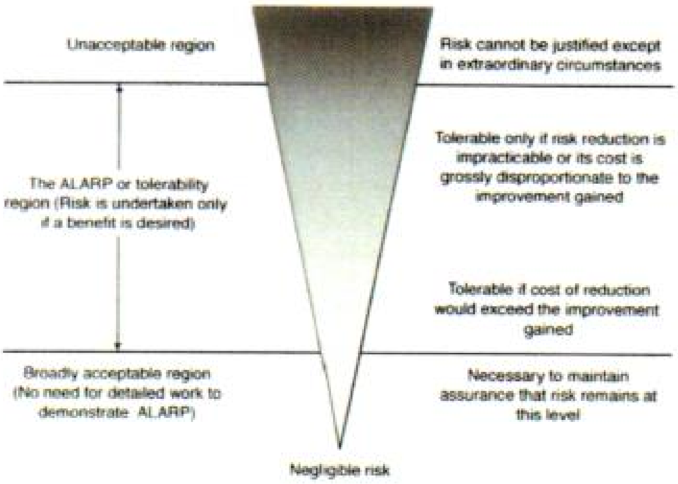

Figure 3.2: Individual risk triangle

Table 3.3: IRPA acceptability criteria (workers) [HSE UK]

Level of IR	Risk Criteria
Broadly acceptable region	Risk < 1.00E-06 ev/yr
ALARP Region	1.00E-06 ≤ Risk < 1.00E-03 ev/yr
Unacceptable region	Risk ≥ 1.00E-03 ev/yr

Table 3.4: IRPA acceptability criteria (public) [HSE UK]

Level of IR	Risk Criteria
Broadly acceptable region	Risk < 1.00E-06 ev/yr
ALARP Region	1.00E-06 ≤ Risk < 1.00E-04 ev/yr
Unacceptable region	Risk ≥ 1.00E-04 ev/yr

4 NAVIGATION STUDY

In this section, the main assumptions and hypothesis related to the navigation study are listed.

4.1 REVIEW OF APPLICABLE INDUSTRY STANDARDS AND PRACTICE

As preliminary general understanding, it has to be highlighted that up to now the LNG ships have been handled at Port Qasim since the establishment of the first LNG terminal in 2015 along the Main Navigation Channel.

During the last three years, another LNG terminal came to operation in Chara Creek and the overall number of LNG operations operated at port Qasim is now exceeding 150 ships. Among the several LNG Carriers, the maximum size currently experienced is Q-Flex size. All the carriers have been operated in the Main Navigation Channel in accordance with the Standard Operating Procedures for LNG (Ref.[10]).

In the light of above, considering that the Chann Waddo Channel is currently not operating, a tentative channel profile, in terms of minimum required depth and width, will be defined and agreed with Client in order to consider a realistic bathymetric scenario for the subsequent simulation runs.

Since the future plans for the development of the mentioned channel is currently not known, RINA suggests to consider a 1-way channel maintaining the same operating philosophy of the Main Channel. The channel dimensions used in the simulations will be based on this assumption.

The mentioned verifications and assumptions will be made according to Ref. [5], [6], [7], [8] and duly discussed with the expert Ship Master that will be involved in the navigation simulation session.

4.2 METHODOLOGY

The navigation study proposed is mainly addressed to perform a risk assessment regarding manoeuvring key aspects for the proposed locations of the new LNG Terminal. The simulation runs will be performed by means of a real time simulator tool described in Section 4.3.1.

All simulations will be carried out in order to optimize the manoeuvring strategy in order to safely operate the terminal and handle the different kind ships in several metocean conditions. In particular the overall runs matrix will be defined in accordance with:

- ✓ Type of ships (Moss type 170,000 m3, Membrane type 130,000 m3, Q-Max);
- ✓ Type of manoeuvre (access or exit)
- ✓ Ship loading condition (full load, ballast);
- ✓ Metocean conditions (tbd);
- ✓ Different kind of failures (main propulsion system, rudder, tug, etc.)

The simulation will be carried out by an experienced LNG Ship Master with the cooperation of engineers and technicians.

4.3 RINA SIMULATION FACILITY

The simulation runs will be performed by means of RINA Consulting real time ship handling simulator in Genova that is a TRANSAS Full Bridge Simulator qualified as Class C fit for purpose especially for engineering activities.

The System is composed by:

- ✓ 1 (one) Instructor Workplace including:
  - Main Instructor Control and Monitoring Module
  - Tug and Mooring Functionality Module
- ✓ 1 (one) Bridge – Software
  - Conning Software (1 module)
  - Navi Sailor 4000 ECDIS Software (1 module)
  - Navi Planner 4000 (planning tools)
  - RADAR/ARPA Software (1 module)

- 1 (one) Bridge - Hardware
  - Maneuvering Console with
  - Mini Azipod right
  - Mini Azipod left
  - Steering Shaft
  - Steering Wheel
  - IBID display, touchscreen (used for AIS, Autopilot, rotate visuals, ...)
  - Mini Telegraph (split, for 1 or 2 propellers)
- 1 (one) General Console Including ECDIS, RADAR, Conning (3 pcs) with dedicated keyboards and 24" monitors
- 3D Scenario on Monitor LCD 50 inches (7 pcs) installed into metal mock-up for 210 degrees visual

Figure 4.1: RINA Consulting Simulator in Genova, Italy (May 2018)

4.3.1 Simulation Tool

RINA Consulting real time ship handling simulator is named NaviTrainerPro 5000, the tool has been developed by TRANSAS and enables simulator training and certification of Officers, Captains and Pilots on all types of vessels as well as port assessment studies.

NTPRO 5000 simulates integration of ship/channel hydrodynamic effects and operational procedures so that simulators can be used not only for traditional maritime training but for number of R&D applications as an effective port /channel /terminal design tool.

In the following, the general algorithms used in the Simulation Mathematical modelling algorithms:

- 6-DoF ship motion equation;
- Hull hydrodynamic model;
- Stability and flotation model;
- Air cushion model;

- ✓ Heel tank model;
- ✓ Ballast tank model;
- ✓ Hull aerodynamic model;
- ✓ Main engine model;

Propulsive algorithm agents model:

- ✓ Active steering devices model;
- ✓ Rudder model;
- ✓ Engine model;
- ✓ Model of environmental effects (wind, waves, current);
- ✓ Model of shallow water effect;
- ✓ Model of 6-DoF pitch, additional wave resistance and drifting effect;
- ✓ Wave roll/pitch model;
- ✓ Wind-generated and swell wave model;
- ✓ Model of the distributed current effect;
- ✓ Model of hydrodynamic interaction with other ships (tugboats, barges) and geographical peculiarities of the area;
- ✓ Model of mechanical interaction with other ships (tugboats, barges) and mooring walls;
- ✓ Anchor model;
- ✓ Model of multi-functional autopilot;
- ✓ SMM incorporates the following model types: displacement ships, semi-glider ship, catamaran ships, tugs, barges, helicopters and aircrafts;
- ✓ Models are based on the actual prototypes and are adjusted from the data of sea and tank tests (if available).

Furthermore, the following real modelled effects are considered in the mathematical model:

- ✓ Shallow water effect on the hydrodynamic properties of the hull, propulsive agents/propeller and helms;
- ✓ Shallow water effect on changing the propulsive quality;
- ✓ Squat effect;
- ✓ Hydrodynamic interaction with other ships (tugboats, barges) and geographical peculiarities of the area (uneven seabed, shoal, mooring wall);
- ✓ Hydrodynamic interaction between the ship and waterway boundaries (walls, inclined bottom, channels, underwater banks);
- ✓ Ship collision with a ship (tugboat, barge);
- ✓ Ship bump with mooring walls and aids to navigation;
- ✓ Grounding;
- ✓ Soft grounding effect;
- ✓ Navigation in muddy strata areas;
- ✓ Lock effect;
- ✓ Enhanced Planning Effect;
- ✓ Air cushion effect;
- ✓ Propeller going of water.

In addition to the Simulator itself, each particular scenario can be detailed modeled or modified by means of Model Wizard software (provided by TRANSAS).
Model Wizard allows creation of a 3D model of a geographical area (scene) for Navi-Trainer simulator, therefore the file with scene construction results has a format compatible with one of the scenes to be installed in the simulator.
Bathymetry, berth layouts, navigation aids, and all the other components of the scenario can be properly updated in order to match the actual characteristics of the area.

4.4 METOCEAN DATA

Metocean data are certainly among the most significant parameters affecting the ships navigation and the manoeuver of the ships approaching the berthing area located along Chhan Waddo Creek.

Since no current map are available, in order to provide input data for manoeuver analyses, maximum values of metocean parameters will be estimated at the access channel, along the navigation route, and at the turning basin

area, based on site specific waves and currents measured data provided by the Client and on critical interpretation of the available data in accordance with the previous similar jobs performed.
As concern the wind speed, Standard Operating Procedures of Port Qasim Authority (Ref.[10]) gives as terminal operation limit for the FSRU and LNG carrier berthing manoeuvres a mean wind speed of 20 knots. So that, the manoeuvring simulations will be carried out with a constant wind speed of 20 knots with gusting (30 and 60 seconds of gust will be considered in the simulation runs).
As per available information, the main incoming wind direction are SW and NE. The prevailing direction is SW which is also the most demanding one, even though also NE direction due to monsoon winds will be taken into account in some simulation runs.

4.5 ANALYSIS ASSUMPTIONS

4.5.1 Berth Locations

The proposed location for the LNG terminal to be investigated in the present navigation study is along the Chann Waddo Channel that is currently not operational.

The site to be investigated during the navigation study is the one shown in the following figure.

Figure 4.2: Site Location

4.5.2 Berth Orientation and Layout

The overall layout of the jetty, including loading platform, breasting structures and mooring dolphins will be modelled inside the different scenarios according to the drawing provided by the Client.

The terminal orientation (approx. 080 N°) will be considered along to the navigational direction at the specific proposed location at the minimum distance from the shore-line in accordance with PQA recommendations regarding the minimum channel width and center channel line required for the safety navigation of the Chann Waddo Channel. As per information provided by Client, the minimum distance to be kept between the center of the channel and the LNGC manifold is 250 meters. This value will be consider for the development of the area to be used during the simulation session.

4.5.3 Ship and Tugs models

In accordance with Client request, for the present study the following ship models will be considered for the simulations.

The main data reported below are relevant to ships available in RINA library already tested and reliable.

Table 4.1: LNG Carrier Moss Type 170k m^3 – main particulars

Ship type – Main Characteristics		Moss 170k m^3
Length Overall	L_{OA} [m]	299.98
Length between perpendicular	L_{BP} [m]	286.00
Beam	B [m]	52.00
Depth	D [m]	28.00
Draught (Full Load)	T_{AM} [m]	11.55
Draught (Ballast)	T_{AM} [m]	9.50
Gas Capacity	[m^3]	177,422
Displacement (Full Load)	Δ [ton]	124,700
Displacement (Ballast)	Δ [ton]	81,550

Table 4.2: LNG Carrier Membrane Type 130k m^3 – main particulars

Ship type – Main Characteristics		Membrane 130k m^3
Length Overall	L_{OA} [m]	274.34
Length between perpendicular	L_{BP} [m]	260.56
Beam	B [m]	43.30
Depth	D [m]	25.40
Draught (Full Load)	T_{AM} [m]	10.86
Draught (Ballast)	T_{AM} [m]	9.50
Gas Capacity	[m^3]	130,300
Displacement (Full Load)	Δ [ton]	89,640
Displacement (Ballast)	Δ [ton]	67,600

Table 4.3: LNG Carrier Membrane Type 260k m^3 – main particulars

Ship type – Main Characteristics		Membrane 260k m^3
Length Overall	L_{OA} [m]	345.00
Length between perpendicular	L_{BP} [m]	332.00
Beam	B [m]	53.80
Depth	D [m]	27.00
Draught (Full Load)	T_{AM} [m]	12.00
Draught (Ballast)	T_{AM} [m]	9.60
Gas Capacity	[m^3]	266,000
Displacement (Full Load)	Δ [ton]	171,300
Displacement (Ballast)	Δ [ton]	142,000

The FSRU will be a membrane type 170,000 m^3 LNG carrier and for all simulations it will be assumed already berthed to the jetty.

Furthermore, the tug fleet available at Port Qasim will be considered during the simulations.

Two different type of tugs are available at Port Qasim and they are involved in different steps of the manouvers depending on their bollard pull capacity.

Lamnalco Mukalla, Lamnalco Hodeidah and Lamnalco Sana'a main characteristics are reported in Table 4.4 for tug type 1, Lamnalco Aden main characteristics are reported in Table 4.4 for tug type 2.

Table 4.4: Tug – main characteristics

Tug type – Main Characteristics		1	2
Length Overall	L_{OA} [m]	33.31	33.31
Beam	B [m]	14.5	14.5
Gross Tonnage	GT	724	724
Bollard Pull	[t]	75	85
Speed	[kn]	14	14
Installed Power	[kW]	6,120	6,120

In accordance with PQA recommendations, one tug will be escorting the LNGC at stern during arrival manoeuver starting from the entrance of the channel while the other three tugs will be involved in the manoeuvers when the LNGC is approaching the jetty only.

Since RINA is not able to predict which type of tugs will be involved in the manoeuvers, conservatively four ASD tugs with a bollard pull of 75 tons will be considered in the simulations.

4.5.4 Chann Waddo Channel Bathymetry

The Chann Waddo Channel is currently not operational because of low water depth level in some of its sections. Inside Model Wizard suite of software, Chann Waddo Channel configuration needs to be updated according to the latest information available.

The update bathymetric layout made available by the Client (Ref. [12]) will be imported in the main scenario built up with the Electronic Chart of the area.

In addition to the above, the definition of the minimum channel depth and width according to the main international standards (Ref. [5] to [8]) will be developed taking into account the size of ships that will sail into the channel.

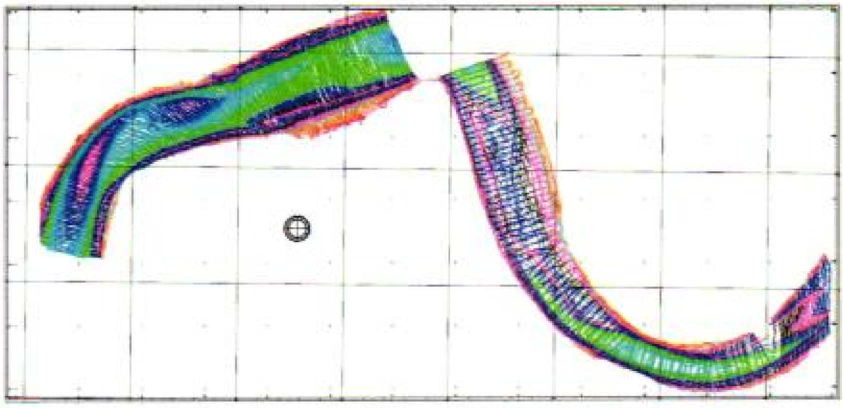

Figure 4.3: Bathymetric data

4.5.5 Navigation aids

Considering that the Channel is currently non-operational, no navigation aids are currently present, therefore, once the fairway dimension will be defined, the necessary Navigation Buoys will be placed all along the channel according to the applicable Standards (Ref.[9]).

Furthermore, the above mentioned navigation aids layout will be further discussed with the expert Ship Master that will be involved in the navigation simulation session in order to propose a tentative layout that not only is compliant with regulations but it is also supported by human LNG expert judgement.

4.6 PRELIMINARY RUNS MATRIX

4.6.1 Manoeuvring strategy

During the whole simulations the FSRU will be assumed already berthed to the jetty. The manoeuvres will be carried out with the ship models of LNG carriers reported in Section 4.5.3.

As general approach already in use at Port Qasim for handling LNG Traffic, the manoeuvring strategy foresees that the LNG carried should arrive in theoretical optimum conditions in the turning basin with high water slack current condition.

However, considering that this is highly theoretical and in order to properly take into account random variables affecting the scheduling of ships, scenario of high water +1/-1 h. will be considered.

The above described manoeuvering strategy is, theoretically, currently applied by PQA for the existing LNG Terminals, nevertheless also some particular cases at low tide will be performed during the simulation session.

4.6.2 Simulation Matrix

Table below reports an example of simulation matrix that may be considered as reference.

The final simulation matrix will be provided and agreed with the Client before starting the simulation session.

Table 4.5: Simulation Matrix example

Test no.	Description	Arrival / Departure	Ship type	Wind		Current		Failures
				[°]	[kts]	[°]	[kts]	
1	LNG carrier navigation from outside to the turning basin & evolution in the turning basin	Arrival	Membrane 130k m^3	SW	Strong (*)	Flood	Strong (*)	(**)
2	LNG carrier arrival/departure to/from mooring platform	Departure	Q-Max 260k m^3	NE	Strong (*)	Ebb	Strong (*)	(**)

(*) to be agree before starting the simulation session according to available metocean data and contributions from the team. Typical value might be 20 knots with gusts up to 30 knots.

(**) manoeuver repetitions with failures will be agreed during the study, based on captain feedbacks and contributions from the team. Typical failures simulated are (1) tug, (2) steering, (3) black-out.

REFERENCES

[1] OGP, 2010, "Process Release Frequencies", Risk Assessment Data Directory, Report No.434-1;

[2] DNV, 2010; RP-F107, "Risk Assessment of Pipeline protection";

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[11] JGC Corporation – General Plot Plan for Jetty and Onshore Facility [dwg. no. D-000-1225-001];

[12] CW-Jhari 13th June bathymetry Chann Waddo Channel;

[13] P0009270-1-A2 Minute of Meeting relevant to Clarification Meeting held on 9th July 2018.

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RINA

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JGC Corporation
Karachi, Pakistan

QRA and Navigation Simulations for LNG terminal at Port Qasim

Appendix B: Event Tree Analysis

Doc. No. P0009270-1-H2 Rev. 0 – July 2018

Rev.	0
Description	First Issue
Prepared by	M. Di Francesco
Controlled by	M. Pontiggia
Approved by	G. Uguccioni
Date	030/08/2018

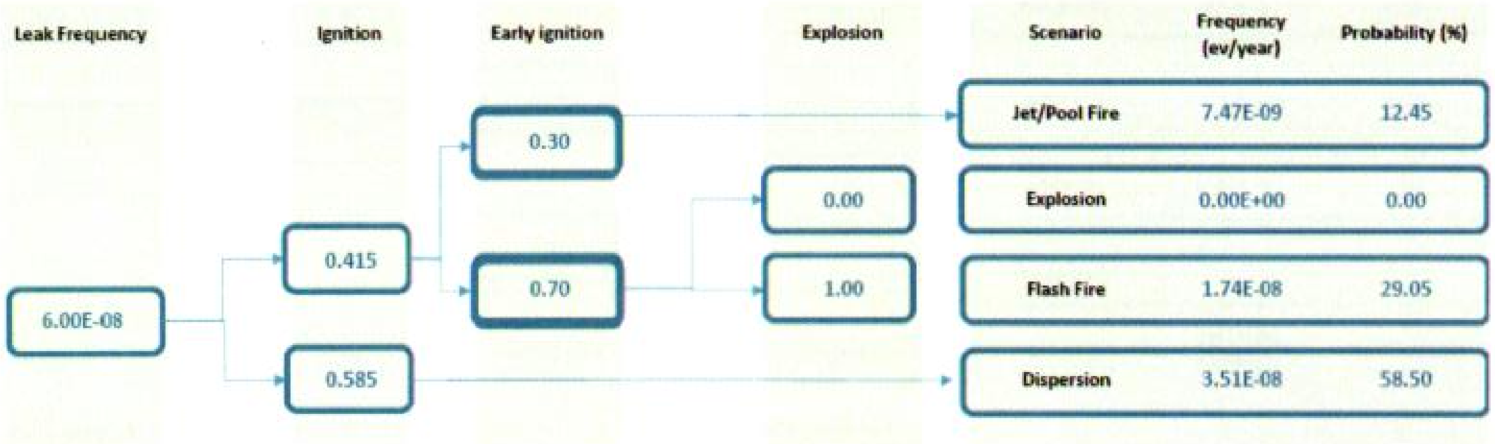
QRA and Navigation Simulations for LNG terminal at Port Qasim

Appendix B: Event Tree Analysis

Rev.	Description	Prepared by	Controlled by	Approved by	Date
0	First Issue	Michele Di Francesco	Marco Pontiggia	Giovanni Uguccioni	03/08/2018

1 EVENT TREES

Event	1		
Rupture size	>150 mm		
Event Frequency	6.00E-08		
Liquid release		**Event**	
Type of release	Large Plant Liquid	Type of release	Small Plant Gas LPG
Flowrate [kg/s]	0.0	Flowrate [kg/s]	302.13
Ign. Probability	0	Ign. Probability	0.415



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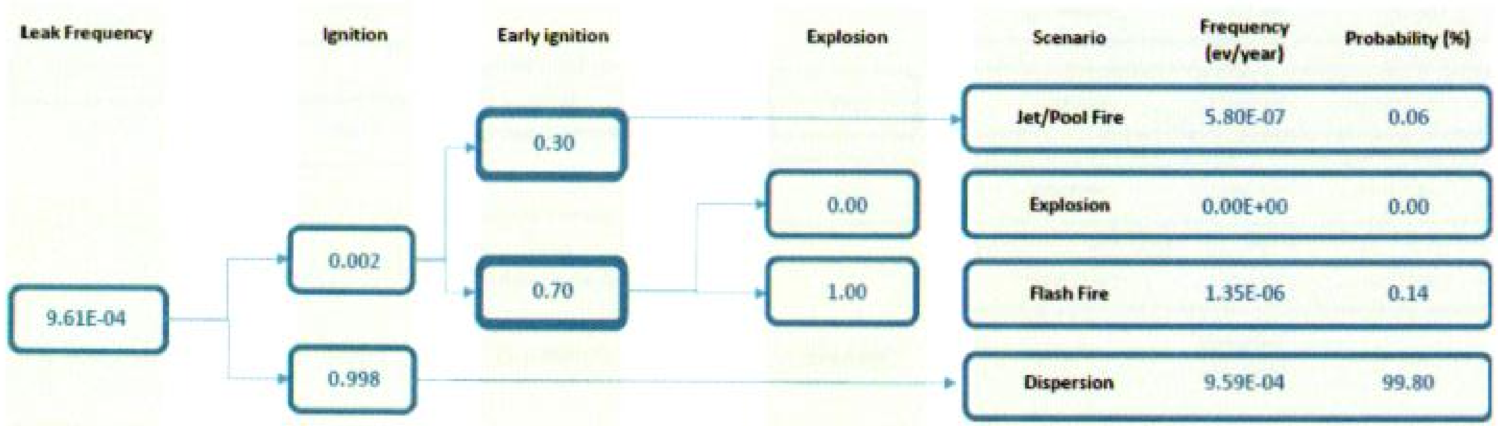
Event	2
Rupture size	10 mm
Event Frequency	9.61E-04

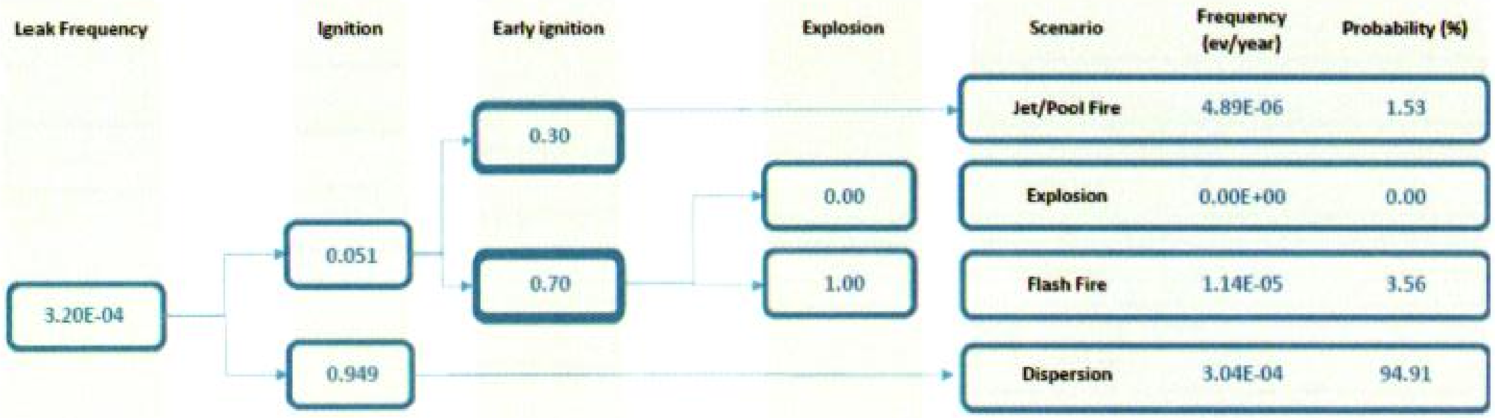
Liquid release	
Type of release	Large Plant Liquid
Flowrate [kg/s]	0.0
Ign. Probability	0

Event	
Type of release	Small Plant Gas LPG
Flowrate [kg/s]	0.65
Ign. Probability	0.002



Event	2
Rupture size	50 mm
Event Frequency	3.20E-04

Liquid release		**Event**	
Type of release	Large Plant Liquid	**Type of release**	Small Plant Gas LPG
Flowrate [kg/s]	0.0	**Flowrate [kg/s]**	17.40
Ign. Probability	0	**Ign. Probability**	0.051



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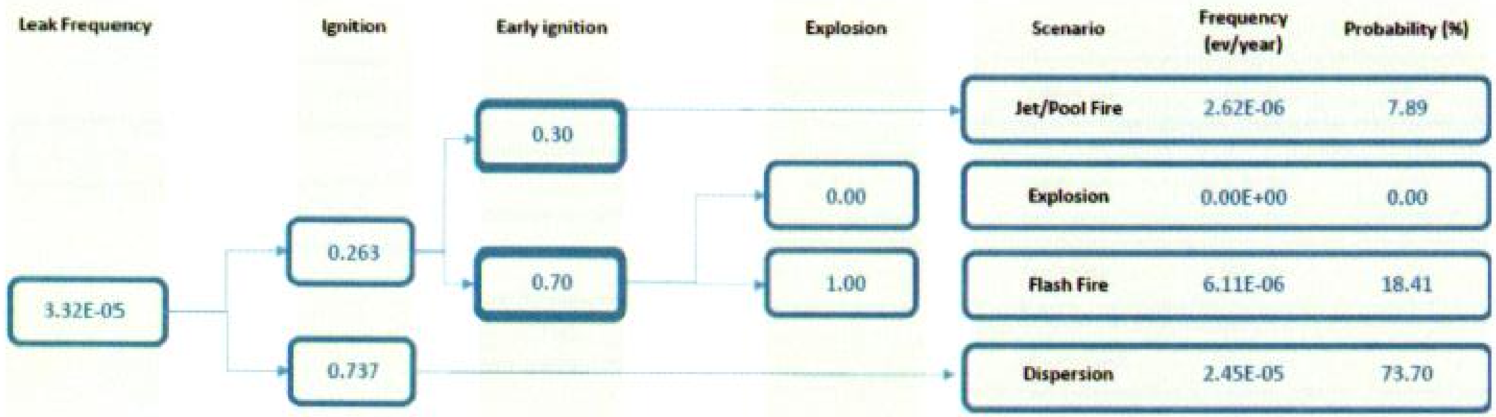
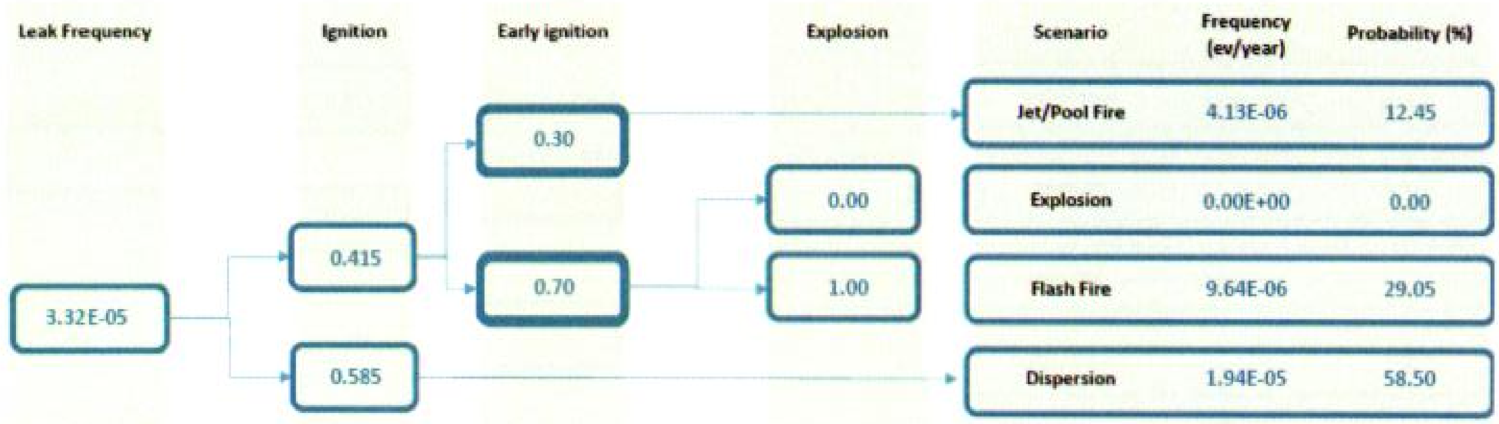
Event	2
Rupture size	150 mm
Event Frequency	3.32E-05

Liquid release		**Event**	
Type of release	Large Plant Liquid	Type of release	Small Plant Gas LPG
Flowrate [kg/s]	0.0	Flowrate [kg/s]	162.40
Ign. Probability	0	Ign. Probability	0.263



Event	2
Rupture size	>150 mm
Event Frequency	3.32E-05

Liquid release		Event	
Type of release	Large Plant Liquid	Type of release	Small Plant Gas LPG
Flowrate [kg/s]	0.0	Flowrate [kg/s]	302.10
Ign. Probability	0	Ign. Probability	0.415



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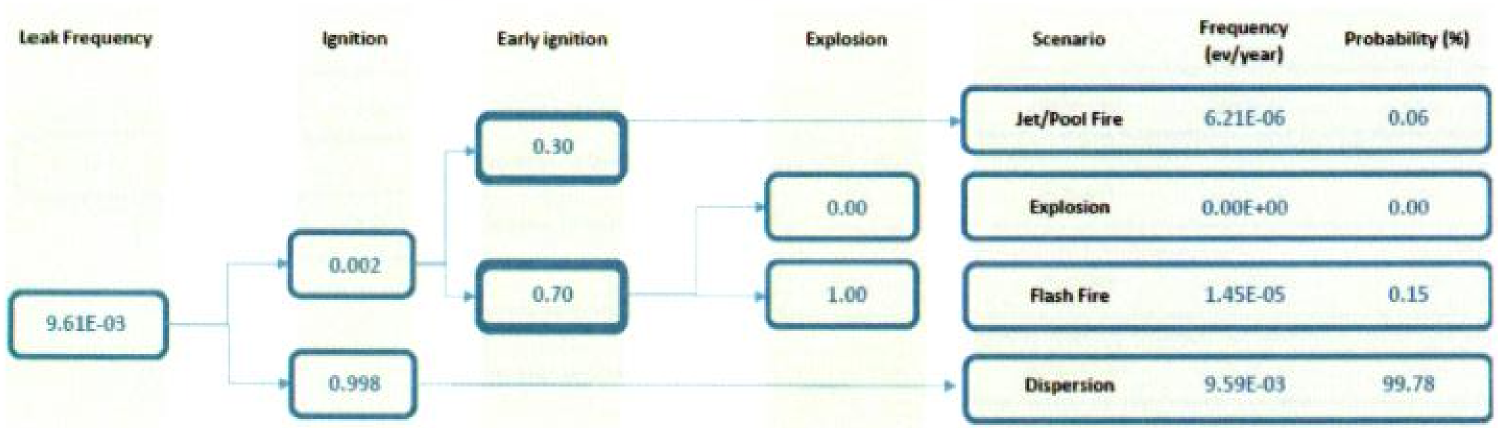
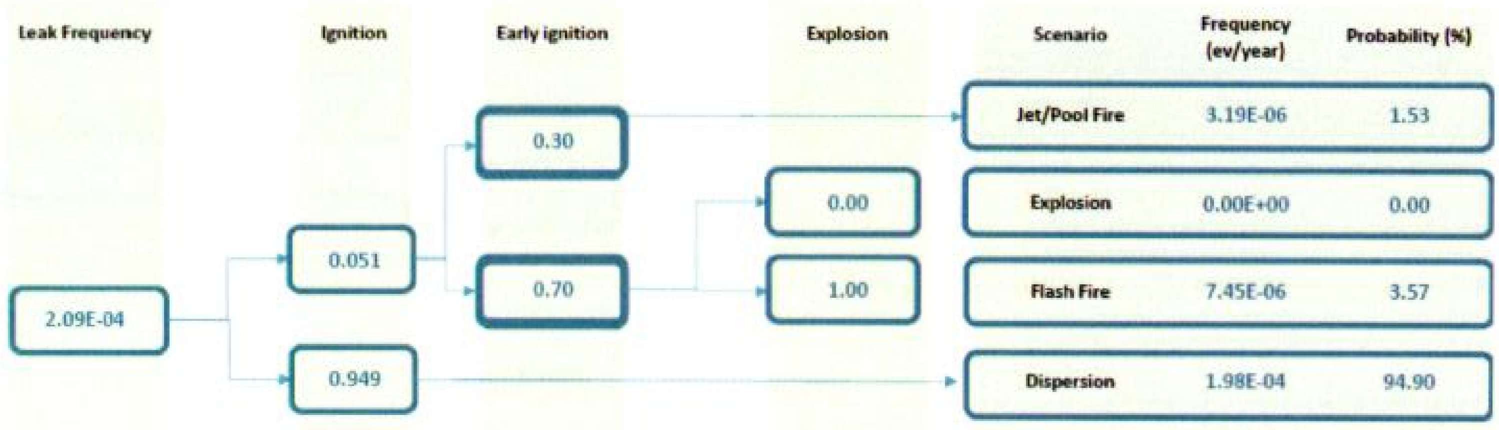
Event	3
Rupture size	10 mm
Event Frequency	9.61E-03

Liquid release		**Event**	
Type of release	Large Plant Liquid	Type of release	Small Plant Gas LPG
Flowrate [kg/s]	0.0	Flowrate [kg/s]	0.66
Ign. Probability	0	Ign. Probability	0.002



Event	3
Rupture size	50 mm
Event Frequency	2.09E-04

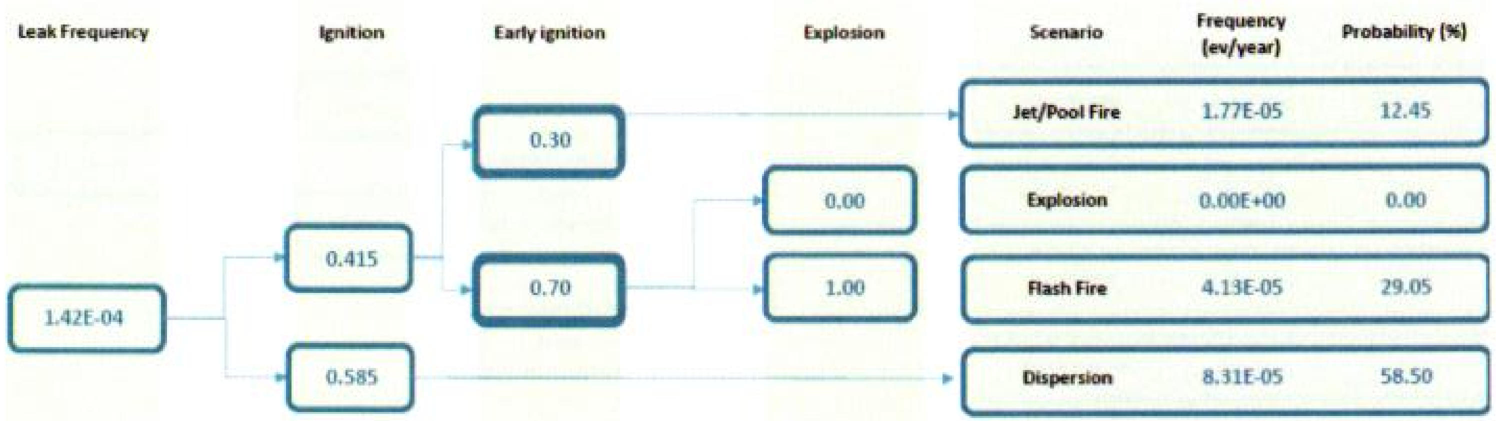
Liquid release		Event	
Type of release	Large Plant Liquid	Type of release	Small Plant Gas LPG
Flowrate [kg/s]	0.0	Flowrate [kg/s]	17.40
Ign. Probability	0	Ign. Probability	0.051



658

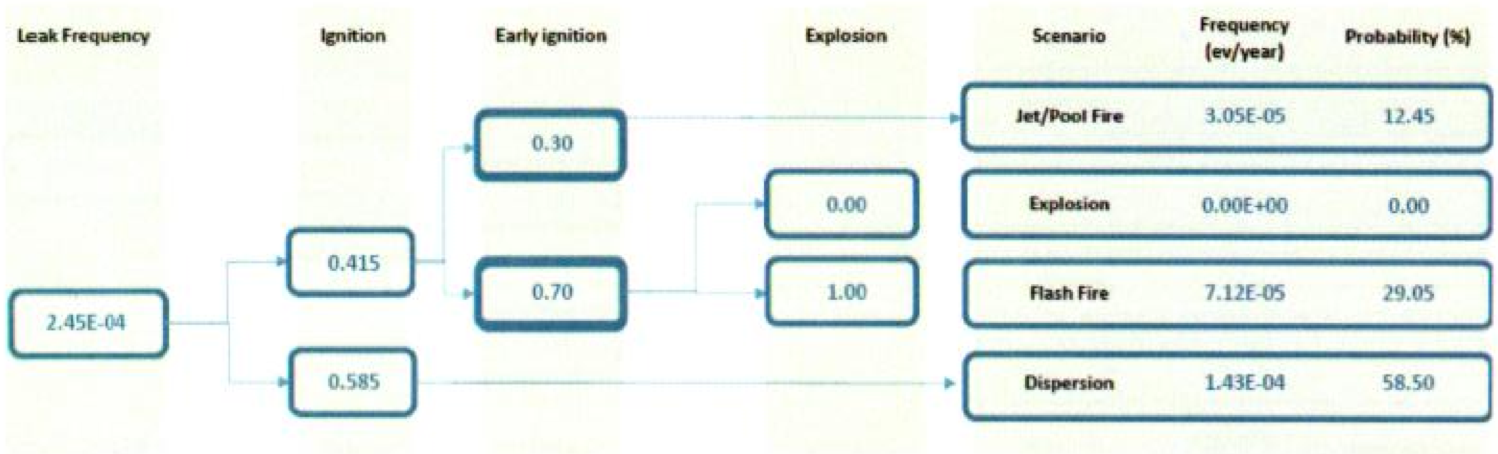
659

Event	3		
Rupture size	150 mm		
Event Frequency	1.42E-04		
Liquid release		**Event**	
Type of release	Large Plant Liquid	Type of release	Small Plant Gas LPG
Flowrate [kg/s]	0.0	Flowrate [kg/s]	302.10
Ign. Probability	0	Ign. Probability	0.415



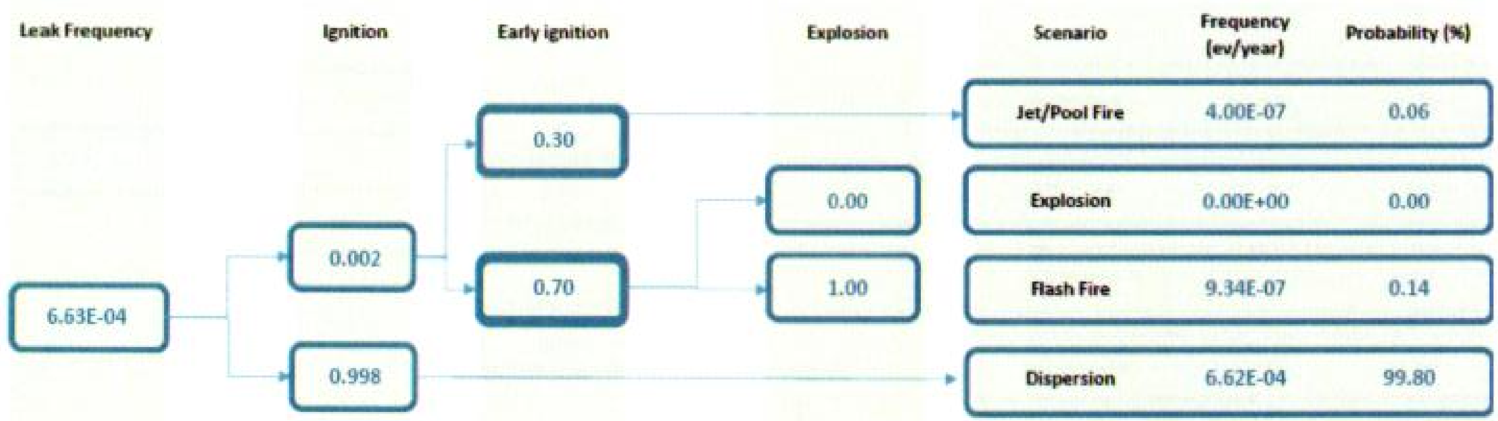
Event 3
Rupture size >150 mm
Event Frequency 2.45E-04

Liquid release		Event	
Type of release	Large Plant Liquid	Type of release	Small Plant Gas LPG
Flowrate [kg/s]	0.0	Flowrate [kg/s]	302.10
Ign. Probability	0	Ign. Probability	0.415



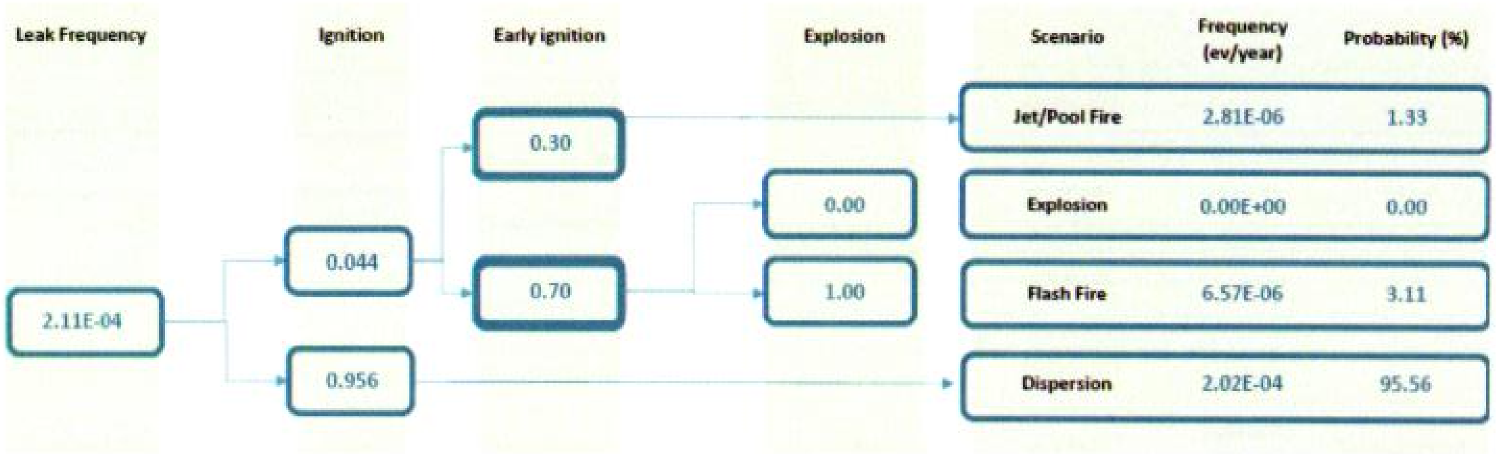
Event	4
Rupture size	10 mm
Event Frequency	6.63E-04

Liquid release		**Event**	
Type of release	Large Plant Liquid	Type of release	Small Plant Gas LPG
Flowrate [kg/s]	0.0	Flowrate [kg/s]	0.54
Ign. Probability	0	Ign. Probability	0.002



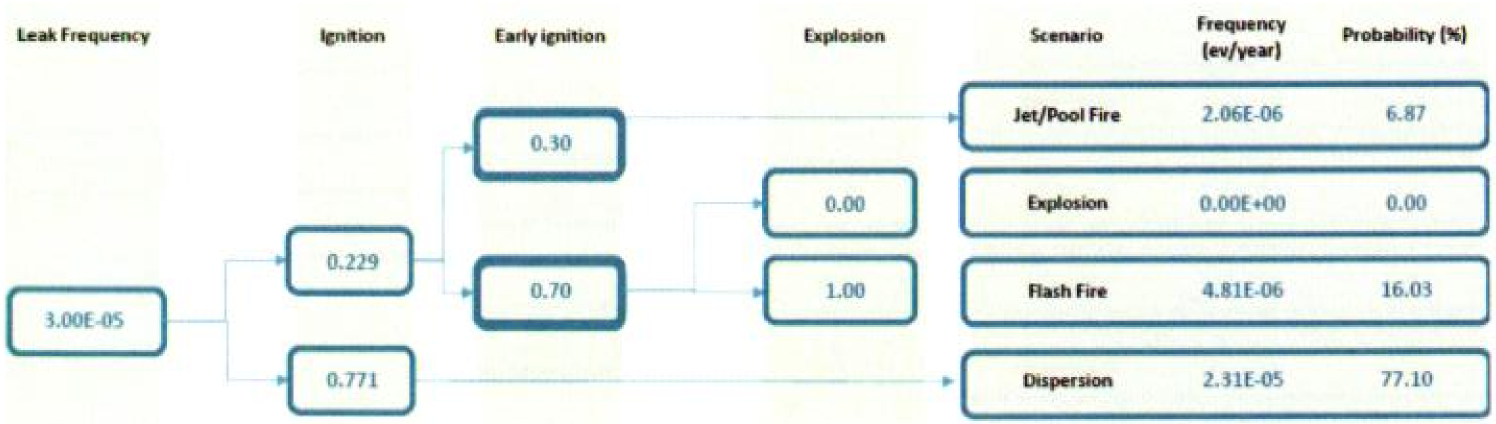
Event	4
Rupture size	50 mm
Event Frequency	2.11E-04

Liquid release		**Event**	
Type of release	Large Plant Liquid	Type of release	Small Plant Gas LPG
Flowrate [kg/s]	0.0	Flowrate [kg/s]	14.40
Ign. Probability	0	Ign. Probability	0.044



662

Event	4		
Rupture size	150 mm		
Event Frequency	3.00E-05		
Liquid release		Event	
Type of release	Large Plant Liquid	Type of release	Small Plant Gas LPG
Flowrate [kg/s]	0.0	Flowrate [kg/s]	134.60
Ign. Probability	0	Ign. Probability	0.229



599

Event	4
Rupture size	>150 mm
Event Frequency	2.94E-05

Liquid release		Event	
Type of release	Large Plant Liquid	Type of release	Small Plant Gas LPG
Flowrate [kg/s]	0.0	Flowrate [kg/s]	250.30
Ign. Probability	0	Ign. Probability	0.361

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JGC Corporation
Karachi, Pakistan

QRA and Navigation Simulations for LNG terminal at Port Qasim

Appendix C: Consequence Plots

Doc. No. P0009270-1-H2 Rev. 0 – July 2018

Rev.	0
Description	First Issue
Prepared by	M. Di Francesco
Controlled by	M. Pontiggia
Approved by	G. Uguccioni
Date	03/08/2018

1967

QRA and Navigation Simulations for LNG terminal at Port Qasim

Appendix C: Consequence Plots

Rev.	Description	Prepared by	Controlled by	Approved by	Date
0	First Issue	Michele Di Francesco	Marco Pontiggia	Giovanni Uguccioni	03/08/2018

1 CONSEQUENCE PLOTS

In the following plots, consequences for considered scenarios (Flash fire and Jet/pool fire) are graphically shown as contours over the layout. Given the map length scale, only worst case (that is, 150 mm hole size, 5/D meteo aggregation) has been plotted.

668

69A

IS1

Hole diameter: 150 mm

Direction: H

Meteo: 5/D

Consequences:

Jet Fire Radiation

- 3 kW/m2
- 5 kW/m2
- 7 kW/m2
- 12.5 kW/m2
- 37.5 kW/m2
- Source


IS2
Hole diameter: 150 mm
Direction: H
Meteo: 5/D
Consequences:
Flash Fire
LFL
LFL/2
Source

670

149

IS2

Hole diameter: 150 mm
Direction: H
Meteo: 5/D
Consequences:
Jet Fire Radiation

- 3 kW/m2
- 5 kW/m2
- 7 kW/m2
- 12.5 kW/m2
- 37.5 kW/m2
- Source

IS3A

Hole diameter: 150 mm
Direction: H
Meteo: 5/D
Consequences:
Flash Fire

- LFL
- LFL/2
- Source

672

679


IS3A
Hole diameter: 150 mm
Direction: H
Meteo: 5/D
Consequences:
Jet Fire Radiation
3 kW/m2
5 kW/m2
7 kW/m2
12.5 kW/m2
37.5 kW/m2
Source

IS3B
Hole diameter: 150 mm
Direction: H
Meteo: 5/D
Consequences:
Flash Fire

LFL
LFL/2
Source

674


IS3B
Hole diameter: 150 mm
Direction: H
Meteo: 5/D
Consequences:
Jet Fire Radiation
3 kW/m2
5 kW/m2
7 kW/m2
12.5 kW/m2
37.5 kW/m2
Source

IS3C

Hole diameter: 150 mm
Direction: H
Meteo: 5/D
Consequences:
Flash Fire

LFL
LFL/2
Source

676

677

IS3C
Hole diameter: 150 mm
Direction: H
Meteo: 5/D
Consequences:
Jet Fire Radiation

- 3 kW/m2
- 5 kW/m2
- 7 kW/m2
- 12.5 kW/m2
- 37.5 kW/m2
- Source

IS3D

Hole diameter: 150 mm

Direction: H

Meteo: 5/D

Consequences:

Flash Fire

LFL

LFL/2

Source

678

679


IS3D
Hole diameter: 150 mm
Direction: H
Meteo: 5/D
Consequences:
Jet Fire Radiation
3 kW/m2
5 kW/m2
7 kW/m2
12.5 kW/m2
37.5 kW/m2
Source

IS3E

Hole diameter: 150 mm

Direction: H

Meteo: 5/D

Consequences:

Flash Fire

LFL

LFL/2

Source

680

189

IS3E

Hole diameter: 150 mm

Direction: H

Meteo: 5/D

Consequences:

Jet Fire Radiation

- 3 kW/m2
- 5 kW/m2
- 7 kW/m2
- 12.5 kW/m2
- 37.5 kW/m2
- Source


IS4
Hole diameter: 150 mm
Direction: H
Meteo: 5/D
Consequences:
Flash Fire
LFL
LFL/2
Source

682

683

RINA

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	JOB No. 0-7918-20	DOC. No. S-000-1250-001	Rev. 1
TABEER ENERGY	DATE 16 - MAY - 2018 SHEET 1 OF 11		
	PREP'D	D. Akinlade	
	CHK'D	N. Hara	
	APP'D	N. Hara	

MITSUBISHI PAKISTAN FSRU PROJECT
REPORT FOR HAZARD IDENTIFICATION WORKSHOP

Pakistan LNG Receiving Facilities/Site Selection Follow-up Activities

FOR FEED

REV.	Date	Page	DESCRIPTION	PRE'D	CHK'D	APP'D
0	16 May 2018	All	For Review	D. Akinlade	N. Hara	N. Hara
1	10 Oct 2018	1	For FEED	D. Akinlade	N. Hara	N. Hara

JGC JGC CORPORATION

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Contents

1 INTRODUCTION

1.1 Background

JGC Corporation is responsible for the Pre-FEED of the proposed LNG Terminal at Pakistan using Floating Storage Regasification Unit (FSRU) technology (hereinafter referred as "the Project") owned by Mitsubishi Corporation.

Environmental Resources Management (ERM), an independent Health, Safety and Environment (HSE) consultancy, was commissioned by JGC Corporation to conduct a Hazard Identification (HAZID) for the Project.

1.2 Objectives of Study

The main objectives of HAZID workshop were identification of:

- Identification of major accident events (MAE) that may cause serious or immediate risk to personnel health and safety;
- Identification of potential causes or threats that may lead to MAEs;
- Assignment of risk ratings to MAEs to allow for prioritization of risk reduction measures;
- Identification of safeguards, both engineering or operational control measures that have already been included in the design;
- Identification of controls measures that are safety critical in managing and controlling potential escalation of MAEs; and
- Identification of additional risk reduction measures to achieve ALARP; and.
- Provide inputs for subsequent HSE studies.

1.3 Scope

The scope of work of the HAZID Study includes the following facilities:

- FSRU Vessel;
- Interaction with other Vessels/ Facilities in Vicinity;
- Jetty including Operation Concept and Vessel Navigation in Vicinity;
- Connecting Pipeline from Jetty to Onshore Facilities; and
- Onshore facilities.

2 HAZID METHODOLOGY

2.1 Overview

Hazard Identification (HAZID) study is systematic, multi-disciplinary review carried out for the identification of hazards.
The basis for the study is primarily based on the site layout drawings and process flow diagram.

The HAZID study is a brainstorming exercise, guided by the prepared checklist and taking benefit from the previous experience of the HAZID study participants from various disciplines.

The HAZID study includes the assessment of:
Hazards;

- Potential causes and consequences;
- Existing preventive and mitigative safeguards; and
- Proposed Prevention, Control, and Mitigation Measures.

The HAZID team discussed recommendations for risk reduction and/or further study as appropriate.

2.2 Node Definition

The process was divided into smaller sections, called nodes, representing a design intention. The Node is a portion of the plant subject to the study, where single or limited process functions are assigned. A reference number was given to identify the selected node.

The facilities were broken down in to 4 major nodes for this workshop:

- Node 1: Connecting Pipelines including Jetty to Onshore Facilities and Vicinity
- Node 2: Onshore Facilities and Vicinity;
- Node 3: Proposed LNG Terminal Operation including Ship Berthing, Vessel Navigation (and Vicinity); and
- Node 4: FSRU Vessel.

2.3 Guidewords

The HAZID team used a guideword approach for identifying hazards. Each hazard was identified along with its cause, an assessment of the potential consequences, and identifying the safeguards in place to prevent the hazard being realized or mitigate its effects.

This HAZID study focused on the hazards from the facility as well as external hazards and natural hazards.

The study session started with a brief explanation of the process of facility. This was to understand the function and the design intention. The HAZID Chairman then directed the team in determining the possible causes of deviations from the normal design intention. The guidewords used for the HAZID workshop are presented in Table 2.1 which is referred in ISO 17776 (2016). Each system was considered to identify any potential hazards in safety or environmental issue under each guideword. The credible cause that would lead to the associated hazard was discussed and recorded. The consequence of each hazard was identified assuming no safeguards are in place and recorded.

Table2.1 HAZID Guidewords

HAZARDS	DESCRIPTIONS
PROCESS CATEGORY	- Flammable Gas - LNG - Refrigerant
NON- PROCESS FLAMMABLE HAZARDS	- Diesel - Chemicals - Electrical fires, - Turbine enclosure gas/diesel/lube oil - Explosive gas generators (batteries, organic waste) - Calibration Gas
TRANSPORT/DYNAMIC HAZARDS	Attendant vessels (standby, supply, flotel, others) Passing vessels (fishing, merchant, naval, submarines, others) - Passing helicopter or aircraft - Carrier - Bunkering - Transfer Boat collision hazard to other vessels and offshore structures
ELEVATED OBJECTS	- Dropped loads (overboard /onboard/ supply vessel) - Swinging loads - Vent stacks - Anchor drops
STRUCTURAL FAILURE	- Primary structures - Secondary structures - Temporary structures
OCCUPATIONAL HEALTH AND SAFETY - ASPHYXIANTS, PHYSICAL, TOXICS AND HEALTH AND ENVIRONMENTAL HAZARDS	- Asphyxiants/Drowning - Toxic Substances - High Pressure Liquid/ Gases - Extreme Temperature Fluids/ Gases - Ionising Radiation - Lighting discharge/electrical hazard - Environmental emission source
ENVIRONMENTAL	- Weather - Sea state - Tectonic - Tsunami - Lightning
EXTERNAL FACTORS	- Piracy - Terrorism
SIMOPS/ OTHER INSTALLATIONS	

2.4 Scenario Identification

Cause

The HAZID team identified and recorded all possible causes related to the guidewords that were applicable to the study section.

The cause identification considers only a single event; that is, the failure of only one independent initial event (no double jeopardy). Two initial events are independent when they do not have any common mode of failure, and when the demand of the first event is not due to the failure of the other event.

Consequence

All possible consequences were investigated but were limited to the failure of only one independent initial event.

Consequences were analyzed without the consideration of safeguards, i.e. defining the consequences of concerns that need to be prevented, mitigated or controlled.

Safeguard

Safeguards included any technical, operational and organizational measures that can prevent, detect, protect or control a given scenario.

Studies, good engineering practices and specifications part of Project scope of work were considered and recorded as safeguards in place, even if not yet implemented at the time of the HAZID workshop.

Studies, specifications and other actions that were not yet included in the Project scope, but required for the safety of the facility, were recorded as actions.

The safeguards in place shall be efficient and do not generate new hazards. When a safeguard appeared inappropriate, or was deemed to lead to new hazards, the team highlighted the issue and formulated adequate action.

2.5 Risk Ranking Matrix

As per World Bank Group's "*Environmental, Health, and Safety Guidelines for Liquefied Natural Gas Facilities, April 11, 2017*", one of the recommended internationally recognized risk assessment standard is EN 1473. The risk matrix for both on-site working personnel and off-site public, summarised in Appendix B, are adopted for the HAZID Study.

2.6 HAZID Recommendations

A number of recommendations were identified during the HAZID workshop, which, in the team's opinion, would improve the safety of the facility.

List of recommendations are presented in Table4.2

3 HAZID SESSIONS

3.1 HAZID Study Session

The HAZID workshop was held over a period of 2 working days from 24th to 25th April 2018 via teleconference between Meeting Venue in Karachi, Pakistan and JGC Corporation Head Office in Yokohama, Japan.

3.2 Study Team

The HAZID study team comprised a multidisciplinary team of personnel involved with the project and having adequate experience of design, operations and maintenance and HSE. Representatives from OWNER, Engineer, and representatives from Port Authority participated in the sessions, which were chaired by an independent consultant from ERM.

The details (name, company and discipline) of the study team members who attended the sessions are presented in Appendix A.

3.3 Software For Recording

The workshop proceedings were recorded using PHA Pro-8 software for the HAZID study. The records were projected on a screen for comment and agreement by the team members during the sessions.

HAZID worksheets are presented in Appendix C. The worksheets cannot be modified outside the workshop, unless the HAZID team is reconvened.

4 CONCLUSION & RECOMMENDATIONS

4.1 Overview

The HAZID Study identified all the hazards arising from the project and assessed the cause and consequence associated with the hazards, enabling suggestions to be made to eliminate the source if possible, control and/or mitigate otherwise.

A total of 37 recommendations were generated as presented in Table4.2. These recommendations will be reviewed by Mitsubishi and JGC for resolution.

Table4.2 List of Recommendations

No.	Recommendations
1.	Evaluate the risk of fire escalation to FSRU from jetty area.
2.	Evaluate the potential anchor drop impact on pipeline based on the expected anchor size at main navigation channel - Gharo Creek.
3.	Marine chart to be updated to show pipeline routing during later phase of project.
4.	Consider implementing early leak detection system on jetty.
5.	Ensure Emergency Response Plan is develop and integrated with Port Emergency Response Plan during later phase of project.
6.	Evaluate the potential anchor drop impact on pipeline based on the expected anchor size along subsea pipeline route.
7.	Consider the risk of ship grounding in selecting pipeline route.
8.	Review the risk of land erosion during pipeline route selection and consider appropriate soil stabilization if required.
9.	Review appropriate means to control uplift of pipeline (e.g. concrete lining). Confirm suitable environmental friendly material for coating (e.g. concrete).
10.	Emergency Response Plan to consider third party assistance (e.g. from Port Authority).
11.	Consider permanent presence of firefighting capable tug boat (considering that terminal is far away from the port).
12.	Consider developing efficient MEDEVAC plan.
13.	Review lesson learnt on hydrocarbon release from pipeline (i.e. at insulation joint location) of one of the existing terminal on jetty.
14.	Review the orientation of pig receiver/ launcher to avoid potential damage by pig in case of door is blasted.
15.	Review appropriate escape routing and muster plan for incident at Jetty area.
16.	Review the requirement for metocean monitoring system.
17.	Consider provision of vessel traffic monitoring system.
18.	Review whether vessel traffic is monitored from cargo control room.
19.	Develop FSRU Standard Operating Procedure for monitoring passing vessels.
20.	Review the current PQA Standard Operating Procedure for consideration of bunkering of FSRU when LNGC is not alongside the FSRU.
21.	Review the risk of LNG vaporisation and dispersion in case of LNG release.
22.	Review the safety requirement associated with ship to ship transfer operation by cryogenic hose and in case of hose failure.
23.	Reconfirm the location of turning circle. The concerns is proximity of the turning circle to jetty.
24.	Review leak detection and containment for cryogenic release.
25.	Consider perform dropped object/ mechanical handling study during subsequence project stage.
26.	Review the requirements for safe handling of excess BOG in FSRU.
27.	Review the requirement for fire extinguishing system on vents.

No.	Recommendations
28.	Consider performing dispersion and radiation study on vent release.
29.	Confirm the requirement for F&G detection and fire protection of ORF area.
30.	Confirm design condition of pipeline downstream of tie-in point.
31.	Develop security plan in conjunction with the local authority requirement (to cover terminal, jetty and ORF).
32.	Consider early approval of turning circle location with Port Authority.
33.	Dispersion study to determine the safety zone of the terminal.
34.	Review the effect of waves and body motion on unloading arm, hose and mooring lines.
35.	Consider develop SIMOPS plan in association with SSGC for ORF.
36.	In case there is requirement of transfer of data between terminal and onshore facility, cyber security should be in place.
37.	Consider developing spill response plan for ORF.

5 REFERENCE DOCUMENTS

[1] ISO 17776 (2000) - Petroleum and natural gas industries – Offshore production installations – Guidelines on tools and techniques for hazard identification and risk assessment

[2] EN 1473 (2016) – Installation and equipment for liquefied natural gas. Design of onshore installations

6 ATTACHMENTS

Attachment -1 Attendance List
Attachment -2 HAZID Worksheet
Attachment -3 Risk Ranking

TEPL HAZID WORKSHOP

Dated: 24th April '18

ATTENDEE LIST
(Karachi).

Name	Organization/email
T. Sakamoto	JGC Corporation
Y. Ishida	JGC
Kishu Fujita	MC Tokyo
Francis Frei	MC Tokyo
M. Ali	MC KAR ali
Kinza Hanif	MC KAR
Shahid Rafi	PQA manager channel Dredging
Zaheer Talpur	PQA
Ramesh Lal	PQA
Captain Bisaver Essani	PQA - Harbour master
Asad	PQA
-	
Jacob Sb	PQA
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Saad Qazi	MC-KAR
Jawad Majeed	" "
- Ramesh Lal	PQA - rameshlal21@gmail.co
- Saquib Ejaz Hussain	Team Leader ESIA_EMC Pakistan

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TEPL HAZID WORKSHOP

ATTENDEE LIST (Karachi)

No	Name	Organization
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2	Koshu Fujita	MC Tokyo
3		
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Document No. S-000-1250-001
Attachment - 1: 3/3

ERM

Attendance Record

Project: JGC FSRU HAZID

Week:

Location:

No.	Name	Company	Position / Department	Email	Mon	Tue 24/04	Wed 25/04	Thurs	Fri	Sat
1	HERVE BONNEL	ERM	Safety Consultant - Oasis	herve.bonnel@erm.com		HB	[illegible]			
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9	Nobuyuki Isao	JGC	HSE	isao.nobuyuki@jgc.com		[illegible]				
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15										
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25										

System: 1. Connecting Pipelines including Jetty to Onshore Facilities and Vicinity

Hazard Category/ Guideword	Hazard/ Location	Top Event/ Cause	Consequence	Safeguard	Risk to Facility S	Risk to Facility L	Risk to Facility RR	Risk to Surrounding S	Risk to Surrounding L	Risk to Surrounding RR	Recommendations	Remark
1. Process Category - Flammable Gas - LNG - Refrigerant - Propane	High pressure (98 barg) natural gas / Unloading arm	1. Mechanical failure (e.g. joint failure, material defect (welds))	1.1. Loss of containment of natural gas leading to environmental impact and potential fire and explosion. Possibility of fire escalation to FSRU/ jetty area. Loss of cargo	1.1.1. QA/QC process and technical bid evaluation 1.1.2. Compliance with international standard (e.g. API) 1.1.3. ESD for natural gas supply 1.1.4. Standard Operating Procedure 1.1.5. F&G detection 1.1.6. Firewater system 1.1.7. Provision for emergency communication system 1.1.8. Emergency Response Plan	Class 2	5	1	Class 3	5	1	1. Evaluate the risk of fire escalation to FSRU from jetty area.	**Mohsin Siddiqui:** Determine and provide steps for mitigation in the ERP of the Terminal
		2. Excessive movement of vessel leading to arm damage (e.g. due to extreme metocean condition)	2.1. Loss of containment of natural gas leading to environmental impact and potential fire and explosion. Possibility of fire escalation to FSRU/ jetty area. Loss of cargo	2.1.1. Mooring study 2.1.2. Design specification for mooring system 2.1.3. Operating guidance based on mooring study 2.1.4. LNGC and FSRU Standard Operating Procedure from Port Authority 2.1.5. DCS alarm for unloading arm 2.1.6. ESD for natural gas supply including PERC 2.1.7. Ongoing supervision by captain (cargo control room is continuously manned during unloading) 2.1.8. F&G detection 2.1.9. Firewater system 2.1.10. Provision for emergency communication system 2.1.11. Emergency Response Plan	Class 2	5	1	Class 3	5	1	16. Review the requirement for metocean monitoring system.	**Mohsin Siddiqui:** Remarks same above
		3. External corrosion and pinhole leaks	3.1. Loss of containment of natural gas leading to environmental impact and potential fire and explosion.	3.1.1. QA/QC process and technical bid evaluation 3.1.2. Compliance with international standard (e.g. API) 3.1.3. Material selection 3.1.4. External coating for piping 3.1.5. Baseline survey of piping integrity 3.1.6. ESD for natural gas supply 3.1.7. Standard Operating Procedure 3.1.8. F&G detection 3.1.9. Firewater system 3.1.10. Provision for emergency communication system 3.1.11. Emergency Response Plan	Class 3	5	1	Class 5	5	1		**Mohsin Siddiqui:** Remarks same as above
		4. Operation beyond safe operating limit (e.g. overpressure, liquid carryover)	4.1. Loss of containment of natural gas leading to environmental impact and potential fire and explosion. Possibility of fire escalation to FSRU/ jetty area. Loss of cargo	4.1.1. Design specification 4.1.2. DCS system 4.1.3. ESD for natural gas supply including PERC 4.1.4. F&G detection 4.1.5. Firewater system 4.1.6. Provision for emergency communication system 4.1.7. Emergency Response Plan	Class 2	4	2	Class 3	4	2		**Mohsin Siddiqui:** Remarks same as above
	High pressure (98 barg) natural gas / Jetty area	1. Mechanical failure (e.g. gasket/ flange failure, material defect (welds))	1.1. Loss of containment of natural gas leading to environmental impact and potential fire and explosion. Possibility of fire escalation to FSRU/ jetty area. Loss of cargo	1.1.1. QA/QC process and technical bid evaluation 1.1.2. Compliance with international standard (e.g. API) 1.1.3. ESD for natural gas supply 1.1.4. Standard Operating Procedure 1.1.5. F&G detection 1.1.6. Firewater system 1.1.7. Provision for emergency communication system 1.1.8. Emergency Response Plan	Class 2	5	1	Class 3	5	1	10. Emergency Response Plan to consider third party assistance (e.g. from Port Authority). 11. Consider permanent presence of firefighting capable tug boat (considering that terminal is far away from the port). 12. Consider developing efficient MEDEVAC plan.	**Mohsin Siddiqui:** 1. This matter should be dealt with in detail after agreement regarding response for this failure with PQA in the ERP of the Terminal. 2. Deployment of the Tug for Fire Fighting will have to be taken up and agreed with the PQA during the finalization of the Implementation Agreement
		2. External corrosion and pinhole leaks	2.1. Loss of containment of natural gas leading to environmental impact and potential fire and explosion.	2.1.1. QA/QC process and technical bid evaluation 2.1.2. Compliance with international standard (e.g. API) 2.1.3. Material selection 2.1.4. External coating for piping 2.1.5. Baseline survey of piping integrity	Class 3	5	1	Class 5	5	1	13. Review lesson learnt on hydrocarbon release from pipeline (i.e. at insulation joint location) of one of the existing terminal on jetty.	

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System: 1. Connecting Pipelines including Jetty to Onshore Facilities and Vicinity

Hazard Category/ Guideword	Hazard/ Location	Top Event/ Cause	Consequence	Safeguard	Risk to Facility S	Risk to Facility L	Risk to Facility RR	Risk to Surrounding S	Risk to Surrounding L	Risk to Surrounding RR	Recommendations	Remark
				2.1.6. ESD for natural gas supply 2.1.7. Standard Operating Procedure 2.1.8. F&G detection 2.1.9. Firewater system 2.1.10. Provision for emergency communication system 2.1.11. Emergency Response Plan								
		3. Human error during pigging operation (temporary equipment)	3.1. Loss of containment of natural gas leading to environmental impact and potential fire and explosion. Possibility of fire escalation to FSRU/ jetty area. Loss of cargo	3.1.1. Standard Operating Procedure 3.1.2. Mechanical locking device on pig trap to avoid inadvertent opening of receiver/ launcher door 3.1.3. F&G detection 3.1.4. Firewater system 3.1.5. Provision for emergency communication system 3.1.6. Emergency Response Plan	Class 2	6	1	Class 3	6	1	14. Review the orientation of pig receiver/ launcher to avoid potential damage by pig in case of door is blasted. 15. Review appropriate escape routing and muster plan for incident at Jetty area.	Mohsin Siddiqui: Detailed procedure for pigging with safety issues will have tobe included in the Operation Manual of the Terminal.
			3.2. Direct injury due to exposure to high pressure natural gas	3.2.1. Standard Operating Procedure 3.2.2. Mechanical locking device on pig trap to avoid inadvertent opening of receiver/ launcher door	Class 2	6	1	Class 5	6	1		
		4. Jetty structural failure	4.1. Loss of containment of natural gas leading to environmental impact and potential fire and explosion. Possibility of fire escalation to FSRU/ jetty area. Loss of cargo	4.1.1. QA/QC process and design review 4.1.2. Compliance with international standard (e.g. API) 4.1.3. ESD for natural gas supply 4.1.4. F&G detection 4.1.5. Firewater system 4.1.6. Provision for emergency communication system 4.1.7. Emergency Response Plan	Class 2	7	1	Class 3	7	1		
		5. Operation beyond safe operating limit (e.g. overpressure, liquid carryover)	5.1. Loss of containment of natural gas leading to environmental impact and potential fire and explosion. Possibility of fire escalation to FSRU/ jetty area. Loss of cargo	5.1.1. Design specification 5.1.2. DCS system 5.1.3. ESD for natural gas supply including PERC 5.1.4. F&G detection 5.1.5. Firewater system 5.1.6. Provision for emergency communication system 5.1.7. Emergency Response Plan	Class 2	4	2	Class 3	4	2		
	High pressure (98 barg) natural gas / Offshore pipeline	1. Mechanical failure (e.g. material losses, material defect (welds))	1.1. Loss of containment of natural gas leading to environmental impact, potential fire and impact to surrounding population (e.g. fisherman). Loss of cargo	1.1.1. QA/QC process and technical bid evaluation 1.1.2. Compliance with international standard (e.g. API) 1.1.3. Baseline survey of pipeline integrity (such as by intelligent pigging) 1.1.4. Flow monitoring of pipeline 1.1.5. Upstream ESD for natural gas supply 1.1.6. Standard Operating Procedure 1.1.7. Provision for emergency communication system 1.1.8. Emergency Response Plan				Class 2	6	1	4. Consider implementing early leak detection system on jetty. 5. Ensure Emergency Response Plan is develop and integrated with Port Emergency Response Plan during later phase of project.	
		2. External corrosion (e.g. due to coating failure) and pinhole leaks	2.1. Loss of containment of natural gas leading to environmental impact, potential fire and impact to surrounding population (e.g. fisherman). Loss of cargo	2.1.1. QA/QC process and technical bid evaluation 2.1.2. Compliance with international standard (e.g. API) 2.1.3. Material selection 2.1.4. Long life coating for pipeline 2.1.5. Cathodic protection 2.1.6. Baseline survey of pipeline integrity (such as by intelligent pigging) 2.1.7. Flow monitoring of pipeline 2.1.8. Upstream ESD for natural gas supply 2.1.9. Standard Operating Procedure 2.1.10. Provision for emergency communication system 2.1.11. Emergency Response Plan				Class 4	5	1		
		3. Drop/ drag anchor (e.g. from third party vessels)	3.1. Loss of containment of natural gas leading to environmental impact, potential fire and impact	3.1.1. Buried pipeline				Class 2	6	1	6. Evaluate the potential anchor drop impact on pipeline based on the expected anchor size along	

System: 1. Connecting Pipelines including Jetty to Onshore Facilities and Vicinity

Hazard Category/ Guideword	Hazard/ Location	Top Event/ Cause	Consequence	Safeguard	Risk to Facility S	Risk to Facility L	Risk to Facility RR	Risk to Surrounding S	Risk to Surrounding L	Risk to Surrounding RR	Recommendations	Remark
			to surrounding population (e.g. fisherman). Loss of cargo	3.1.2. Flow monitoring of pipeline 3.1.3. Upstream ESD for natural gas supply 3.1.4. Provision for emergency communication system 3.1.5. Emergency Response Plan							subsea pipeline route. 3. Marine chart to be updated to show pipeline routing during later phase of project.	
		4. Ship grounding/ beaching	4.1. Loss of containment of natural gas leading to environmental impact, potential fire and impact to surrounding population (e.g. fisherman). Loss of cargo	4.1.1. Channel is not used for heavy ship traffic 4.1.2. Flow monitoring of pipeline 4.1.3. Upstream ESD for natural gas supply 4.1.4. Provision for emergency communication system 4.1.5. Emergency Response Plan				Class 4	4	1	7. Consider the risk of ship grounding in selecting pipeline route.	• **Mohsin Siddiqui:** Currently the PQA has started study for opening the Chhan Waddo Channel for navigation of all types of vessels in combination with the current navigation of the port. Pipeline routing should take into account the planned layout of the Chhan Waddo Channel
		5. Third party excavation/ dredging	5.1. Loss of containment of natural gas leading to environmental impact, potential fire and impact to surrounding population (e.g. fisherman). Loss of cargo	5.1.1. PQA permit is required for excavation/ dredging near pipeline 5.1.2. Pipeline marking for non-subsea portion 5.1.3. Regular patrol along pipeline 5.1.4. Flow monitoring of pipeline 5.1.5. Upstream ESD for natural gas supply 5.1.6. Provision for emergency communication system 5.1.7. Emergency Response Plan				Class 2	4	2		
		6. Land erosion	6.1. Loss of containment of natural gas leading to environmental impact, potential fire and impact to surrounding population (e.g. fisherman). Loss of cargo	6.1.1. Flow monitoring of pipeline 6.1.2. Upstream ESD for natural gas supply 6.1.3. Provision for emergency communication system 6.1.4. Emergency Response Plan				Class 3	3	2	8. Review the risk of land erosion during pipeline route selection and consider appropriate soil stabilization if required.	
		7. Pipeline displacement (e.g. uplift)	7.1. Loss of containment of natural gas leading to environmental impact, potential fire and impact to surrounding population (e.g. fisherman). Loss of cargo	7.1.1. Flow monitoring of pipeline 7.1.2. Upstream ESD for natural gas supply 7.1.3. Provision for emergency communication system 7.1.4. Emergency Response Plan				Class 3	3	2	9. Review appropriate means to control uplift of pipeline (e.g. concrete lining). Confirm suitable environmental friendly material for coating (e.g. concrete).	
		8. Operation beyond safe operating limit (e.g. overpressure, liquid carryover, operator error)	8.1. Loss of containment of natural gas leading to environmental impact, potential fire and impact to surrounding population (e.g. fisherman). Loss of cargo	8.1.1. Design specification of pipeline 8.1.2. Upstream DCS system 8.1.3. Upstream ESD for natural gas supply including PERC 8.1.4. Provision for emergency communication system 8.1.5. Emergency Response Plan				Class 3	4	2		
	High pressure (98 barg) natural gas / Offshore pipeline (Main navigation channel - Gharo Creek)	1. Same as Offshore pipeline	1.1. Loss of containment of natural gas leading to environmental impact, potential fire and impact to surrounding population (e.g. fisherman and passing/ anchored ships). Loss of cargo	1.1.1. Pipeline installation is by HDD at -25m CD 1.1.2. Pipeline would be buried at more than 5m (minimum) below sea bed				Class 3	4	2	2. Evaluate the potential anchor drop impact on pipeline based on the expected anchor size at main navigation channel - Gharo Creek. 3. Marine chart to be updated to show pipeline routing during later phase of project.	
2. Transport: - Attendant vessels (standby, supply, flotel, others) - Passing vessels (fishing vessel, etc) - Passing helicopter or aircraft - LNG Carrier - Bunkering	Refer to Node 3											
3. Environmental: - Weather - Sea state - Earthquake - Tsunami - Lightning	Refer to Node 3											
	High pressure (98 barg) natural gas	1. High seismic load	1.1. Loss of containment of natural gas leading to environmental impact, potential fire and impact to surrounding population (e.g. fisherman). Loss of cargo	1.1.1. Seismic and Tsunami Hazard Assessment to reconfirm design basis								Design consideration, no risk ranking is required.
4. SIMOPS/ Other Installations	High pressure natural gas/ Proximity of adjacent pipeline	1. Crossing of pipelines leading to potential damage of pipeline	1.1. Potential release of natural gas leading to fire hazard	1.1.1. Port Authority approval of pipeline routing								Design consideration, no risk ranking is required.
5. External Factors: - Piracy - Terrorism	Refer to Node 3											
6. Non- process	Refer to Node 3											

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System 1: Connecting Pipelines including Jetty to Onshore Facilities and Vicinity

Hazard Category/ Guideword	Hazard/ Location	Top Event/ Cause	Consequence	Safeguard	Risk to Facility			Risk to Surrounding			Recommendations	Remark
					S	L	RR	S	L	RR		
Flammable Hazards: - Diesel - Chemicals / glycol water - Lube oil - Electrical fires - Explosive gas generators (batteries) - Calibration Gas (e.g. hydrogen)												
7. Elevated Objects - Dropped loads (overboard /onboard/ supply vessel) - Swinging loads - Anchor drop/ drag - Vent stacks	Refer to Top Event above for Anchor drop/ drag											
8. Structural Failure - Primary structures - Temporary structures	Refer to Top Event above for structural failure											
9. Occupational Health and Safety - Asphyxiants/ Drowning - Toxic Substances - High Pressure Liquid/ Gases - Extreme Temperature Fluids/ Gases - Ionising Radiation - Lighting discharge/ electrical hazards - Environmental emission source	No significant issue - should be review before start of operation											

System: 2. Onshore Facilities and Vicinity

Hazard Category/ Guideword	Hazard/ Location	Top Event/ Cause	Consequence	Safeguard	Risk to Facility S	Risk to Facility L	Risk to Facility RR	Risk to Surrounding S	Risk to Surrounding L	Risk to Surrounding RR	Recommendations	Remark
1. Process Category - Flammable Gas - LNG - Refrigerant - Propane	High pressure (98 barg) natural gas / ORF	1. Mechanical failure (e.g. gasket/ flange failure, material defect (welds))	1.1. Loss of containment of natural gas leading to environmental impact and potential fire and explosion. Loss of cargo	1.1.1. QA/QC process and technical bid evaluation 1.1.2. Compliance with international standard (e.g. API) 1.1.3. ESD for natural gas supply 1.1.4. Standard Operating Procedure 1.1.5. Provision for emergency communication system 1.1.6. Emergency Response Plan	Class 2	5	1	Class 3	5	1	29. Confirm the requirement for F&G detection and fire protection of ORF area.	
		2. External corrosion and pinhole leaks	2.1. Loss of containment of natural gas leading to environmental impact and potential fire and explosion.	2.1.1. QA/QC process and technical bid evaluation 2.1.2. Compliance with international standard (e.g. API) 2.1.3. Material selection 2.1.4. External coating for piping 2.1.5. Baseline survey of piping integrity 2.1.6. ESD for natural gas supply 2.1.7. Standard Operating Procedure 2.1.8. Provision for emergency communication system 2.1.9. Emergency Response Plan	Class 3	5	1	Class 5	5	1	29. Confirm the requirement for F&G detection and fire protection of ORF area.	
		3. Human error during pigging operation (temporary equipment)	3.1. Loss of containment of natural gas leading to environmental impact and potential fire and explosion. Loss of cargo	3.1.1. Standard Operating Procedure 3.1.2. Mechanical locking device on pig trap to avoid inadvertent opening of receiver/ launcher door 3.1.3. Provision for emergency communication system 3.1.4. Emergency Response Plan	Class 2	6	1	Class 3	6	1	14. Review the orientation of pig receiver/ launcher to avoid potential damage by pig in case of door is blasted. 29. Confirm the requirement for F&G detection and fire protection of ORF area.	
			3.2. Direct injury due to exposure to high pressure natural gas	3.2.1. Standard Operating Procedure 3.2.2. Mechanical locking device on pig trap to avoid inadvertent opening of receiver/ launcher door	Class 2	6	1	Class 5	6	1		
		4. Operation beyond safe operating limit (e.g. overpressure, tie in error)	4.1. Loss of containment of natural gas leading to environmental impact and potential fire and explosion. Loss of cargo	4.1.1. Design specification 4.1.2. DCS system 4.1.3. ESD for natural gas supply 4.1.4. HIPPS 4.1.5. Provision for emergency communication system 4.1.6. Emergency Response Plan	Class 2	4	2	Class 3	4	2	29. Confirm the requirement for F&G detection and fire protection of ORF area. 30. Confirm design condition of pipeline downstream of tie-in point.	
2. Transport: - Attendant vessels (standby, supply, flotel, others) - Passing vessels (fishing vessel, etc) - Passing helicopter or aircraft - LNG Carrier - Bunkering	No issue											
3. Environmental: - Weather - Sea state - Earthquake - Tsunami - Lightning	Refer to Node 1											
	High pressure (98 barg) natural gas/ ORF	1. Lightning strike	1.1. Spurious trip of instrumentation and disruption in ORF operation	1.1.1. Lightning protection system								
	Electrical discharge	1. Lightning strike	1.1. Potential personnel harm	1.1.1. Lightning protection system	Class 2	6	1					
	Flooding (no issue identified for ORF location)											
	High pressure (98 barg) natural gas/ ORF	1. Heavy rain fall	1.1. Flooding leading to disruption in ORF operation	1.1.1. Design specification for drain system								Design consideration, no risk ranking is required.
4. SIMOPS/ Other Installations	High pressure natural gas/ Proximity of adjacent existing ORF	1. Construction near existing ORF	1.1. Potential release of natural gas leading to fire hazard								35. Consider develop SIMOPS plan in association with SSGC for ORF.	
5. External Factors: - Piracy	Security/ Terminal	1. Security	1.1. Potential personnel harm	1.1.1. ORF is designed as per ISPS code	Class 2	4	2				31. Develop security plan in conjunction with the local	

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System: 2. Onshore Facilities and Vicinity

Hazard Category/ Guideword	Hazard/ Location	Top Event/ Cause	Consequence	Safeguard	Risk to Facility S	Risk to Facility L	Risk to Facility RR	Risk to Surrounding S	Risk to Surrounding L	Risk to Surrounding RR	Recommendations	Remark
- Terrorism											authority requirement (to cover terminal, jetty and ORF).	
6. Non- process Flammable Hazards: - Diesel - Chemicals / glycol water - Lube oil - Electrical fires - Explosive gas generators (batteries) - Calibration Gas (e.g. hydrogen)	Diesel fuel/ ORF	1. Mechanical failure, human error etc	1.1. Potential fire with potential for escalation	1.1.1. Firefighting system 1.1.2. Standard Operating Procedure and safety plan	Class 4	3	1	Class 5	3	1		
			1.2. Spillage of diesel to environment								37. Consider developing spill response plan for ORF.	
	Lube oil/ ORF	1. Same as diesel										
	Calibration Gas/ ORF	1. Mechanical failure, human error etc	1.1. Potential fire with potential for escalation	1.1.1. Firefighting system 1.1.2. Standard Operating Procedure and safety plan	Class 4	3	1	Class 5	3	1		
	Battery room/ ORF	1. Hydrogen generated by battery charging	1.1. Potential fire with potential for escalation	1.1.1. Compliance with international standard	Class 4	3	1	Class 5	3	1		
	Electrical fire/ ORF	1. Electrical fault	1.1. Potential fire with potential for escalation	1.1.1. Firefighting system 1.1.2. Standard Operating Procedure and safety plan 1.1.3. Compliance with international standard (i.e. NFPA)	Class 4	3	1	Class 5	3	1		
7. Elevated Objects: - Dropped loads (overboard /onboard/ supply vessel) - Swinging loads - Anchor drop/ drag - Vent stacks	Refer to Node 1 & 4											**Mohsin Siddiqui:** Prevention of all these possible incidents or accidents and response in case of their occurance should be covered in detail in the safety and operations of the Terminal.
8. Structural Failure - Primary structures - Temporary structures	Refer to Node 1											
9. Occupational Health and Safety - Asphyxiants/ Drowning - Toxic Substances - High Pressure Liquid/ Gases - Extreme Temperature Fluids/ Gases - Ionising Radiation - Lighting discharge/ electrical hazards - Environmental emission source	No significant issue - should be review before start of operation											

Document No. S-000-1250-001
Attachment -2: 7/11

System: 3. Proposed LNG Terminal Operation including Ship Berthing, Vessel Navigation (and Vicinity)

Hazard Category/ Guideword	Hazard/ Location	Top Event/ Cause	Consequence	Safeguard	Risk to Facility S	Risk to Facility L	Risk to Facility RR	Risk to Surrounding S	Risk to Surrounding L	Risk to Surrounding RR	Recommendations	Remark
1. Process Category: - Flammable Gas - LNG - Refrigerant - Propane	Refer to Node 1 & 4											
2. Transport - Attendant vessels (standby, supply, flotel, others) - Passing vessels (fishing vessel, etc) - Passing helicopter or aircraft - LNG Carrier - Bunkering	LNG/ Terminal area	1. Ship collision onto LNGC or FSRU from terminal operation (including from bunkering vessel) (e.g. due to human error, adverse weather condition, engine failure)	1.1. LNG/ marine fuel spillage to environment and environmental impact. Potential cloud fire and safety impact	1.1.1. Safety zone around terminal 1.1.2. Standby tug boat 1.1.3. LNGC and FSRU Standard Operating Procedure from Port Authority 1.1.4. Terminal Standard Operating Procedure with speed control 1.1.5. Location of terminal at pocket away from traffic and main channel 1.1.6. Navigation aid 1.1.7. Marine chart will show LNG terminal 1.1.8. Speed control is applicable to approach channel of terminal	Class 2	5	1	Class 2	5	2	17. Consider provision of vessel traffic monitoring system. 18. Review whether vessel traffic is monitored from cargo control room. 19. Develop FSRU Standard Operating Procedure for monitoring passing vessels. 20. Review the current PQA Standard Operating Procedure for consideration of bunkering of FSRU when LNGC is not alongside the FSRU. 21. Review the risk of LNG vaporisation and dispersion in case of LNG release.	**Mohsin Siddiqui:** 1. Safety Zone of the Terminal will have to be determined through a detailed LNG Dispersion Study taking into account the size of the LNG volume of the LNG spillage that can occur due to one of the major accidents like collision of passing vessels with LNG FSRU or delivery vessel while on berth discharging cargo or the failure of the LNG hoses due to various reasons. The impact of the LNG spill will have to be evaluated in this study on the personnel and population within and outside of the Safety Zone. Suitable prevention and mitigation measures inside and outside of the Safety Zone will have to be covered in the Emergency Response Plans of the Terminal and the PQA.
	LNG/ Terminal area	1. Ship collision onto LNGC or FSRU from passing vessels or fishing boats or vessels from adjacent terminal operation (e.g. due to human error, adverse weather condition, engine failure)	1.1. LNG/ marine fuel spillage to environment and environmental impact. Potential cloud fire and safety impact	1.1.1. Safety zone around terminal 1.1.2. Standby tug boat 1.1.3. LNGC and FSRU Standard Operating Procedure from Port Authority 1.1.4. Terminal Standard Operating Procedure with speed control 1.1.5. Location of terminal at pocket away from traffic and main channel 1.1.6. Navigation aid 1.1.7. Marine chart will show LNG terminal 1.1.8. Speed control is applicable to approach channel of terminal	Class 2	5	1	Class 2	5	2	17. Consider provision of vessel traffic monitoring system. 18. Review whether vessel traffic is monitored from cargo control room. 19. Develop FSRU Standard Operating Procedure for monitoring passing vessels.	
	LNG/ During approach	1. Ship collision onto LNGC/ FSRU (e.g. due to human error, adverse weather condition, engine failure, tug boat failure, manoeuvring of vessels)	1.1. LNG/ marine fuel spillage to environment and environmental impact. Potential cloud fire and safety impact	1.1.1. Pilot on vessel 1.1.2. LNGC and FSRU Standard Operating Procedure from Port Authority 1.1.3. Navigation aid 1.1.4. Speed control is applicable to approach channel of terminal 1.1.5. Emergency Response Plan	Class 2	5	1	Class 2	5	2	5. Ensure Emergency Response Plan is develop and integrated with Port Emergency Response Plan during later phase of project. 23. Reconfirm the location of turning circle. The concerns is proximity of the turning circle to jetty.	
	LNG/ Terminal area or during approach	1. Grounding of LNGC or FSRU during approach or manoeuvring (e.g. due to human error, adverse weather condition, engine failure, tug boat failure)	1.1. LNG/ marine fuel spillage to environment and environmental impact. Potential cloud fire and safety impact	1.1.1. LNGC and FSRU Standard Operating Procedure from Port Authority 1.1.2. Vessel Standard Operating Procedure 1.1.3. Standby tug boat	Class 3	5	1	Class 3	5	1		
	LNG/ Terminal area	1. Passing helicopter or aircraft and crash	1.1. LNG/ marine fuel spillage to environment and environmental impact. Potential cloud fire and safety impact	1.1.1. Site location not under flight path 1.1.2. Navigation aid	Class 2	7	1	Class 2	7	1		
	Transport (marine) accident	1. Ship collision during crew transfer	1.1. Potential personnel harm	1.1.1. Terminal Standard Operating Procedure with speed control 1.1.2. Navigation aid 1.1.3. Training of boat crew and passengers 1.1.4. Supervision from Port control tower by PQA	Class 2	4	2					

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System 3: Proposed LNG Terminal Operation including Ship Berthing, Vessel Navigation (and Vicinity)

Hazard Category/ Guideword	Hazard/ Location	Top Event/ Cause	Consequence	Safeguard	Risk to Facility S	Risk to Facility L	Risk to Facility RR	Risk to Surrounding S	Risk to Surrounding L	Risk to Surrounding RR	Recommendations	Remark
		2. Man overboard during personnel transfer	2.1. Potential personnel harm	2.1.1. Terminal Standard Operating Procedure with speed control 2.1.2. Training of boat crew and passengers 2.1.3. Life safety gear as per SOLAS requirement	Class 2	4	2					
3. Environmental - Weather - Sea state - Earthquake - Tsunami - Lightning	LNG/ Terminal area	1. Extreme metocean condition leading to ship collision, refer to above										
		2. Extreme metocean condition leading to sloshing in FSRU (if FSRU is to depart)	2.1. Potential damage to membrane leading to LNG spillage to environment and environmental impact. Potential cloud fire and safety impact	2.1.1. Vessel specification allows for sloshing 2.1.2. FSRU Standard Operating Procedure from Port Authority	Class 2	6	1	Class 2	6	1		
		3. Extreme metocean condition leading to sloshing in LNGC	3.1. Potential damage to membrane leading to LNG spillage to environment and environmental impact. Potential cloud fire and safety impact	3.1.1. LNGC approach is not allowed in case of extreme metocean condition per PQA Standard Operating Procedure	Class 2	7	1	Class 2	7	1		
		4. Extreme metocean condition leading to failure of cryogenic hose	4.1. LNG spillage to environment and environmental impact. Potential cloud fire and safety impact		Class 2	4	2	Class 2	4	2	22. Review the safety requirement associated with ship to ship transfer operation by cryogenic hose and in case of hose failure.	
			4.2. Potential cryogenic damage to fender leading to potential collision of LNGC and FSRU		Class 2	5	1	Class 3	5	1	22. Review the safety requirement associated with ship to ship transfer operation by cryogenic hose and in case of hose failure.	
		5. Extreme metocean condition leading to failure of mooring failure	5.1. Potential damage to FSRU. Potential LNG spillage and high pressure natural gas release to environment and environmental impact. Potential cloud fire and safety impact	5.1.1. Quick release hook 5.1.2. Unloading arm connection for natural gas with PERC and ESD 5.1.3. FSRU Standard Operating Procedure 5.1.4. LNGC Standard Operating Procedure	Class 2	6	1	Class 3	6	1	22. Review the safety requirement associated with ship to ship transfer operation by cryogenic hose and in case of hose failure. 16. Review the requirement for metocean monitoring system.	
4. SIMOPS/ Other Installations	LNG/ Proximity of adjacent terminal	1. Turning circle is defined by first terminal and may not be in the desired location	1.1. Potential increase in ship collision risk								32. Consider early approval of turning circle location with Port Authority.	Design consideration, no risk ranking is required.
		2. Accident scenario in one terminal impacting the other terminal	2.1. Potential dispersion of gas cloud from terminal leading to potential hazard of the other terminal	2.1.1. Port Authority will ensure the safety zone of the terminal is not impacted by any other terminals in the vicinity 2.1.2. Provision for emergency communication system 2.1.3. Emergency Response Plan							33. Dispersion study to determine the safety zone of the terminal.	Design consideration, no risk ranking is required.
5. External Factors - Piracy - Terrorism	Security/ Terminal	1. Security	1.1. Potential personnel harm	1.1.1. Terminal is designed as per ISPS code	Class 2	4	2				31. Develop security plan in conjunction with the local authority requirement (to cover terminal, jetty and ORF).	
	Cyber security/ Terminal	1. Cyber security	1.1. Potential impact to personnel and asset		Class 2	4	2				36. In case there is requirement of transfer of data between terminal and onshore facility, cyber security should be in place.	
6. Non- process Flammable Hazards - Diesel - Chemicals / glycol water - Lube oil - Electrical fires - Explosive gas generators (batteries) - Calibration Gas (e.g. hydrogen)	Diesel fuel/ Terminal, FSRU and Jetty	1. Mechanical failure, human error etc	1.1. Potential fire with potential for escalation	1.1.1. Firefighting system 1.1.2. Emergency Response Plan	Class 4	3	1	Class 5	3	1		
			1.2. Spillage of diesel to environment	1.2.1. FSRU spill response plan								
	Lube oil/ Terminal, FSRU and Jetty	1. Same as diesel										
	Calibration Gas/ Terminal, FSRU and Jetty	1. Mechanical failure, human error etc	1.1. Potential fire with potential for escalation	1.1.1. Firefighting system 1.1.2. Emergency Response Plan	Class 4	3	1	Class 5	3	1		
	Battery room/ FSRU	1. Hydrogen generated by battery charging	1.1. Potential fire with potential for escalation	1.1.1. Compliance with SOLAS requirement	Class 4	3	1	Class 5	3	1		
	Electrical fire/ Terminal, FSRU and Jetty	1. Electrical fault	1.1. Potential fire with potential for escalation	1.1.1. Compliance with international standard (i.e. SOLAS) 1.1.2. Standard Operating Procedure and safety plan 1.1.3. Fire and smoke detection 1.1.4. Firefighting system	Class 4	3	1	Class 5	3	1		
7. Elevated Objects - Dropped loads	Refer to Node 1 & 4											

System: 3. Proposed LNG Terminal Operation including Ship Berthing, Vessel Navigation (and Vicinity)

Hazard Category/ Guideword	Hazard/ Location	Top Event/ Cause	Consequence	Safeguard	Risk to Facility			Risk to Surrounding			Recommendations	Remark
					S	L	RR	S	L	RR		
(overboard /onboard/ supply vessel) - Swinging loads - Anchor drop/ drag - Vent stacks												
8. Structural Failure: - Primary structures - Temporary structures	Refer to Node 1											
9. Occupational Health and Safety - Asphyxiants/ Drowning - Toxic Substances - High Pressure Liquid/ Gases - Extreme Temperature Fluids/ Gases - Ionising Radiation - Lighting discharge/ electrical hazards - Environmental emission source	No significant issue - should be review before start of operation											

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System: 4. FSRU Vessel

Hazard Category/ Guideword	Hazard/ Location	Top Event/ Cause	Consequence	Safeguard	Risk to Facility S	Risk to Facility L	Risk to Facility RR	Risk to Surrounding S	Risk to Surrounding L	Risk to Surrounding RR	Recommendations	Remark
1. Process Category - Flammable Gas - LNG - Refrigerant - Propane	LNG/ FSRU	1. Mechanical failure (e.g. gasket/ flange failure, material defect (welds))	1.1. LNG spillage to environment and environmental impact. Potential cloud/ jet fire and safety impact	1.1.1. QA/QC process and technical bid evaluation 1.1.2. Compliance with international standard (e.g. API, IGC, SOLAS) 1.1.3. ESD 1.1.4. Standard Operating Procedure 1.1.5. F&G detection 1.1.6. Firewater system 1.1.7. Provision for emergency communication system 1.1.8. Emergency Response Plan	Class 2	4	2	Class 2	4	2	24. Review leak detection and containment for cryogenic release.	
			1.2. Cryogenic impact on structure								24. Review leak detection and containment for cryogenic release.	
		2. External corrosion and pinhole leaks	2.1. Same as above		Class 3	5	1	Class 5	5	1		
		3. Human error (i.e. misconnection of cryogenic hose)	3.1. LNG spillage to environment and environmental impact. Potential cloud/ jet fire and safety impact	3.1.1. Refer to Node 3	Class 2	6	1	Class 3	6	1		
			3.2. Cryogenic impact on structure	3.2.1. Refer to Node 3								
		4. Relative motion of two vessels due to waves generated by passing vessels leading to unloading arm, hose and mooring line failures	4.1. LNG spillage to environment and environmental impact. Potential cloud/ jet fire and safety impact	4.1.1. Refer to Node 3	Class 2	6	1	Class 3	6	1	34. Review the effect of waves and body motion on unloading arm, hose and mooring lines.	
			4.2. Cryogenic impact on structure	4.2.1. Refer to Node 3								
		5. Operation beyond safe operating limit (e.g. overpressure, liquid carryover, overfilling, roll over)	5.1. LNG spillage to environment and environmental impact. Potential cloud/ jet fire and safety impact	5.1.1. Design specification 5.1.2. DCS system 5.1.3. ESD 5.1.4. HIPPS 5.1.5. Pressure relief system as per IGC 5.1.6. Standard Operating Procedure 5.1.7. F&G detection 5.1.8. Firewater system 5.1.9. Provision for emergency communication system 5.1.10. Emergency Response Plan	Class 2	4	2	Class 3	4	2	24. Review leak detection and containment for cryogenic release	
		6. Dropped object due to mishandling of heavy equipment	6.1. Potential damage to piping. Potential LNG spillage to environment and environmental impact. Potential cloud/ jet fire and safety impact		Class 2	5	1	Class 3	5	1	25. Consider perform dropped object/ mechanical handling study during subsequence project stage.	
	High pressure (98 barg) natural gas/ FSRU	1. Refer to Node 1										
	BOG/ FSRU - regas module, vent and tank	1. Mechanical failure (e.g. gasket/ flange/ seal failure, material defect (welds))	1.1. Loss of containment of natural gas leading to environmental impact and potential fire and explosion. Possibility of fire escalation to FSRU/ jetty area.	1.1.1. QA/QC process and technical bid evaluation 1.1.2. Compliance with international standard (e.g. API, IGC, SOLAS) 1.1.3. ESD 1.1.4. Standard Operating Procedure 1.1.5. F&G detection 1.1.6. Firewater system 1.1.7. Provision for emergency communication system 1.1.8. Emergency Response Plan	Class 2	6	1	Class 3	6	1		
		2. External corrosion and pinhole leaks	2.1. Same as above		Class 3	5	1	Class 5	5	1		
		3. Human error (i.e. misconnection of cryogenic hose)	3.1. Refer to Node 3									
		4. Operation beyond safe operating limit (e.g. overpressure, liquid carryover, overfilling, roll over, ship motion)	4.1. Loss of containment of natural gas leading to environmental impact and potential fire and explosion. Possibility of fire escalation to FSRU/ jetty area.	4.1.1. Design specification 4.1.2. DCS system 4.1.3. ESD 4.1.4. Pressure relief system as per IGC	Class 2	6	1	Class 3	6	1	26. Review the requirements for safe handling of excess BOG in FSRU.	

System: 4. FSRU Vessel

Hazard Category/ Guideword	Hazard/ Location	Top Event/ Cause	Consequence	Safeguard	Risk to Facility S	Risk to Facility L	Risk to Facility RR	Risk to Surrounding S	Risk to Surrounding L	Risk to Surrounding RR	Recommendations	Remark
				4.1.5. Standard Operating Procedure 4.1.6. F&G detection 4.1.7. Firewater system 4.1.8. Provision for emergency communication system 4.1.9. Emergency Response Plan								
		5. Dropped object due to mishandling of heavy equipment	5.1. Potential damage to piping. Loss of containment of natural gas leading to environmental impact and potential fire and explosion. Possibility of fire escalation to FSRU/ jetty area.		Class 2	5	1	Class 3	5	1	25. Consider perform dropped object/ mechanical handling study during subsequence project stage.	
2. Transport - Attendant vessels (standby, supply, flotel, others) - Passing vessels (fishing vessel, etc) - Passing helicopter or aircraft - LNG Carrier - Bunkering	Refer to Node 3											
3. Environmental: - Weather - Sea state - Earthquake - Tsunami - Lightning	Refer to Node 3											
	BOG/ FSRU - regas module, vent and tank	1. Lightning strike	1.1. Potential ignition of vent BOG leading to fire	1.1.1. Flame arrester 1.1.2. Lightning protection system compliance with international standard (e.g. IGC)	Class 3	6	1				27. Review the requirement for fire extinguishing system on vents. 28. Consider performing dispersion and radiation study on vent release.	
4. External Factors: - Piracy - Terrorism	Refer to Node 3											
5. SIMOPS/ Other Installations	Refer to Node 3											
6. Non- process Flammable Hazards: - Diesel - Chemicals / glycol water - Lube oil - Electrical fires - Explosive gas generators (batteries) - Calibration Gas (e.g. hydrogen)	Refer to Node 3											
7. Elevated Objects: - Dropped loads (overboard /onboard/ supply vessel) - Swinging loads - Anchor drop/ drag - Vent stacks	Refer to Top Event above for Dropped loads											
8. Structural Failure - Primary structures - Temporary structures	Refer to Node 1											
9. Occupational Health and Safety - Asphyxiants/ Drowning - Toxic Substances - High Pressure Liquid/ Gases - Extreme Temperature Fluids/ Gases - Ionising Radiation - Lighting discharge/ electrical hazards - Environmental emission source	No significant issue - should be review before start of operation											

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Table B1: Determination of Level of Risk Inside Plant Boundary

Risk		Consequences class	Consequences Class	Consequences Class	Consequences Class	Consequences Class
Frequency for all plant accidents	Cumulative frequency (per year)	5	4	3	2	1
Range 1	> 0,1	2	2	3	3	3
Range 2	0,1 to 0,01	1	2	2	3	3
Range 3	0,01 to 0,001	1	1	2	2	3
Range 4	0,001 to 10^{-4}	1	1	1	2	2
Range 5	10^{-4} to 10^{-5}	1	1	1	1	2
Range 6	10^{-5} to 10^{-6}	1	1	1	1	1
Range 7	< 10^{-6}	1	1	1	1	1

TOLERABILITY OF HAZARDS:

1 = normal situation

2 = ALARP region

3 = not acceptable

Table B2: Determination of Level of Risk Outside the Boundary Plant

Risk		Consequences class	Consequences Class	Consequences Class	Consequences Class	Consequences Class
Frequency for all plant accidents	Cumulative frequency (per year)	5	4	3	2	1
Range 1	> 0,1	2	3	3	3	3
Range 2	0,1 to 0,01	2	2	3	3	3
Range 3	0,01 to 0,001	1	2	2	3	3
Range 4	0,001 to 10^{-4}	1	1	2	2	3
Range 5	10^{-4} to 10^{-5}	1	1	1	2	2
Range 6	10^{-5} to 10^{-6}	1	1	1	1	2
Range 7	< 10^{-6}	1	1	1	1	1

TOLERABILITY OF HAZARDS:

1 = normal situation

2 = ALARP region

3 = not acceptable

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Table B3: Classes of Consequence for Hazard Assessment

	Criteria unit	**Class 1**	**Class 2** [a]	**Class 3**	**Class 4**	**Class 5**
Fatalities	Dead persons	More than 10	1 to 10	0	0	0
Accident with loss time	Injured persons	More than 100	11 to 100	2 to 10	1	0
Release of hydrocarbons	Tons	More than 100	10,01 to 100	1,01 to 10	0,1 to 1	Less than 0,1

[a] The class is close to SEVESO Directive criteria [Council Directive 96/82/EC of 9 December 1996 on the control of major-accident hazards involving dangerous substances].

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	JOB No.	DOC. No.	Rev.
TABEER ENERGY	0-8069-20	S-000-1240-005	1
	DATE 28 - Jun - 2019	SHEET 1 OF 15	
	PREP'D	D.Akinlade	
	CHK'D	N.Hara	
	APP'D	N.Hara	

MITSUBISHI PAKISTAN FSRU PROJECT
LNG RECEIVING FACILITIES
PRELIMINARY HAZARD AND OPERABILITY (HAZOP) STUDY REPORT

Pakistan LNG Receiving Facilities / FEED

Preliminary HAZOP Report

REV.	Date	Page	DESCRIPTION	PRE'D	CHK'D	APP'D
0	27 March 2019	All	Issue for Review	D.Akinlade	N.Hara	N.Hara
1	28 June 2019	No Change	For Final FEED	D.Akinlade	N.Hara	N.Hara

JGC JGC CORPORATION

Contents

EXECUTIVE SUMMARY

Environmental Resources Management (ERM), an independent Health, Safety and Environmental (HSE) consultancy, has been commissioned by JGC Corporation to perform a Hazard and Operability (HAZOP) study workshop for LNG Receiving Facilities in Mitsubishi Pakistan FSRU Project. JGC Corporation is responsible for the engineering design of the proposed offshore LNG receiving facilities in Pakistan.

This report summarises the methodology and key findings of the HAZOP Study for the LNG receiving facilities.

The objective of the HAZOP Study is to identify hazards and operability issues that may be encountered during the operation of the Project facility such that suitable safeguards (i.e. mitigation measures) could be incorporated in the design and / or in the operating procedures.

The HAZOP workshop was performed for 2 working days between 26 Feb 19 and 27 Feb 19. The HAZOP Study can be summarized as follows:

- Duration: 2 working days
- Nodes studied: 4
- Number of HAZOP recommendations: 39

Follow-up and close-out of all recommendations will be undertaken by the respective parties as indicated in the HAZOP worksheet and monitored by Engineering Contractor through their HAZOP Study recommendation close-out system.

1 INTRODUCTION

1.1 Background

JGC Corporation is responsible for the engineering design of the proposed Offshore LNG receiving facilities at Pakistan using Floating Storage Regasification Unit (FSRU) technology (hereinafter referred as "the Project") owned by Mitsubishi Corporation.

Environmental Resources Management (ERM), an independent Health, Safety and Environmental (HSE) consultancy, was commissioned by JGC Corporation to perform a Hazard and Operability (HAZOP) workshop study for the Project.

1.2 Scope of Work

The HAZOP workshop study covered the following facilities:

- NG Unloading Arm & Jetty to Pipeline
- Pipeline to Onshore & Metering Station
- Gas Sendout Line
- Fire Water System

1.3 HAZOP Objectives

The objective of the HAZOP Study is to identify hazards and operability issues that may be encountered during the operation of the Project facility such that suitable measures (i.e. mitigation measures) could be incorporated in the design and / or in the operating procedures.

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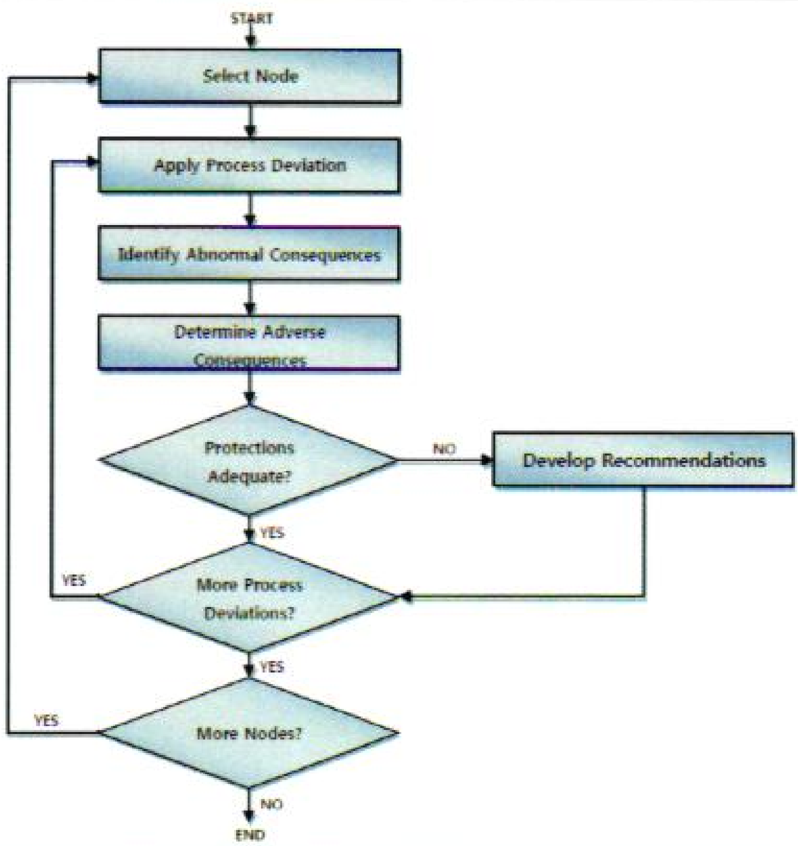
2 HAZOP METHODOLOGY

2.1 Overview

The HAZOP technique applies a combination of a Parameter and a Guide Word to generate a Deviation from design intent. The Causes and Consequences of each deviation are identified. Safeguards that can prevent or mitigate the hazards, and which are already provided in the design, are recorded. Where deemed necessary, recommendations are made to ensure that suitable consideration, modification or improvement is made to ensure safety and operability of the Project.

The HAZOP Study was conducted in accordance with IEC 61882 – Hazard and Operability Studies – Application Guide, Project HAZOP Procedure and other international standards. This approach was systematically applied to all sections within a Unit, such that safety and operability concerns on the complete system could be identified.

Figure 2.1 System Approach to HAZOP Study



2.2 Study Nodes

The Project was firstly partitioned into manageable sections (nodes) based on plant design and its complexity. A list of nodes and their descriptions for the Project are provided in ***Appendix B***. The Node List also includes design parameters, equipment numbers, reference drawings and any items that have been extracted from HAZOP Workshop for each node. The Nodes were marked on HAZOP Master P&IDs and summarised in ***Appendix E***.

2.3 Parameter and Guideword

The parameters applied to all nodes are flow, pressure, temperature, level, composition, failure, and operation start-up / shutdown / maintenance issues etc. It is noted that not all parameters are applicable to each node covered.

Deviations represent diversion from design intent of a process and can be identified by combining parameters with guidewords.

Each node was considered in detail to identify any potential deviation related to safety, machine damage, environment and / or operational problems that may arise due to changes in parameters.

Based on parameters and guide words, a Deviation is created from design intent. A list of Deviation used is depicted in ***Table 2.1***.

Table2.1 HAZOP Deviation

Parameter	Guide Word	Deviation
Flow	No / Less	1. No/Less Flow
	More	2. More Flow
	Reverse / Misdirected	3. Reverse/Misdirected Flow
Pressure	High	4. High Pressure
	Low	5. Low Pressure
Temperature	High	6. High Temperature
	Low	7. Low Temperature
Level	High	8. High Level
	Low	9. Low Level
Contamination or Change in Composition / Concentration	-	10. Contamination or Change in Composition / Concentration
Utility	Failure	11. Utilities failure
Start-up/Shutdown/Maintenance	-	12. Start-up/Shutdown/Maintenance
Others	Other	13. Others

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2.4 Causes and Consequences

The Causes and Consequences of each deviation were identified. The causes can be instrument malfunction, equipment trips, human errors (where applicable) etc. Only credible causes were identified for the HAZOP Study. The HAZOP team then evaluated the adequacy of existing safeguards in place. Additional safeguards may be proposed as Recommendations, if deemed necessary.

The potential consequences of each cause were discussed and assessed within the available information and expertise of the HAZOP team. The potential consequences were assessed without considering operator or instrument intervention or any mitigation or safeguards. Consequences focused on possible major effects in terms of personal safety, environment, production equipment damage and reputation.

2.5 Safeguards

The HAZOP team has identified safeguards that are effective in preventing or controlling the hazards. Only safeguards that are independent of initial cause of the deviation have been considered. Safeguards that depend on operator response to alarms have only been considered if sufficient response time is available. The time allowance was agreed with the HAZOP team at start of sessions.

2.6 Recommendations and Actions

The HAZOP team provides recommendations if the existing protective measures / safeguards are found to be inadequate. Actions are recommended to eliminate or mitigate any residual hazards that is considered significant.

Documentation / drafting errors are formalized after agreement with the HAZOP team through mark-up on HAZOP Master P&IDs, without registering a formal recommendation in the worksheets.

Follow-up and close out of recommendations will be undertaken by the responsible party as identified during the HAZOP Study.

3 STUDY ASSUMPTIONS

The following HAZOP premises were made as basis for discussion:

- All active safeguard should be assumed to fail. Passive safeguards may be assumed to succeed;
- No quantitative analysis will be performed during HAZOP meeting;
- If there is more than one train or pass, only one will be reviewed;
- Misoperation of manual valve due to operator error could be considered based on operator experience and recorded by exception;
- Impact on environment (e.g. dispersion) will not be analysed;
- No design work will be done;
- Mechanical protection devices (PSV, rupture disc) are expected to function on demand;
- Equipment is deemed suitable for the specified design conditions;
- Single check valve is adequate for contamination protection or excessive temperature unless special circumstances exist;
- Single check valve is adequate unless reverse flow may cause pressure to exceed test pressure; and
- Car sealed open valve are assumed to be controlled according to standard operation procedures.

The following assumptions / scenarios were not considered for the HAZOP workshop:

- Simultaneous occurrence of two (2) unrelated incidents, or simultaneous failure of more than one independent protection devices (double jeopardy);
- Natural event (flood, earthquake) except where it is a design case;
- Dropped objects on live line;
- Sabotage;
- Hazards arising from double jeopardy were not considered;
- Rupture of equipment or piping is not considered as probable cause of any HAZOP deviation, but may be a potential consequence as a result of system upset, resulting in potential hazard;
- In case of multiple equipment / systems (with duty and standby / spare equipment / system) inside a unit, the analysis was conducted for one set of equipment only. Any recommendations are applicable to all similar equipment / systems. Note that the analysis has taken into account the impact of simultaneous operation of systems in parallel or series, including control requirements and effect of trip of one system on the other; and
- Global utility failures (e.g. instrument air (IA), pressurised air (PA), electrical power, steam, cooling water or nitrogen) should be discussed separately for the respective nodes (subsystems). Local failure associated with control valve failures to each will be examined one by one at each HAZOP node.

The following items are deemed as protection / safeguard for HAZOP analysis:

- Interlock / shutdown system / trip;
- Alarm system for operator action;
- Mechanical protection device;
- Sample monitoring system combined with alarm for operator action;
- Operating instruction and operating manuals;
- Car sealed open/ car sealed close valve (CSO / CSC);
- Holding time criteria should be explained at the start of the session for general understanding in terms of response time necessary to take some action;
- The plant will be well maintained with daily care and equipment surveying;
- PSV is considered as a safeguard if it is sized based on the available information for the particular scenario;
- Appropriate and sufficient safety apparatus will be provided for the operating staff; and
- DCS continuously monitor electrical signals in the input and output system (between DCS and field instruments) and notifies the operator by alarm in case an erroneous signal is detected. At that time, output (control) signal will be locked and manoeuvrable by the operator from DCS. Loss of electrical signal will actuate the CV to the failsafe position as indicated in P&ID.

  DCS itself is highly reliable with a redundant system, which enables automatic change over to other systems in case any abnormal situation is detected by self-diagnosis.

4 HAZOP SESSIONS

4.1 Study Period

The HAZOP Study Workshop took place 2 working days between 26 Feb 2019 and 27 Feb 2019 at JGC office Yokohama, Japan.

4.2 Study Team

The HAZOP Study team comprised multi-disciplinary members involved in the Project and having experience in process design, operations, instrumentation and maintenance. The participants included representatives from Owner, Engineering Contractor, and Vendors. The HAZOP workshop was facilitated by ERM, an independent HSE consultancy.

The attendance record of workshop team members is listed in ***Appendix A***.

4.3 Workshop Recording and Reporting

The HAZOP session proceedings were recorded using PHA-Pro 8 developed by IHS (formerly Dyadem International). The worksheets were projected on a screen for comments and agreement by HAZOP team members during the HAZOP sessions. The completed HAZOP worksheets and recommendation list are presented in ***Appendix D***.

5 CONCLUSION & FOLLOW-UP

The HAZOP Study was divided into 4 nodes, and 39 HAZOP recommendations were identified by the HAZOP Study team for resolution or further investigation, as listed in ***Table 5.2***. The details of HAZOP worksheets and recommendation list are presented in ***Appendix D***. Discussion points needed to be discussed separately from HAZOP Workshop between JGC, owner and vendors are included in parking lot shown in ***Table 5.1***.

Table 5.1 Parking Lot to be discussed separately

No.	Discussion Point
1	Diesel refilling facilities to be discussed to be either manually or automatic
2	Jetty Water Spray for loading arms and ship sides
3	Implementation of wet system or dry system for fire water pumps system
4	Piping material specification for corrosion and marine growth issues
5	Continuously injection of biocide at water intake
6	Automatic activation by fire detection system
7	Fire water demand scenarios and philosophy to be reviewed
8	Check if the main fire water pumps casing is always full of water
9	Fire water pumps type and maintainability
10	Loading arm type and maintainability

Table 5.2 List of Recommendations

No.	Recommendations	Stage	Resp.	Place(s) Used
1	Confirm velocity through unloading arm is not an issue in case of second unloading arm is operating and FSRU reach the maximum operating pressure. Otherwise consider three arms operating philosophy.	EPC	EPC Contractor	1.1.1.2, 1.1.2.2
2	As per SIGTTO requirement, specify with vendor to provide limit switch for ERS valves with position indication to initiate ESD1.	FEED	JGC	1.1.1.1
3	Review the protection provided on the FSRU side after FSRU vendor selection and whether alarm is provided from FSRU side in case of pressure built up.	EPC	EPC Contractor	1.1.2.1
4	Provide alarm in case of 100ESDV004 is not open.	FEED	JGC	1.1.3.1
5	Review ESD requirement (fire and gas emergency) for 26 inch bypass line across 100ESDV004 as per ESD emergency philosophy.	FEED	JGC	1.1.3.1
6	Confirm tie in condition with pipeline company including minimal / maximum allowable / design temperature to align design temperature between FSRU and tie in point.	FEED	Owner	1.7.1.1
7	Confirm FSRU will shutdown in case temperature drop below 5 degC to align design temperature between FSRU and tie in point.	FEED	Owner/ FSRU vendor	1.7.1.1
8	Startup philosophy to be developed to avoid low temperature and embrittlement during startup.	FEED	JGC	1.12.1.1, 2.12.1.1
9	Confirm low pressure alarm is provided on the low nitrogen supply.	FEED	JGC	1.11.1.1, 1.11.1.2, 1.11.1.3, 3.11.1.1,

No.	Recommendations	Stage	Resp.	Place(s) Used
				3.11.1.2
10	Confirm if Emergency Diesel Generator provide backup power to Hydraulic Power Units (HPU) and Uninterruptible Power Supply (UPS).	FEED	JGC	1.11.2.1
11	Review the requirement to shut down the jetty on loss of power from FSRU. (Currently loss of power FSRU shutdown the entire jetty)	FEED	JGC	1.11.2.2
12	Make sure 100ESDV001/2A are provided with bleed to prevent high pressure gas trapped between valves.	FEED	JGC	1.12.2.1
13	Provide alarm in case of 300ESDV001 is not open.	FEED	JGC	2.1.1.1
14	Review ESD requirement (fire and gas emergency) for 26 inch bypass line across 300ESDV001 as per ESD emergency philosophy.	FEED	JGC	2.1.1.1
15	Confirm low pressure alarm on instrument air system is provided.	FEED	JGC	2.11.1.1
16	Develop a procedure for operating the check valve bypass line at CTS pipeline tie in point to prevent reverse flow from CTS pipeline.	FEED	JGC	3.3.2.1
17	Consider providing high pressure alarm upstream of CTS pipeline.	FEED	JGC	3.4.1.1
18	Specify overpressure protection in datasheet for analyzer house package 300-A-003.	FEED	JGC	3.4.2.1
19	Review piping spec location on the analyzer vent 300-NG-0015-1"-1CS1P-NI to prevent overpressure.	FEED	JGC	3.4.2.1
20	Confirm with pipeline company / buyer the requirement for spare analyzer.	FEED	Owner	3.13.1.1
21	Consider providing low temperature alarm on 300TI001 on the downstream of metering station.	FEED	JGC	1.7.1.1
22	Consider separating the vent for analyzer 300-A-003 to avoid continuous purging N2 and to prevent gas accumulation in the ORF vent stack 300-S-001.	FEED	JGC	3.11.1.2
23	Provide goose neck design on the jetty vent stack 100-S-001.	FEED	JGC	1.12.3.1
24	Provide goose neck design on the ORF vent stack 300-S-001.	FEED	JGC	3.12.1.1
25	Review the requirement for the automatic / remote shutdown valves at battery limit.	FEED	JGC	3.13.2.1
26	Provide low pressure alarm to indicate pressure drop before main water pumps 100-P-301A/B start.	FEED	JGC	4.1.1.1, 4.1.3.1, 4.1.4.1
27	Develop philosophy (S-000-1241-001) to ensure regular circulation of fire water with biocide to prevent fouling at the user side.	FEED	JGC	4.2.2.1
28	Review whether biocide is acceptable to be injected continuously for the main water pumps. (from environmental perspective)	FEED	Owner	4.2.2.1, 4.11.1.1
29	Check during EPC stage that valve 100PV811 fully open condition would not lead to end of curve condition.	EPC	EPC Contractor	4.3.1.1
30	Review at EPC stage whether pump shut off condition occurs in case of valve 100PV811 stuck closed.	EPC	EPC Contractor	4.5.1.1
31	Perform surge analysis during EPC stage.	EPC	EPC Contractor	4.3.2.2
32	Specify fire water pumps to be designed with sufficient allowance for fouling and corrosion.	FEED	JGC	4.2.2.2, 4.11.2.1

No.	Recommendations	Stage	Resp.	Place(s) Used
33	Review the acceptability of automatic timer for testing fire water pumps 100-P-301A/B.	FEED	JGC/ Owner	4.14.1.1
34	Develop procedure for biocide injection system to prevent biocide overdosing.	EPC	EPC Contractor	4.11.1.1
35	Review the requirement for biocide storage.	FEED	JGC	4.11.1.1
36	Provide pressure indication to indicate loss of nitrogen supply on volume bottles and indicate on PIDs with note.	FEED	JGC	4.12.1.1
37	Ensure the hydraulic power unit system for 100PV811 is on EDG.	FEED	JGC	4.12.2.1, 4.12.3.1
38	Review the lifting device / maintainability requirement for maintaining fire water pumps 100-P-301A/B and jockey water pumps 100-P-302A/B.	FEED	JGC/ Owner	4.13.1.1
39	Review the noise compliance for fire water pumps 100-P-301A/B operations. (not continuous operation)	FEED	JGC/ Owner	4.14.2.1

6 REFERENCE

[1] IEC 61882 – Hazard and operability studies (HAZOP studies) – Application Guide, International Electrotechnical Commission, First Edition, 2001

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[3] HAZOP: Guide to Best Practice, Brian Tyler , Frank Crawley and Malcolm Preston, Published by Institution of Chemical Engineers (IChemE), Second Edition, 2008

[4] HAZOP and HAZAN - Identifying and Assessing Process Industry Hazards, Trevor Kletz, Published by Institution of Chemical Engineers (IChemE), Third Edition, 1999

[5] Dyadem International Ltd, PHA-Pro – HAZOP Recording Software, Version8.2.0.0.

APPENDICES

1. Appendix A – Attendance Record
2. Appendix B – Node List
3. Appendix C – Drawing List
4. Appendix D – HAZOP Worksheet and Recommendation List
5. Appendix E – Mark-up Master P&IDs

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Appendix A

Attendance Record

Attendance Record

ERM

Project: JGC Pakistan LNG Terminal HAZOP		Week:	Attendance (please sign)					
Location: Yokohama, Japan			Monday	Tuesday Feb 26 19	Wednesday Feb 27 19	Thursday	Friday	Saturday
Name	Company	Position						
Herve Bonnel	ERM	Chairman		[signature]	[signature]			
Henry Hsieh	ERM	Scribe		[signature]	[signature]			
Damilola Akinlade	JGC	HSE		[signature]	[signature]			
~~Jun Gorada~~	~~JGC~~	~~Project Engineer~~						
Yusuke Konishi	JGC	Process Engineer		[signature]	[signature]			
OSAMU ADACHI	JGC	Process		[signature]	[signature]			
Satoshi Kanno	JGC	Fire Protection		[signature]				
Yuzo ISHINO	JGC	Project		[signature]	[signature]			
John Reiersen	HLNG	Eng. Mgr.		[signature]	[signature]			
TAVIS SUVIWIIVS	HLNG	Engineer		[signature]	[signature]			
Ho KONG TATEO	MC			[signature]	[signature]			
Yoichi Koizumi	Mitsubishi	Technical		小泉	小泉			
MOHSIN SIDDIQUI	GRANADA GROUP.	PROJECT ADVISOR.		[signature]	[signature]			
Koshu Fujita	MC	EM		藤田	藤田			
Takahito Koide	MC	PE		小出	小出			
Nobuhiko Higuchi	MC	Technical		樋口	樋口			
Yuta Ishida	MCX	Technical		石田	石田			
KAWASE Yukio	MC.	Advisor		[signature]				

I-DMS

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Attendance Record

ERM

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Project: JGC Pakistan LNG Terminal		Week: HAZOP	Attendance (please sign)					
Location: Yokohama, Japan			Monday	Tuesday Feb 26 19	Wednesday Feb 27 19	Thursday	Friday	Saturday
Name	Company	Position						
Jun Gotoda	JGC	PJE		後藤田	後藤田			
Hideki Otsuka	JGC	PJE		大塚	大塚			
YANG YANG	JGC	COMM		Yang	Yang			

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Appendix B

Node List

Node List

Node	Node Description	Design Conditions/Parameters	Drawings / References	Session
1. NG Unloading Arm & Jetty to Pipeline	Sendout capacity is from minimal 50 MMSCFD up to 1000 MMSCFD. Normal operation is intended to be 750 MMSCFD and might sift up to 1000 MMSCFD during high demand seasons. The sendout system is operating under ambient temperature. 2 unloading arms are operated and one standby as spare. A permanent vent stack is provided for maintenance. Temporary pig launcher is provided for construction and as required.	Operating Condition: Unloading Arm (each) Capacity: 500 MMSCFD. Pressure: - 115 Barg, Temperature: 50 degC, Material: low temperature carbon steel Jetty Vent Stack: Pressure: 3.5Barg, Temperature: - 70 - 80 degC, Material: SA	D-100-1225-001_Rev.1 D-100-1225-002_Rev.1	1. 26/02/2019
2. Pipeline to Onshore & Metering Station	Refer to Node 1	Operating Condition: Metering Station Capacity: 50 - 1000 MMSCFD, Pressure 115 Barg, Temperature: -29 - 75 degC	D-300-1225-001_Rev.1 D-300-1225-002_Rev.1	1. 26/02/2019
3. Gas Sendout Line	Refer to Node 1	Operating Condition: Analyzer House Package Pressure: 115 Barg, Temperature: -29 - 75 degC ORF Vent Stack: Pressure: 3.5 Barg, Temperature: -70 - 80 degC, Material: SA	D-300-1225-003_Rev.1	1. 26/02/2019
4. Fire Water System	Two firefighting water pumps with capacity of 2000 GPM are provided with jockey pumps 30 GPM for jetty area as per NFPA 20 standard.	Operating Condition: Water Pumps with Fuel Tanks: Capacity 454.3 m3/h, Design Pressure: 12.5 Barg Fire Water Jockey Pumps: Capacity 6.9m3/h, Design Pressure: 12.5 Barg Elevated Fire Water Monitor: Capacity: 228 m3/h, Design Pressure: 12.5 Barg	D-100-1225-801_Rev.0 D-100-1225-802_Rev.0 D-100-1225-803_Rev.0	2. 27/02/2019

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Appendix C

Drawing List

Drawing List

Drawings	Description	Nodes Used
D-100-1225-001_Rev.1	NG Unloading Arms	Node: 1
D-100-1225-002_Rev.1	Jetty to Pipeline	Node: 1
D-300-1225-001_Rev.1	Pipeline to Onshore	Node: 2
D-300-1225-002_Rev.1	Metering Station	Node: 2, 3
D-300-1225-003_Rev.1	Gas Sendout Line	Node: 3
D-100-1225-801_Rev.0	Fire Water Pumps	Node: 4
D-100-1225-802_Rev.0	Fire Water Jockey Pumps	Node: 4
D-100-1225-803_Rev.0	Fire Water System	Node: 4