Lloyd's Register Energy

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# Review of proposed solution for Gib Elec LNG terminal

Report for:
Gibraltar Electricity Authority

Report no: 105913-2/R1 Rev: C
Date: 15 October 2015

# Review of proposed solution for Gib Elec LNG terminal

**Security classification of this report:** Distribute only after client's acceptance

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# Document history

| Revision | Date | Description/changes | Changes made by |
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| Draft A | 5 October 2015 | For comment | Raymond Netland, Tony Gjerde, Knut Jøssang |
| Rev. B | 9 October 2015 | A review of HSL's report is included.<br>Minor corrections to wording and spelling | Raymond Netland, Knut Jøssang |
| Rev. C | 15 October 2015 | A technical note for HSL's report and additional information included.<br>Minor corrections to wording and spelling | Raymond Netland, Knut Jøssang |

# Executive summary

On behalf of Gibraltar Electricity Authority (GEA), Lloyd's Register EMEA (Lloyd's Register) has carried out a study of Shell's proposed solution for a LNG terminal facility located at the port of Gibraltar. The objective of the study has been to review the proposed design with regard to safety and to evaluate the extent to which applicable regulation, safety rules and common industrial standards and practices have been considered and applied.

The review consist of three main parts; preparation, review meeting and following evaluations based on the review meeting. The concept selection, hazards identification (HAZID) and Quantitative Risk Assessment (QRA) are examined in detail and observation and recommendations are given.

Upon request by GEA Lloyd's Register EMEA was asked to include a review of HSL's quantitative risk assessment report. The main deliverable from HSL is a "three-zone map".

The overall conclusion from the study is that Shell has offered a solution based on thorough engineering practices compliant with relevant legislation and practices for this kind of facilities applicable for Gibraltar and the UK HSE. However, as expected at this stage, some further development of the design is necessary in order to finally confirm that the eventual solution will be fully compliant.

Lloyd's Register EMEA support HSL's choice at this project stage to apply the upper bound frequency for catastrophic rupture of pressure vessels.

For Shell's proposed LNG terminal on the North Mole, HSL has made a "Do not advise against" decision. However Shell needs to further pursue risk reduction and demonstrate ALARP measures throughout the whole project.

# Glossary/abbreviations

| | |
|---|---|
| AIPSM | Asset Integrity Process Safety |
| ALARP | As low as reasonably practicable |
| BLEVE | Boiling Liquid Expanding Vapour Explosion |
| BOG | Boil-Off Gas |
| cpm | chances per million |
| ESD | Emergency Shut Down System |
| ERM | Environmental Resources Management Ltd (ERM) |
| GEA | Gibraltar Electricity Authority |
| GoG | Government of Gibraltar |
| HAZID | Hazards and risks Identification |
| HSE | Health and Safety Executive |
| HSL | Health and Safety Laboratory |
| HSSE | Health, Safety, Security and Environment |
| LNG | Liquefied Natural Gas |
| MoU | Memorandum of Understanding |
| QRA | Quantitative Risk Assessment |

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**Appendix A – Q&A sheet from review meeting with Shell**

# 1 Introduction

Under contract to Gibraltar Electricity Authority based on our Request for Consultancy Services signed 26th September 2015, Lloyd's Register EMEA has carried out a review of Shell's proposed solution for a LNG terminal facility located at the port of Gibraltar. The objective of the study has been to review the proposed design with regard to safety and to evaluate the extent to which applicable regulation, safety rules and common industrial standards and practices have been considered and applied.

The Gibraltar LNG terminal, will supply natural gas to the planned power plant located at the North Mole of Gibraltar harbour.

This document is a result of discourse with Shell personnel and review of confidential documentation made available by Shell during meetings held at Shell's premises in Rijswijk 29th and 30th September 2015.

The Gibraltar Electricity Authority (GEA) is in the process of constructing an 80 MWe dual-fuel power plant with prime intention to fuel the plant with LNG (~ 50 ktpa). As there is no gas available in Gibraltar a front end LNG terminal and regasification facility is required.

Shell and the Government of Gibraltar (GoG) entered into a Memorandum of Understanding (MoU) in September 2014 to initiate a concept selection study Shell presented their concept selection work in March 2015 and since then further developed.

Health & Safety Laboratory (HSL) has conducted an independent quantitative risk assessment based on Shell's proposed solution. The HSL report was issued and made available to Shell after the review of Shell's solution performed by Lloyd's Register EMEA. Upon request by GEA Lloyd's Register EMEA was asked to include a review of HSL's quantitative risk assessment report. The main deliverable from HSL is a "three-zone map". According to HSL this type of map is important with regard to how the Health and Safety Executive (HSE) give advice to local authorities in their domain: "Three-zone maps are key input to the process whereby the Health and Safety Executive (HSE) provides hazardous substances consent and land-use planning advice to local authorities in GB".

# 2 Objective

On behalf of Gibraltar Electricity Authority, Lloyd's Register has carried out a study of Shell's proposed solution for a LNG terminal facility located at the port of Gibraltar. The objective of the study has been to review the proposed design with regard to safety and to evaluate the extent to which applicable regulation, safety rules and common industrial standards and practices have been considered and applied.

In addition a review of the independent quantitative risk assessment report conducted by HSL has been requested by GEA.

# 3 Gibraltar LNG terminal

## 3.1 Concept development

The Gibraltar Electricity Authorities (GEA) is in the process of constructing an 80 MWe dual-fuel power plant, with prime intention to use LNG as fuel.

Shell and the GoG entered a Memorandum of Understanding (MoU) in September 2014 to initiate a concept selection study. During the concept selection study several concepts and locations were analysed.

The proposed concept is a small scale LNG terminal located in the Port at the North part of the North mole. The LNG terminal will be located on recently reclaimed land covering an area of approximately 100 x 150 meters.

The LNG terminal will be located adjacent to the power plant with a storage capacity of 5,000 $m^3$ (5 x 1,000 $m^3$) LNG. LNG shipment will take place by a dedicated LNG carrier, estimated at approximately 14 days intervals.

Important operational premises for the supply concept are:

- LNG offloading from LNG carrier will only be performed at night
- LNG offloading will not be performed whilst there is a cruise liner in the port

The project development conducted by Shell has followed Shell's internal systems for project development including full compliance with Shell's HSSE&SP control framework and relevant requirements for Asset Integrity Process Safety Management (AIPSM).

For projects with relatively small subcontractors such as this Shell set forward their technical requirements in portfolio requirements specification documents (PRS) instead of applying their Design and Engineering Practice (DEP) documents. The main difference in this respect is that in a PRS Shell's own DEP custodians and technical authorities have come together and selected the relevant requirements for the specific type of facility. It is considered to make it easier for subcontractors to comply with the project's process safety requirements as non-relevant requirements are taken away.

An important early phase activity is identification of hazards. All Identified risks are copied into the Hazard & Effects register. In this register actions are tracked in order to give an overview of all control and mitigating actions implemented throughout the entire project.

For the LNG terminal in Gibraltar the input to the H&E register has mainly come from two HAZIDs conducted during the concept study. The first HAZID was conducted in December 2014 and covered the FSRU alternative. A second HAZID was conducted in May 2015 covering the north mole alternative. The HAZIDs give input to the QRAs developed for the same alternatives. The H&E register was looked into in LR's review meeting with Shell. It appears to be in frequent use hence functions as a live document as intended.

Under the Discipline Controls and Assurance Framework (DCAF) a project control and assurance protocol is kept for each project and project phase. For the coming phases a list of forthcoming HSSE & SP activities are listed in the document "Gibraltar Project. Pre-Screening, Hazardous Consents Permit Application Advice. July 2015".

The following studies or documents will be developed for the next phase:

- Detailed HAZID
- HSSE Philosophy
- Bow-Tie Analysis for Major Accident Events
- Emergency Response Plan
- HAZOP
- SIL Classification
- Layout Review
- Human Factors Engineering
- Fire Safety Assessment
- Pressure System Safety Study/Safeguarding Memorandum
- Quantitative Risk Assessment (QRA)

In addition to the above a number of additional assessments are planned for the LNG import terminal addressing risks and safety issues identified during the conceptual HAZID.

Examples of additional assessments are:

- Vent study, including impact on airport operations and dispersion of methane from stack
- Ship collision study for LNG carrier at berth during night-time offloading
- Airport risk assessment to assess the risk of domino effects to/from airport operations
- Domino effects to/from incidents at the neighbouring power plant
- Impounding basin hazard assessment
- 3D gas dispersion modelling for wall design, physical barrier wall to protect the road and cruise terminal

The document "Gibraltar Project. Pre-Screening, Hazardous Consents Permit Application Advice. July 2015" describes the planned way forward for Shell to ensure compliance with United Kingdom Health and Safety Executive COMAH regulations.

## 3.2 Proposed location and site description

The proposed location of the selected concept, an LNG terminal located at the North part of the North mole, is shown in Figure 3.1. The figure shows an overview of the Port of Gibraltar, with a blue square indicating the proposed LNG terminal location


Figure 3.1 - Overview of Port of Gibraltar. The blue square indicates the proposed LNG terminal location

The port is subject to controlled access, and is primarily used for industrial purposes. A cruise liner terminal is located at the south of the site. Visiting cruise liners are normally moored during daytime, and cruise liner arrivals are scheduled ~ 2 years in advance.

During a cruise liner stay there will be passengers passing through the port to the downtown area using the public access road.

Taxis and public transport vehicles are normally stationed outside the ports exit gate.

The airport is located northeast of the site. Typically there are up to five take-offs and landings per day taking place during daylight hours only.

There is a navigation channel north of the site used by the ferry to Tangier and boats sailing to/from the sport marina. This area is also adjacent to the west approach for the airport.

The power plant will be located east of the site, and warehouses are located further east in the port. Residential areas are located outside the port on the eastern side.

# 4 Review of safety studies

## 4.1 Methodology

The review consist of three main parts; preparation, review meeting and following evaluations based on the review meeting. The concept selection, HAZID and QRA are looked into in detail and observation and recommendations are given. The review results in the overall concluding remarks given in Section 6.

## 4.2 Preparation

Shell's pre-screening report "Shell. Gibraltar Project. Pre-Screening, Hazardous Consents Permit Application Advice. July 2015" was made available by Shell for Lloyd's to review prior to arrival.

## 4.3 Review meeting

The team from Lloyd's Register Consulting – Energy AS travelled to Shell P&T offices in Rijswijk, Netherlands where meetings were held 29-30th September 2015.

Prior to the meeting Shell P&T and Lloyd's Register Consulting – Energy agreed upon an agenda for the review meeting. The agenda is shown in Table 4.1.

Table 4.1 – Agenda for review meeting at Shell's premises

| Day | Time | Agenda item |
|---|---|---|
| Tues, Sept. 29 | 10:30 | HSSE, introductions |
| | 10:45 | Review purpose/objectives, agenda for week, and discuss outcomes |
| | 11:15 | Concept development |
| | 11:45 | Overview of selected concept |
| | 12:15 | Lunch |
| | 13:00 | HSSE studies for concept |
| | 13:30 | Review of HSSE studies (review of printed copies of HAZID, QRA) |
| | 15:30 | Plan of development – HSSE studies & ALARP process |
| | 16:00 | Review Day 1 Q&A register |
| Weds, Sept. 30 | 09:30 | Review agenda for day 2 |
| | 10:00 | Update on open questions from Day 1 |
| | 10:30 | Regulations, standards and norms for the development |
| | 11:00 | Further questions following review of HAZID and QRA |
| | 12:00 | Lunch – 1st floor restaurant |
| | 13:00 | Update on open questions from Day 2 morning sessions |
| | 14:00 | Closing remarks |

All agenda items were covered All questions raised by Lloyd's were responded to in an open and constructive way, Shell allowed for sufficient time for the Lloyd's team to conduct the review as well as providing availability personnel as required.

## 4.4 Document review and examination

The following documents have been reviewed during the course of this study:

Prior to visit:

- Shell. Gibraltar Project. Pre-Screening, Hazardous Consents Permit Application Advice. July 2015

During visit:

- Shell. SR.15.12823 Gibraltar LNG Terminal Conceptual HAZID. 30th July 2015
- ERM. Gibraltar Onshore Phase 2 QRA, Gibraltar LNG Onshore Terminal – Design with 5 x 1,000 $m^3$ LNG Tanks. 0278551-R04. 28th August 2015

The following documents were made available during the review:

- PRS 30.06.10.34 – Gen.
- DEP 31.06.15.10 - Gen.
- Current version of the Hazard & Effects register, revision date 29.09.2015
- Technical note - assessment of credible scenarios to be used in the QRA
- Minutes of Meeting, Shell internal discussion of the QRA results
- PCAP list for this project and the current project phase

As part of the review a Question & Answer log was recorded by Shell. The Q&A log is found in Appendix A.

Additionally GEA has request Lloyd's Register EMEA to include a review of HSL's quantitative risk assessment report:

- Health & Safety Laboratory Project Note. Three-zone map for Shell Gibraltar LNG storage design concept. Rev. 2. Project reference number: PE03136. Date 6th October 2015

# 5 Observations

## 5.1 Concept selection

The chosen concept of the terminal is a result of a thorough process performed by Shell during the concept phase. Several concepts have been considered and assessed located both inside and outside the port.

Concepts involving floating storage and regasification units (FSRUs) have been assessed, both moored nearshore and inside the detached mole.

For the onshore alternatives, different types of storage tank arrangements have been assessed such as atmospheric full containment tanks and pressurized iso-containers and bullet tanks.

Benefits for the proposed solution i.e. onshore bullet tanks located on the north mole are by Shell considered as:

- The LNG terminal concept is simple
- Nearshore concepts involving FSRUs is considered to increase risk for ship collision
- A nearshore LNG terminal will require a sub-surface pipeline connected to the power plant whereas an onshore LNG terminal adjacent to the power plant reduces the amount of piping, thus considered to reduce the risk
- The pressurized double walled stainless steel vacuum insulated bullet tanks are considered beneficial from a safety and operational perspective. Double walled full containment tanks are considered to enhance safety as it includes doubled barriers. The fact that the outer

vessel is made of stainless steel rather than carbon steel, further reduces the risk for full rupture events

- Pressurized tanks require less equipment to manage the boil-off gas (BOG). In this case BOG management equipment is not considered necessary as the BOG will be handled by the operational window the pressurized tanks allow for
- No venting during normal operations
- Detached mole is not designed nor built for mooring of large vessels, such as FSRU's and LNG carriers
- A small scale LNG terminal is considered to impose less construction risk as opposed to larger LNG terminals. This is based on general considerations of total number of man-hours and the complexity of the alternatives
- An onshore LNG terminal requires shorter construction period than for offshore concepts. Shell anticipates that their proposed solution will meet the power plant start-up date

A preliminary safety philosophy is developed for the LNG terminal, which will be further matured during the later project phases. Shell has based the current safety philosophy on previous project experience, internal requirements and standards as well as HSE requirements.

## 5.2 Risk assessment

There have been conducted QRAs for both the detached mole FRSU and the onshore North mole alternatives proposed by Shell. Shell's own judgement of the latest location proposed, on the northern mole adjacent to the new electrical power plant, was to conduct a QRA for the LNG terminal in this location in order to be able to conclude if this was a feasible option. ERM was contracted for conducting this QRA.

The QRA carried out by ERM does not follow a standard Shell methodology for QRAs. The reason for this is explained to be due to uncertainties regarding HSE/HSL's jurisdictions in Gibraltar, hence Shell decided to conduct this analysis in a similar way as would be the case if the proposed LNG terminal had been located in England. This is by Shell considered to lead to the most stringent assessment of the Gibraltar LNG terminal. Normally, when planning for similar facilities in the UK, HSL assess the planned facility by application of their own methodology and tools and advices accordingly. Shell therefore engaged ERM to conduct this QRA in the same way as HSL would perform the analysis. The choice of ERM was partly due to ERM's experience with similar onshore facilities in UK and that they for this particular assignment would use consultants with such particular experience.

Shell considers that there are still some challenges with regards to specific key inputs:

1. HSL apply in-house tools which are not publically available. Thus, one was aware that some intermediate QRA results would not be identical to HSL results. One example is related to gas dispersion calculations. ERM applied recognised software codes to model the consequences from potential hazards in the risk analysis. This software code is recognised by the industry to be applicable for the relevant hazards including gas dispersion
2. HSL selection of most credible worst case scenarios

   A thorough assessment of the credible scenarios has been performed by Shell. Shell summarized their evaluations and argumentation in a technical note which was looked into in the review meeting with Shell. The technical note is not a controlled document and carries no doc. number, approval date or revision no.

   The technical note gives guidance to the contractor (ERM) regarding which MHA scenarios to be analysed in the QRA. Shell has in their assessment excluded BLEVE and escalation of fire between the LNG storage tanks
3. How HSL would categorise the cruise ship terminal relative to the land use planning acceptance criteria (i.e. Level 2 or 3)

4. ERM use generic failure frequencies published by HSE. However, the rupture frequency for the bullet LNG storage tanks could not be taken directly from this information as HSE simply do not publish rupture frequency for this category of storage tanks separately. ERM apply HSE failure frequencies for single shell LPG storage tanks. Failure frequencies for horizontal bullet tanks are can be found in the Dutch Purple Book. Rupture frequencies from Dutch purple book are applied in one of the sensitivities to the base case. The result from this sensitivity indicates reduced risk level for the proposed LNG terminal. This is demonstrated by the iso-risk contour plots

The QRA contains an overview of risks and how specific scenarios and hazardous outcomes contribute to the risk picture of the facility. However, this is limited to the equipment in the LNG terminal only.

Lloyd's Register would like to recommend a complete list of how the surroundings contribute to the risk from the LNG terminal. As required by the latest version of the COMAH framework. In the future course of this project, it is anticipated that the latest COMAH framework is applied (COMAH was updated by HSE in the summer of 2015).

Results from the QRA conducted by ERM show that both the base case and sensitivity A have overlap between the middle zone (i.e. 1 cpm contour) and Level 3 areas.

The ambient temperatures used in the calculations in the QRA are limited to 15 °C at daytime and 5 °C at night. It could be a good approach to perform a parameter sensitivity of the ambient temperatures used in the calculations to assess the effect of the ambient temperatures. The choice of other ambient temperatures is believed to have limited impact on the risk results.

The worst credible scenario included in the QRA is full instantaneous rupture of one of the five LNG tanks. The possibility of escalation from one tank to another is not evaluated in the QRA. This event has been evaluated internally in Shell. The following two scenarios leading to escalation from one tank to another are considered; a pool fire underneath the tanks heating an adjacent tank, and a jet fire from one tank impinging a neighbouring tank. The argumentation for escalation not to take place is based on the following design mitigating barriers;

- Sloping ground in the concrete bund will avoid large pool formation directly underneath the tanks. In case of a jet fire, segmentation of the storage tanks equipped with ESD valves will limit the amount of LNG contained per segment
- The design (double wall) will withstand relatively large doses of external heat

Shell's "Technical note - assessment of credible scenarios to be used in the QRA" was shared with Lloyd's Register Consulting during the review meeting.

A BLEVE (Boiling Liquid Expanding Vapour Explosion) scenario is not included in the risk quantification, but the consequences associated with a BLEVE are shown. Shell believes the double wall of the tank will withstand relatively large doses of external heat. The internal fire integrity assessment concludes that a BLEVE is not a credible scenario.

Crosswind scenarios are not considered in the QRA. I.e. direction of jet leaks are not the same as the wind direction. As Lloyd's Register understands all jet leaks evaluated in the QRA are aligned with the wind direction hence the wind direction defines the direction of the jet release. Close to a jet leak, the jet momentum dominates and the direction of the dispersion is approximately the same as the direction of the jet leak. Further away from the leak point, the external wind forces will dominate the jet direction and the initial direction of the jet has reduced impact. The approach used in the calculations in the QRA is considered represent a more conservative view of the stretch of the gas dispersion than when more realistic crosswind scenarios are applied.

## 5.3 Independent quantitative risk assessment by HSL for the proposed concept at the North Mole

Health & Safety Laboratory (HSL) has conducted an independent quantitative risk assessment in parallel with the review of Shell performed by Lloyd's Register EMEA. After HSL issued their

report GEA requested Lloyd's Register EMEA to include a review of HSL's quantitative risk assessment report. In the report from HSL it is explained how they have developed a standard "three-zone map". According to the HSL the calculations of the "three-zone map" uses HSE's standard methodology, software and input assumptions. In the report HSL has also discussed further information provided by Shell in relation to the "three-zone map" input assumptions.

In general HSL has used the same input parameters for the proposed LNG terminal as ERM and Shell have used in their analysis. However, the frequency for catastrophic failure, which is an important basis input parameter, is set more conservatively. The end result from HSL shows shorter risk ranges than is the case for Shell's internal risk studies. It is anticipated that the reason for this is mainly related to modelling tools and methods, e.g. gas dispersion modelling and ignition probability model that is applied.

The result for the base case calculated by HSL is seen in Figure 5.1 below:

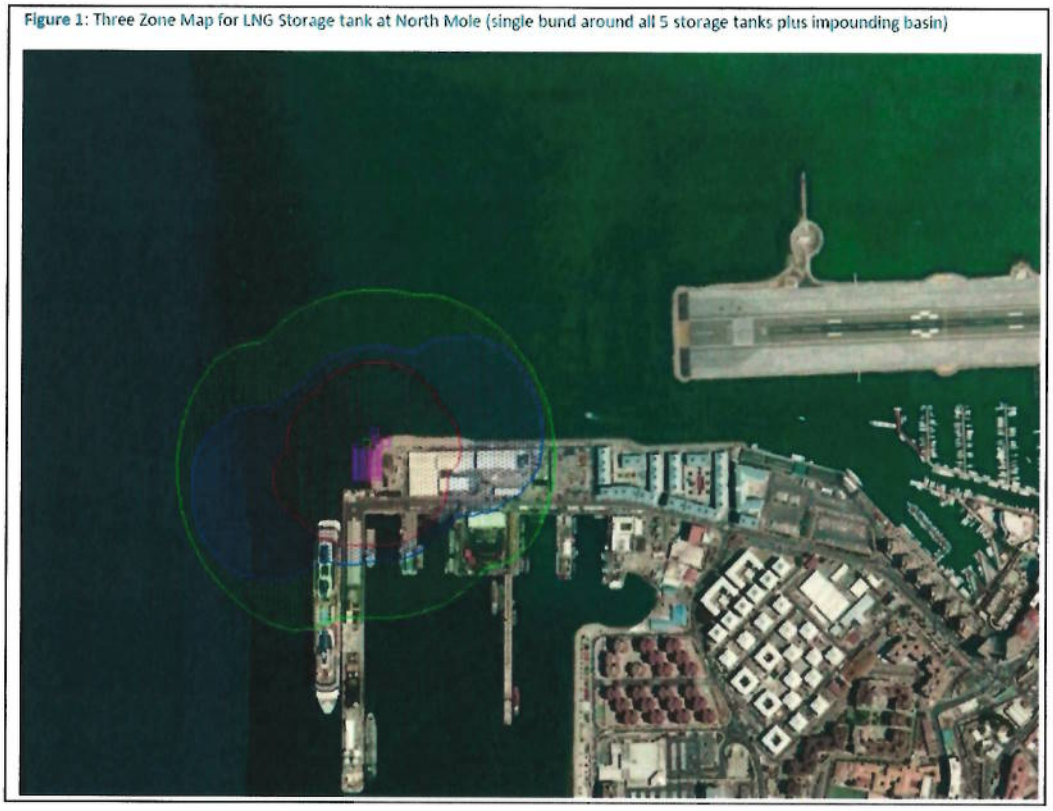


Figure 5.1 - Risk picture (3 zone map) developed by HSL for Shell's proposed base case

HSL's report shows that the middle (blue) zone does not cover the residential area east of the LNG storage facility proposed location.

A catastrophic rupture of one LNG tank is the worst credible scenario evaluated both in the QRA provided by ERM and HSL. The frequency of this scenario has a relatively large impact on the total risk picture.

Table 5.1 – A comparison of HSE and PB99 failure frequencies (cpm) for pressure vessels, Ref. /2/

| Frequency of catastrophic rupture for pressure vessels | | | |
|---|---|---|---|
| PB "default" | PB "complete" | HSE "lower bound" | HSE "upper bound" |
| Sensitivity input in the QRA from ERM | | Basis input in the QRA from ERM | Basis input in the QRA from HSL |
| 0.5 | 5.5 | 2 | 6 |

The QRAs from ERM and HSL have different frequencies for catastrophic rupture of one LNG tank. Looking into the two data sources one will see that there are certain considerations the analyst have to assess depending on which data source and number that is chosen. The "default" frequency from Purple Book (PB) does not include any "external damage and (internal) domino effects", Ref. /1/. The "complete" frequency form Purple Book includes human error, external impacts etc., Ref. /2/.

The frequency used for the risk contours provided by ERM and HSL applies HSE "lower bound" and "HSE upper bound", respectively. Both choices can be justified; apply the "lower bound" as the tank design is double walled stainless steel tanks or apply the "upper bound" since the project is in an early stage and a conservative approach may be preferred.

The QRA provided by ERM includes sensitivities of the frequency of catastrophic rupture. The HSE "lower bound" and the Purple Book "default" frequencies are applied and the risk contours are compared. The differences are considerable.

For Shell's proposed LNG terminal on the North Mole HSL give the "Do not advise against". To this HSL themselves comment that: "For the Shell proposal, "Do not advise against" is appropriate provided that there is also a planning condition that Shell design the proposed physical barrier wall to protect the road and cruise terminal from fire scenarios, i.e. protection from thermal radiation from fire scenarios and to provide a vapour barrier to protect against flash fire. It is expected that such a barrier should be achievable. Shell should provide modelling results to HSL to demonstrate the suitability of the barrier as part of detailed design", i.e. Shell needs to further pursue risk mitigation and demonstrate ALARP throughout the whole project. One should note that this is common practice and required by law in the UK for such projects, and thus not an extraordinary requirement from HSE & HSL.

Shell has also provided HSL with an evaluation of the information and assessments carried out by Shell regarding BLEVE and catastrophic failure of the tanks. HSL agree to the conclusions in these assessments.

## 5.4 Reliability and availability of power supply

The LNG terminal concept design includes equipment redundancy on major equipment units to ensure a reliable gas supply to the power plant. Single major equipment units can be taken out of service for maintenance without affecting the gas supply, at LNG terminal design capacity.

The LNG pumps and vaporizers are the only flanged equipment units within the current design. All other equipment, piping, valves and instrumentation will be welded in order to reduce the number of potential leak points.

The power plant (outside Shell's scope of supply) has a total of 6 engines, which primarily will be fueled by gas from the LNG terminal. The 6 engines are rated for 80 MW in total. According to Shell, the typical power demand in Gibraltar is around 30 MW, which ensures that there is a high degree of redundancy on engine capacity.

Three of the engines will be dual-fuel engines and can run on diesel in case the LNG terminal is shut down. Diesel will always be required when starting-up power generation.

In order to ensure the highest degree of reliability and availability of power supply from the power plant, it is important that the power plant is able to withstand single equipment failures. A

single short circuit/fire on a switchboard/transformer should not impair the power plant's capability of providing sufficient power supply to the grid.

Redundant equipment units on the LNG terminal need redundancy in all utility and support systems on which they depend. As an example, the LNG pumps must be fed with power from different bus bars in order to achieve full redundancy.

Safety instrumented functions, fire and gas detection system and emergency shutdown systems are included in the concept design to ensure a high safety standard. All safety instrumented functions will be included in a Safety Integrity Level (SIL) classification, based on international recognized standards such as IEC 61508/61511, as well as Shell internal guidelines. This work was not started at the time of the review.

Later project phases will include Bow-Tie analysis for major accident events, which will identify safety critical elements and safety critical tasks.

## 5.5 Recommendations

The following list summarizes the recommendations given based on the review:

- A complete list of how the surroundings contribute to the risk from the LNG terminal. As required by the latest version of the COMAH framework, the QRA should not be limited to the risk picture of the facility only
- In the future course of this project, it is anticipated that the latest COMAH framework is applied (COMAH was updated by HSE in the summer of 2015)
- We recommend that all relevant project documents (including "Technical note - assessment of credible scenarios to be used in the QRA") be treated as controlled documents with document number, approval date or revision number included, in order to provide auditable assurance of correct control and authorisation
- We understand that HSL have reviewed and not objected to the rationales put forward in document "Technical note - assessment of credible scenarios to be used in the QRA". GEA should confirm that this is the case
- Perform a parameter sensitivity of ambient temperatures used in the calculations in the QRA to evaluate the impact on the overall risk picture

# 6 Conclusions

On behalf of Gibraltar Electricity Authority, Lloyd's Register EMEA has carried out a study of Shell's proposed solution for a LNG terminal facility located at the port of Gibraltar. The objective of the study has been to review the proposed design with regard to safety and to evaluate the extent to which applicable regulation, safety rules and common industrial standards and practices have been considered and applied.

The overall conclusion from the study is that Shell has offered a solution based on thorough engineering practices compliant with relevant legislation and practices for this kind of facility as applicable for Gibraltar and the UK HSE. However, as expected at this stage, some further development of the design is necessary in order to finally confirm that the eventual solution will be fully compliant.

Lloyd's Register EMEA support HSL's choice at this project stage to use the upper bound of the frequency of catastrophic rupture for pressure vessels.

For Shell's proposed LNG terminal on the North Mole, HSL has made a "Do not advise against" decision. However Shell needs to further pursue risk reduction and demonstrate ALARP throughout the whole project.

# 7 References


/1/ National Institute of Public Health and the Environment (RIVM): "Reference Manual Bevi Risk Assessments Introduction", The Netherlands, Version 3.2, 01.07.2009.

/2/ Clive Nusset: "Failure frequency for major failures of high pressure storage vessels at COMAH sites: A comparison of data used by HSE and the Netherlands", December 2006, available at http://www.hse.gov.uk/comah/highpressure.pdf.

Appendix A

# Q&A sheet from review meeting with Shell

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# 1 Introduction

As part of the review a Question & Answer log was recorded by Shell. This appendix includes the Question & Answer log as received from Shell after the review.

# Gibraltar LNG Terminal

## Gibraltar LNG Terminal - Concept Information Session Question & Answer Register

| | |
|---|---|
| **Subject:** | **Gibraltar LNG Terminal - Concept Information Session** |
| **Location:** | Shell Projects & Technology, Lange Kleiweg 40, Rijswijk, NL |
| **Day and Date:** | 29-30 September 2015 |
| **Meeting chaired by:** | Shell |
| **Minutes recorded by:** | Shell |
| **Attendees:** | **Lloyds Register Consulting - Energy AS**<br>Knut Jossang, Consultant<br>Tony Gjerde, Team Manager / Senior Consultant<br>Raymond Netland, Principal Consultant<br><br>**Shell** |

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This document provides a register of the Questions and Answers captured during the three day event in Shell Projects & Technology offices in Rijswijk, NL from 29 - 30 September 2015.

**Gibraltar LNG Terminal - Concept Information Session**
**Questions & Answer Register**
**29 September - 1 October 2015**

| # | Originator | Question Raised | Session | Information Shared in Response | Closed? | Comment | Slide |
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| | Day 1 | | | | | | |
| 1 | R. Netland | Is there a PCAP? | Introductions | Yes, there is a deliverables list based on the scaled PCAP using in Sapphire Framework | Closed | | |
| 2 | T. Gjerde | Will the power plant have backup diesel generators in case of interruption of LNG supply? | Concept development | Yes, three of the power plant engines are dual fired. | Closed | | |
| 3 | R. Netland | How is Shell operating Coral Methane? Is it under Shell operational control / 100% Shell management system? | Concept development | Coral Methane is under Time Charter. The vessel is operated by Anthony Veder and as per ISM code will be under their management systems. In addition, Shell has a robust process of completing management review and vessel clearance by our vetting team. | Closed | | |
| 4 | R. Netland | Are the ESDVs connected to LNG tanks welded or flanged? | Overview of selected concept | Design basis is for welded | Closed | | |
| 5 | R. Netland | Is the ERS independent of the ESD system? | Overview of selected concept | Yes, but requested to come back to this. | Closed | | |
| 6 | R. Netland | How does the system avoid venting? | Overview of selected concept | During offloading from LNGC, pressure in LNG tanks would reduce due to subcooled LNG collapsing the vapour pressure. The boil off can be managed much better in pressurised tanks as the margin is e.g. 2barg rather than 30mbarg in an atmospheric LNG tank. The modelling has been correlated to Gasnor operational experience | Closed | | |
| 7 | R. Netland | Is there still the possibility of venting for emergency cases? | Overview of selected concept | Yes, e.g. PSVs and TRVs would be routed to vent | Closed | | |
| 8 | T. Gjerde | Can we look into more detail on further work on SIS, ERS and ESD? | Overview of selected concept | There is generic Safety Instrument design based on the PRS Bunkering and Regasification ammendment, and DEP. | Closed | | |
| 9 | T. Gjerde | Are there any novelties in this concept? | Overview of selected concept | No. Components (tanks, arms, LNGC, vapouriser, etc) are present in industry and other developments, e.g. Gasnor | Closed | | |
| 10 | R. Netland | Does the ERM QRA follow HSE methodology? | Safety studies | As close as ERM could without HSL methodology tools. HSE has their own dispersion model, for example. HSL is assessing our concept with their methodology this week. ERM has used recognized Industry software.<br><br>Shell needs to do a Risk Assessment internally following our own procedures, but we used the public available data from HSE instead our credible frequency failure.<br><br>The only thing that Shell didn't follow was to consider the BLEVE scenario because we don't believe that as a credible scenario for Gibraltar concept. Note submitted to HSL.<br><br>HSL have confirmed that BLEVE is not a credible scenario. They have provided a "do not advise against" decision for the development. | Closed | | |
| 11 | R. Netland | Have Shell used the HSE acceptance criteria?<br>Thermal dose criteria used?<br>Not toxics?<br>Narcotics effect? | Safety studies | Yes. LUP has been develped based on TDU.<br>TOXICS: not toxics on this terminal.<br>NARCOTICS: it is not considered in the hydrocarbons QRA. | Closed | | |
| 12 | R. Netland | Has it been any consideration on explosion in the QRA? | Safety studies | Yes, but it is a very open location and layout. Explosion vapor clouds have been assessed in the ERM QRA. Only the vaporizers and pumps' area can be relatively congested but still small. | Closed | | |

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| 13 | R. Netland | Rapid Phase Transition has been considered? | Safety studies | It has been discarded the possibility to LNG spill on the sea water in normal operation due to the physical barriers. There is still the possibility of small spill during LNG offloading from the LNGC. Shell has done assessment on the RPT on sea water during offloading, even for FLNG, with small consequencies. | Closed | | |
| 14 | R. Netland | Different ignition probabilities in different locations | Safety studies | The ERM QRA assumed that flash fires would be based on the maximum extent to the Lower Flammable Limit. In discussion with HSL, it became clear that the HSL methodology used a progressive gas dispersion model and therefore flammable gas clouds would be included at different time steps of development. This would result in less conservative flash fire scenarios (smaller flammable gas clouds) than have been modelled in the ERM QRA and could result in smaller Land Use Planning Outer Zones. This is relevant to the issue of varying ignition probabilities, because the maximum extent of LFL for the conservative **catastrophic failure of LNG tank scenario could reach residential areas in the ERM** modelling and an ignition probability of 1 was assumed in the ERM QRA for vapour clouds that reached this location. | Closed | | |
| 15 | R. Netland | P.15/ 3.3.2 Sensitivities analysis. Is the isolation measures considered in the base case? | Safety studies | ESD valves are in general not considered, but there are some scenarios where they are included, as the outlet of the tanks and the ERS from the transfer arm. | Closed | | |
| 16 | R. Netland | P.11 table 3.10 is considering ship collision? | Safety studies | Table 3.10 includes frequencies of arms disconnection.<br>Ship collision is not included because the ship berth time is very limited (8h every two weeks) and the North Mole location doesn't include high navigation activity. Detailed assessment will be done together with the Port Authorities to assess if some measures will be required. | Closed | | |
| 17 | R. Netland | The concept of the base case of the QRA, is there any ALARP reduction in design from the study? | Safety studies | During HAZID study we already identified some potential ALARP design improvements: reduce volume per tank, reduce number of tanks to minimize inventory, piping orientation, process area location, hard arm instead of flexible hose, ... | Closed | | |
| 18 | R. Netland | As a risk event has it been considered terrorist attack? | Safety studies | It has been considered in our Security Assessment. The outcome of the assessment is that Gibraltar as "low security risk based" because of the "high security". It has not been included in the QRA. | Closed | | |
| 19 | R. Netland | Is there any independent verification for assurance? Special regards to safety critical elements. | Q&A review | We haven't assessed that aspect yet. A verification plan will be developed and if required, independent entity will be involved. | Closed | | |
| 20 | R. Netland | Management of Change is part of the project development plan? | Q&A review | Yes. The project will be executed by Gasnor, which is a Royal Dutch Shell (RDS) subsidiary and therefore is subject to the RDS HSSE&SP Control Framework. Under the HSSE&SP Control Framework, there is a Process Safety Basic Requirement to implement a Management of Change procedure. This is a mandatory requirement and hence will be applied to the Gibraltar project and future operations. | Closed | | |
| 21 | R. Netland | Flowless project delivery | Q&A review | Not part of the SADPM. Developed normally for major projects. Some experience from the FPD will be applied. | Closed | | |
| | Day 2 | | | | | | |
| 22 | R. Netland | HAZID #23 Is it affected the LNG terminal BOG management by the warm LNG offloading? | | No. Based on the dynamic simulations performed, even the offload of warm LNG will not cause any pressure increase effect that can't be managed building up pressure on the tank. External BOG management system in the LNG terminal is not required.<br><br>Coral Methane will steam out the extra BOG if required, sailing out of the bay. | Closed | | |

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| 23 | R. Netland | Has it been considered different effects on ambient temperatures on the gas dispersion? (see chapter 3.5 on QRA) | | HSL have also used these conditions for their analysis. The majority of the release are jet's which will not be significantly affected by this assumption. For the pool release there would be some influence on the vapour generation rate with time. But since the input to the QRA has used a maximum vapour rate into a steady state dispersion calculation is believed to be less of an influence. | Closed | | |
| 24 | R. Netland | How has dispersion been modeled when it comes to a combination of jet leak direction and wind direction? | | The scenarios are modelled as ellipses which take wind direction into account. The wind direction is in the direction of the pressurised release, which could provide a conservative view on the length of the flammable gas release. In general for methane releases, it is expected that the vapour cloud would reach LFL before the wind direction dominates the momentum of the pressurised release and hence the results are not expected to be highly sensitive to wind directions across the pressurised jet. | Closed | | |
| 25 | R. Netland | Is there weather restriction for offloading operations? | Documents review | Yes. There is limits on metocean conditions to berth and offload the LNGcarrier (wind, Hs, currents) | Closed | | |
| 26 | R. Netland | What is in the surroundings that can be a threat to the LNG terminal? It is missed a clear list on the surroundings potential risks. | Documents review | See attached list in comment column | Closed | Q26.pdf | |
| 27 | T. Gjerde | Has it been considered if LNG terminal **upsets can cause an impact on the power** supply to Gibraltar due to the switch from gas to diesel? | Documents review | The LNG terminal will be designed according to our reliability and availability requirements. It is not in our scope to define the power supply availability. | Closed | | |
| 28 | R. Netland | Has Shell considered other LNG terminal concepts, including storage types? | Documents review | Yes. During screening and identify phase it has been assessed different terminal concepts (FSRU, offshore, onshore) and different type of storage tanks (atmospheric concrete full containment, isocontainers, bullet tanks..) The **pressurized double wall bullet tanks were chosen because: It is not required BOG** management equipment and the BOG can be handle building up pressure on the tanks, less inventory per tank, proven technology, experience in design and operation, less construction risk, no rollover risk... | Closed | | |
| 29 | R. Netland | Has it been considered any impcat on the aviation activities? | Documents review | Yes. Meetings with the Wing Commander and Civil Aviation Director have been hold to assess preliminary impacts of the LNG facility on the airport activities and risk register. The requirements from the Airport Authorities is to perform an Aeronautil Study. In the Aeronautical Study it will be included any potential emissions from the LNG terminal, during normal operation or leaks. | Closed | | |
| 30 | R. Netland | In the QRA for the base case there is an overlap on the level 3 and the residential areas. Based on this result, how would Shell conclude on the results of the base case. | Documents review | During the meeting LR-Shell, Shell showed MoM of internal workshop involving Subject Matter Experts and Senior Managers, where it was concluded that this development was safe and feasible for Shell and the base case QRA was conservative.<br><br>The HSE methodology and guidelines are very conservative and we consider that the base case is not a credible worst scenario. As an example, the cold catastrophic failure with immediate release for the tanks with the same frequency of failure as an LPG single CS wall tank, not giving credit to the double wall or getting better frequency failure (as Dutch Authority) | Closed | | |
| 31 | K. Jossang | Why the worst case credible scenario included in the QRA as base case only considers one tank? | Documents review | The terminal will be design to avoid any escalation. Mitigation barriers as: storage area sloped to an impounding basin to take away any LNG leak from tanks underneath, ESD valves to limit LNG inventory in case of leak or jet fire, welded pipes and instruments, internal fire integrity assessment has performed (Note from Shell Major Hazards has been shared with HSL 25th of September) | Closed | | |

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| 32 | K. Jossang | To increase the ALARP risk on the design will be included walls from Terminal to the public road. More information | Documents review | A wall will be designed between the LNG terminal and the public road for several reasons: physical barriers for disperson/fire/explosion (experience from Harljhem terminal), barrier for visual impact and for security reasons. A CFD study will be performed in the next stage of the development. | Closed | | |
| 33 | T. Gjerde | Will the impounding basin pump be tripped on fire and gas or low temperature | Documents review | This has not yet been designed. However, expected design practice for the pump is that it will trip on confirmed gas. | Closed | | |