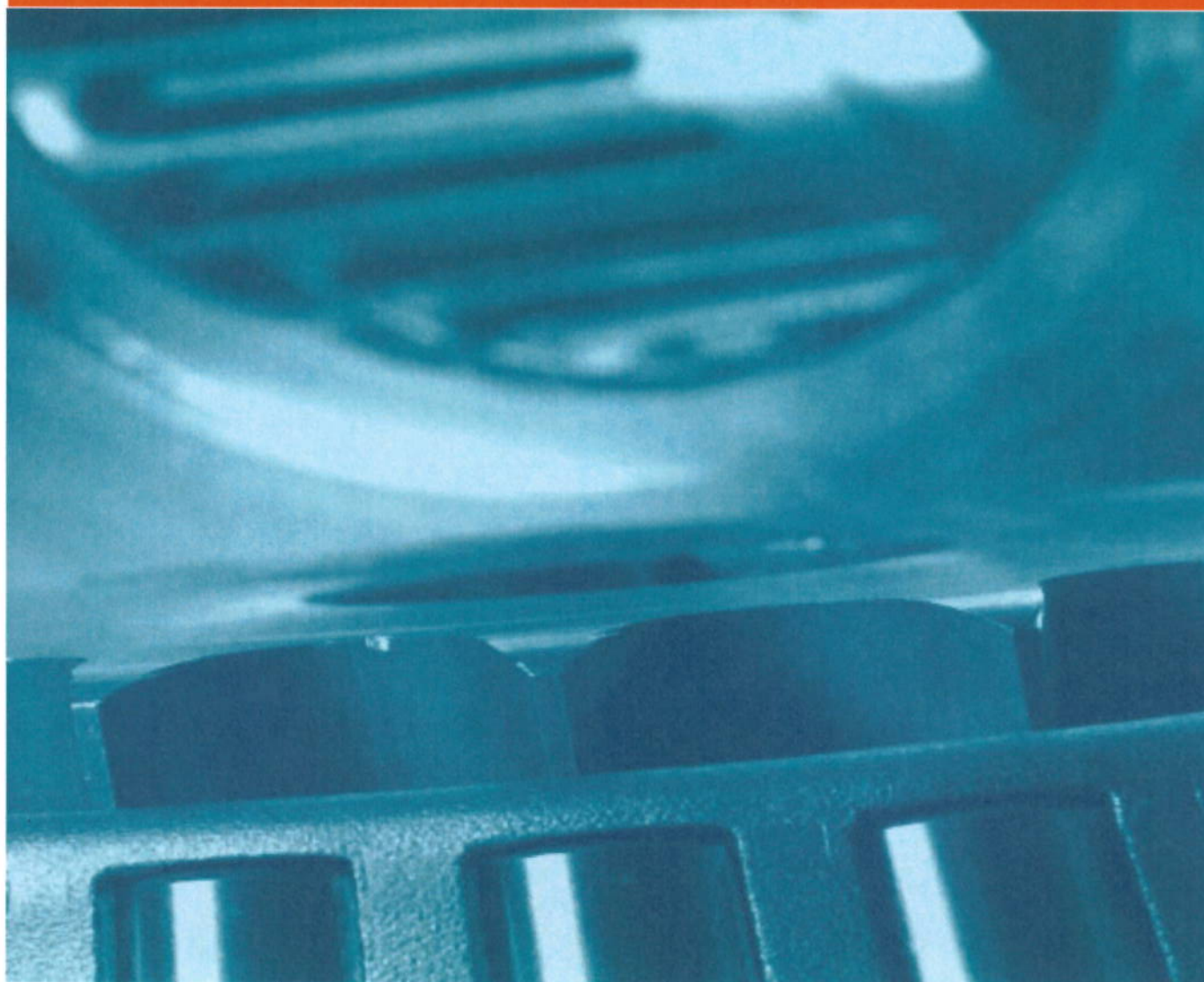


Review of HSL QRA for proposed LNG terminal

Proposed solution for Gib Elec LNG terminal

Technical note for:
Gibraltar Electricity Authority



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Summary

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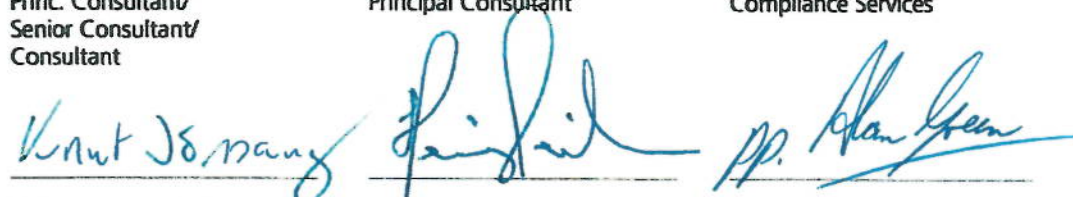
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1 Introduction

Under contract to Gibraltar Electricity Authority based on Request for Consultancy Services signed 26th September 2015, Lloyd's Register EMEA has carried out a review of Health & Safety Laboratory's (HSL) risk assessment of Shell's proposed solution for a Liquefied Natural Gas (LNG) terminal facility located at the port of Gibraltar.

This technical note is following on from the review report issued by Lloyd's Register, Ref. /5/. There has been further development of the proposed concept after Lloyd's Register issued the first review report. The location for the proposed LNG terminal is still the same as referred to in the previous report from Lloyd's Register, Ref. /5/, but some changes have been made to the bund around the 5 horizontal storage tanks.

This technical note aims at reviewing the HSL report, Ref. /3/, addressing the latest proposed concept for a small scale LNG terminal located in the Port at the North part of the North mole. The sensitivity in the HSL report represents the latest proposed concept, Ref. /4/.

2 Review of HSL quantitative risk assessment

Lloyd's Register EMEA has carried out a review of Health & Safety Laboratory's (HSL) risk assessment report, Ref. /3/, for Shell's proposed solution for a LNG terminal facility located at the port of Gibraltar. The objective of this study has been to review the risk assessment report from HSL with regard to risk.

The concept assessed by HSL is a base case and a sensitivity case to this base case. In the base case the 5 horizontal storage tanks are located inside a single bund with a sloping base towards an impounding basin. In the sensitivity the bund is subdivided around all the 5 storage tanks and still the same sloping base towards an impounding basin.

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.

The frequency for catastrophic failure, which is an important basis input parameter, is set relatively conservatively.

The result for the base case calculated by HSL is seen in Figure 2.1 below:

Figure 1: Three Zone Map for LNG Storage tank at North Mole (single bund around all 5 storage tanks plus impounding basin)



Figure 2.1 - 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 by HSL. The frequency of this scenario has a relatively large impact on the total risk picture.

HSL has applied their upper bound for the catastrophic rupture frequency. It could be argued that this is too conservative due to the design of the 5 horizontal storage tanks, the tank design is double walled vacuum insulated stainless steel tanks.

Table 2.1 - 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"
			Basis input in the QRA from HSL
0.5	5.5	2	6

Looking into the data sources for catastrophic rupture frequency 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) (a Dutch data source widely recognised in the industry) does not include any "external damage and (internal) domino effects", Ref. /1/. The "complete" frequency from Purple Book includes human error, external impacts etc., Ref. /2/.

The frequency used for the risk contours provided by HSL is from the "HSE upper bound". Application of both "upper" and "lower" bound 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 HSL does not include sensitivities of the frequency for catastrophic rupture, they have only applied their standard "HSE upper bound" presumably due to the project is in an early stage and a conservative approach may be preferred.

For Shell's proposed LNG terminal on the North Mole HSL give the "Do not advise against" decision.

HSL's own comment is: "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".

In general Shell needs to further pursue risk mitigation and demonstrate As Low As Reasonable Practical (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 Health & Safety Executive (HSE) & HSL.

Shell has provided HSL with an evaluation of the information and assessments carried out by Shell regarding BLEVE (Boiling Liquid Expanding Vapour Explosion) and catastrophic failure of the tanks. Shell believes the double wall of the tank will withstand relatively large doses of external heat. The Shell fire integrity assessment concludes that a BLEVE and catastrophic rupture of more than one tank are not credible scenarios.

HSL agree to the conclusions in these assessments. Hence, for the worst credible scenario HSL exclude:

- BLEVE, and
- catastrophic rupture of more than one tank

This is considered as sound assumptions since *"The further information provided by Shell [9] demonstrates that the outer skin of the tanks and perlite insulation will be capable of protecting against BLEVE caused by pool fire or jet fire. In addition, Shell has undertaken to minimise the potential for jet fires that could impinge on the storage tanks during detailed design"*.

And, *"The further information provided by Shell demonstrated that the outer wall would withstand a 4 inch diameter failure of piping from the inner pressure vessel but did not consider catastrophic failure of the inner vessel. Modelling the storage tanks as standard pressure vessels is conservative but is not expected to be greatly so. The sensitivity to assuming standard pressure vessels is low because of the bunding provided"*.

HSL has also assessed a sensitivity case to the base case. In the sensitivity case the bund is subdivided around all the 5 storage tanks and has the same sloping base towards an impounding basin. The result for the sensitivity calculated by HSL is seen in Figure 2.2 below.

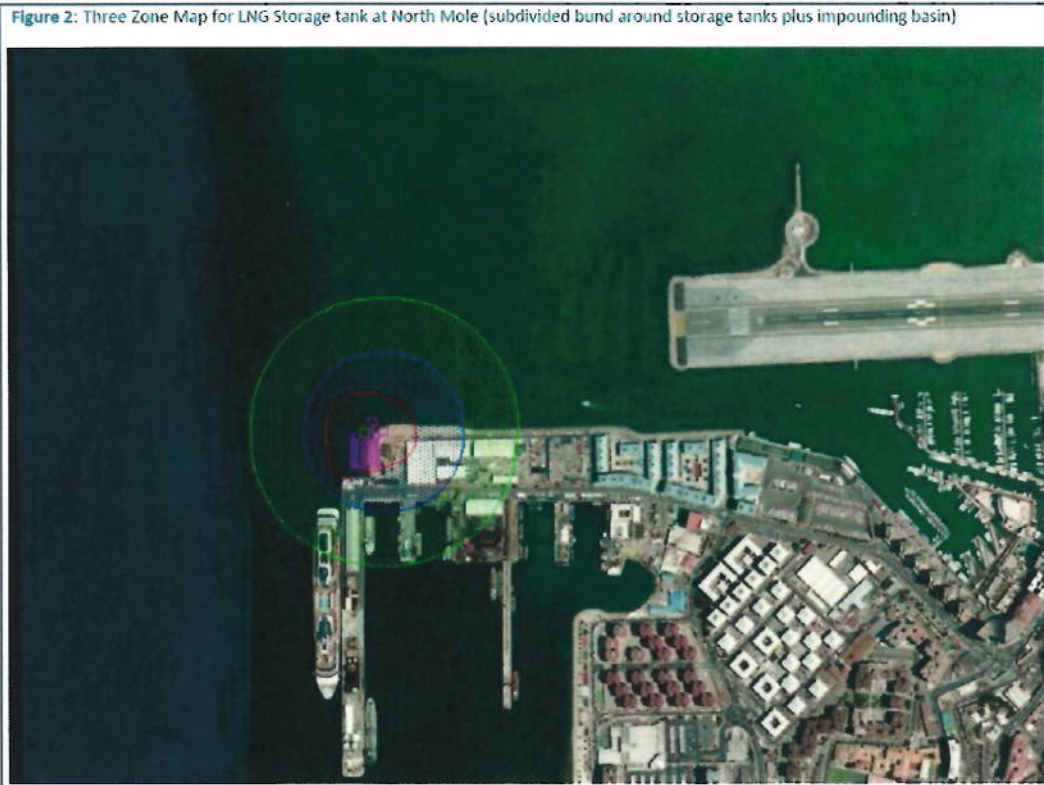


Figure 2.2 - Risk picture (3 zone map) developed by HSL for Shell's proposed sensitivity

This design reduces the extent of all three zones and in particular the two inner zones. This seems to be a good risk reducing measure.

GEA has per mail to Lloyd's Register confirmed that *"I can confirm that the GEA preferred option is to subdivide the bund as this has been demonstrated by Shell to reduce the risk contour maps"*, Ref. /4/.

3 Conclusion

On behalf of Gibraltar Electricity Authority, Lloyd's Register EMEA has carried out a review of Health & Safety Laboratory's (HSL) risk assessment for 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. This has been done by choosing the subdivided bund design (the

sensitivity case assessed by HSL). This risk mitigating measure is a step to reduce the overall risk. HSL also highlight additional mitigating design measures which need to be further evaluated.

4 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>.
- /3/ "Health & Safety Laboratory Project Note. Three-zone map for Shell Gibraltar LNG storage design concept", Project No. PE03136, Rev. 2, 06.10.2015.
- /4/ GEA, by Manuel Alecio, E-mail: "RE: GibElec: LR report Revision B", 14th of October 2015, time 13:45.
- /5/ Lloyd's Register Energy: "Review of proposed solution for Gib Elec LNG terminal", Document No. 105913-2/R1, Rev. C, 15th October 2015.