TECHNICAL REPORT

Quantitative Risk Assessment (QRA) Study for Marine Product Jetty Expansion Project (Berths C&D)

Vadinar Oil Terminal Limited

DNV Reg. No.: PD1293K71-4-2009
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Report title:		DET NORSKE VERITAS AS GLOBAL RESOURCE CENTRE Vatika Business Centre, 3rd Floor, NSL-Icon, Plot No. 1-4 Road No. 12, Banjara Hills, Hyderabad 500 034 Tel: +91 40 4431 1287 Fax: +91 40 4431 1100 http://www.dnv.com
Quantitative Risk Assessment (QRA) Study for Marine Product Jetty Expansion Project (Berth C & D)		
Customer:	Vadinar Oil Terminal Limited	
Customer Address:	Vadinar Oil Terminal Limited (VOTL) Essar House, 11, K K Marg, Mahalaxmi, Mumbai – 400034	
Customer Reference:	Email from Mr. Subbarao Kamma on dated February 05, 2009	
Contact Person:	Mr. Subbarao Kamma (Vice President, Group HSE)	
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Prepared by/Contact Person: *Rajkumar Dhapodkar* *Waseem Akhtar*	*Position:* *Consultant*	*Signature:*
Verified by: *Aditya Venkata Chimmapudi*	*Position:* *Consultant*	*Signature:*
Approved by: *Venkata Emani*	*Position:* *Manager Operation* *DNV Energy, Hyderabad*	*Signature:*

PREFACE

Risk management is essentially a part of any oil and gas installation due to the hazardous nature of operations. Quantitative Risk Assessment provides a thorough understanding of the risks associated with any oil and gas facility. It essentially depicts and quantifies the consequence of any major event apart from the normal plant operations. History has witnessed many such accidents which could have been avoided if a proper Risk Assessment was done. Through Risk Assessment the potential impact of major accidents can be predicted and subsequent measures can be initiated to reduce or mitigate the risk from these events.

Vadinar Oil Terminal Limited (VOTL) maintains and operates the Marine and Offshore Oil terminals as well as all crude oil and refined petroleum product handling and storage facilities for Essar Oil Ltd's Refinery at Jamnagar. The fully integrated and automated Marine and Offshore Terminal facilities consist of Single Point Mooring (SPM) unit for receiving crude oil imports from the ships, Product Jetty for export of finished petroleum products, State of the art Marine Terminal Control Building, Crude Oil Tanks, Intermediate Product Tanks, Finished Product Tanks, Road Gantry, Rail Gantry and all interconnected pipe lines and pumps. The Marine and Offshore terminal facility have been set up within the Port Limits of Kandla Port Trust (KPT). DNV has been requested to carry out Quantitative Risk Assessment (QRA) to assess potential risks associated with the berth C and D of marine product jetty expansion project and give conclusions and recommendations to reduce risk levels if any. The scope of this QRA excludes risks from existing berth A and B.

DNV has been in Risk Management business for many years. It has the required skills and tools to conduct Risk Studies for oil and gas installations. DNV Energy has been involved in many onshore and offshore QRA studies in the past, some of them are mentioned in the references.

The study was conducted and a report was prepared with data provided by VOTL. The assumptions made are given in Appendix V of this report.

The conclusions and recommendations given by DNV are in good faith and are prepared keeping the safety guidelines in mind.

E.1 EXECUTIVE SUMMARY

This Quantitative Risk Assessment (QRA) aims to quantify the risk associated with potential hazards originating from the marine product jetty expansion project (berth C & D). The risks are compared to the corporate risk tolerance criteria of Essar (which is equivalent to UK HSE criteria) as defined in Appendix I and suitable recommendations have been suggested.

E.1.1 Onsite Risks

The final risk contours are shown in **Figure E.1**. The maximum risk within the facility is 10^{-3} (red contour) fatalities/avg. year. Furthermore most of the areas appear to be exposed in this risk range. These locations include process pipeline areas. These results represent the risk to a hypothetical individual standing at that location 24 hours per day, 365 days per year.

The most exposed individuals will be workers on the berths C and D, and near process pipeline areas which are exposed to a risk level above 10^{-3} fatalities/avg. year. The location-specific individual risk for the most exposed worker will therefore be in the range of 10^{-3} fatalities/avg. year which is falling outside the acceptable limits of Risk Acceptance of Essar (which is equivalent to UK HSE criteria).

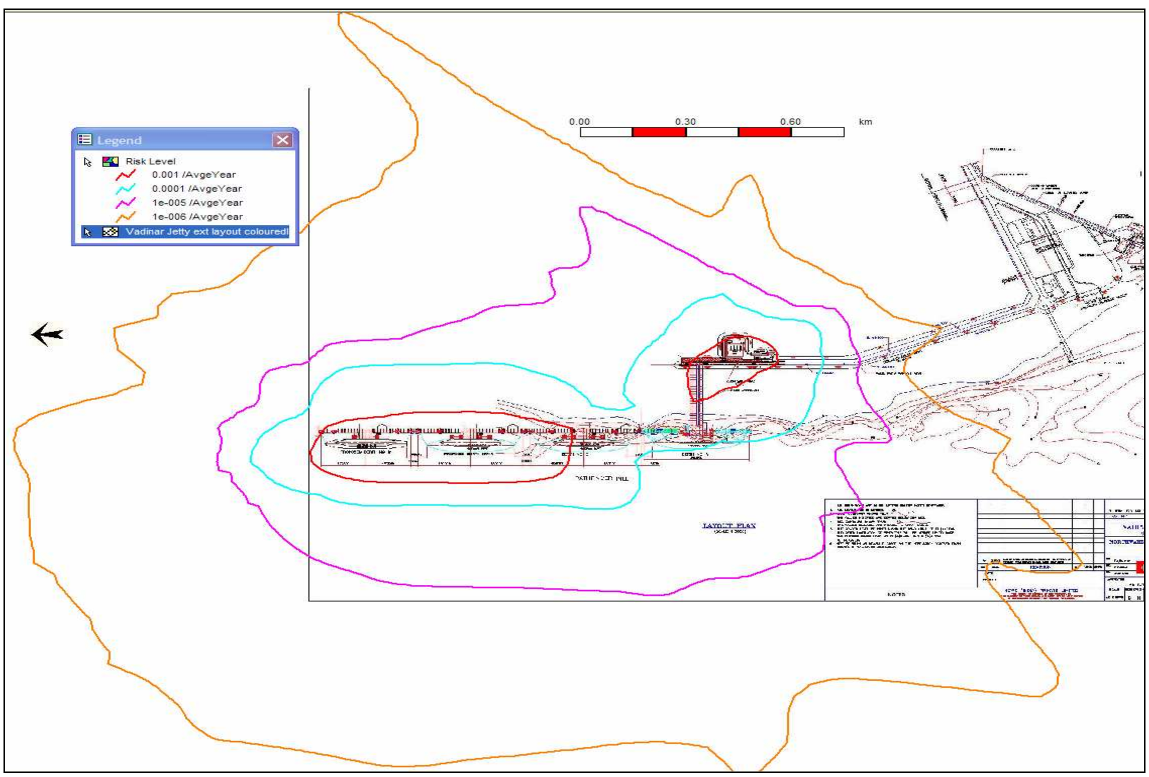


Figure E.1: Risk Contours for Onsite Population

The corresponding F-N curve is as shown in Figure for onsite risks (ALARP) region. As seen in the F-N curve, the onsite societal risk falls in intolerable region in the low fatality range and it is ALARP for medium and high fatality range. The greatest number of onsite fatalities from any event is 80, with a frequency of 6.0E-08 per average year.

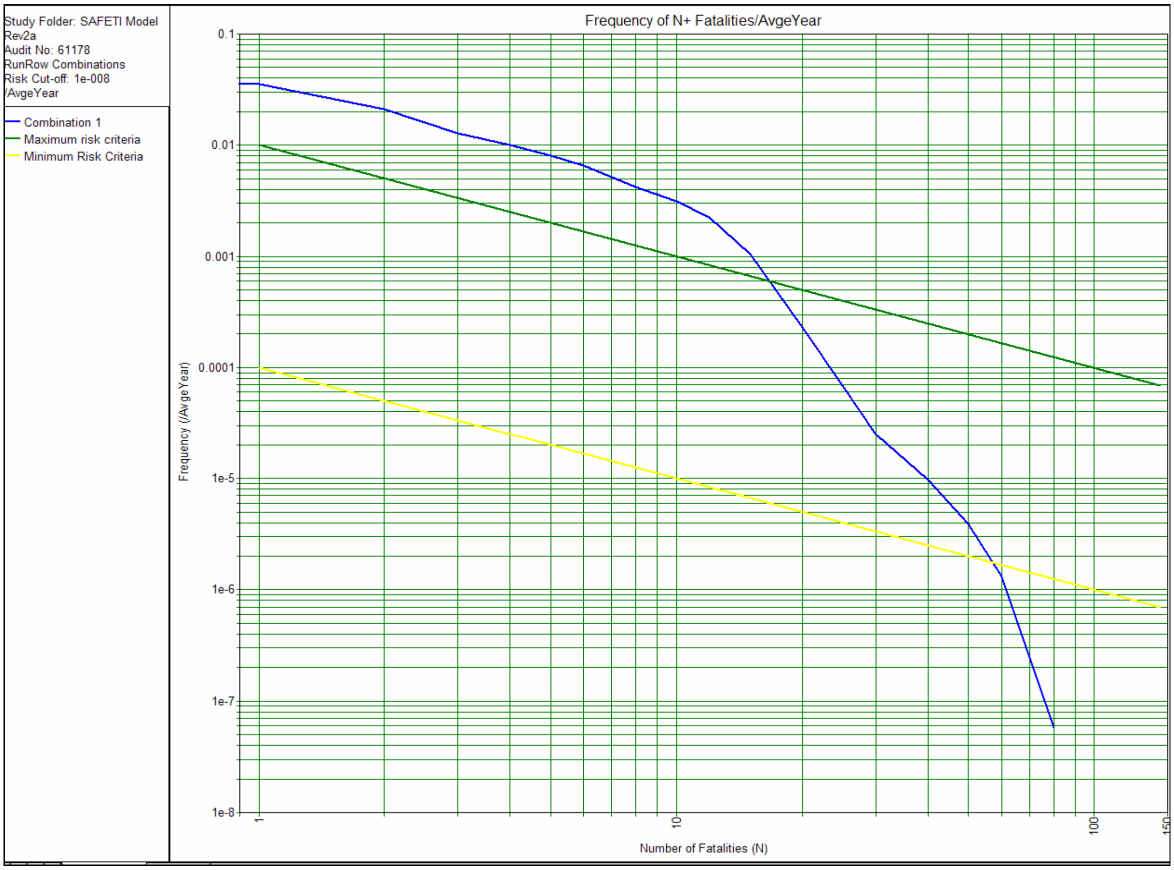


Figure E. 2: **F-N Curve for Onsite Population**

The high fatality range is caused by high pressure oil releases from process pipeline during daytime when there is high population in the site. These events represent the highest pressure process sections and as such have the potential for very large hazard zones.

E.1.2 Escalation Potential

The Oil Process Pipeline is the most susceptible to escalation due to impacts from fire event. This section presents representative, Jet Fire and Pool Fire events in the area which present significant hazards to process equipment and steel structures in the Oil Pipeline Area. Jet and pool Fire results are presented in the form of radiation contours of 4.0, 12.5 and 37.5 kW/m^2.

E.2 Conclusion

The worst case Location-specific individual risk to workers within the Marine Product Jetty facility (including workers outside) appears to be in the range of 1 x 10^{-3} fatalities/avg year. This level of individual risk falls outside the proposed tolerable individual risk criteria for onsite personnel as per Corporate Risk Criteria of Essar.

The worst case individual risk to workers within the facility appears to be in the range of 1 x 10-3 fatalities/avg year near the admin building and on the two jetties (C&D).

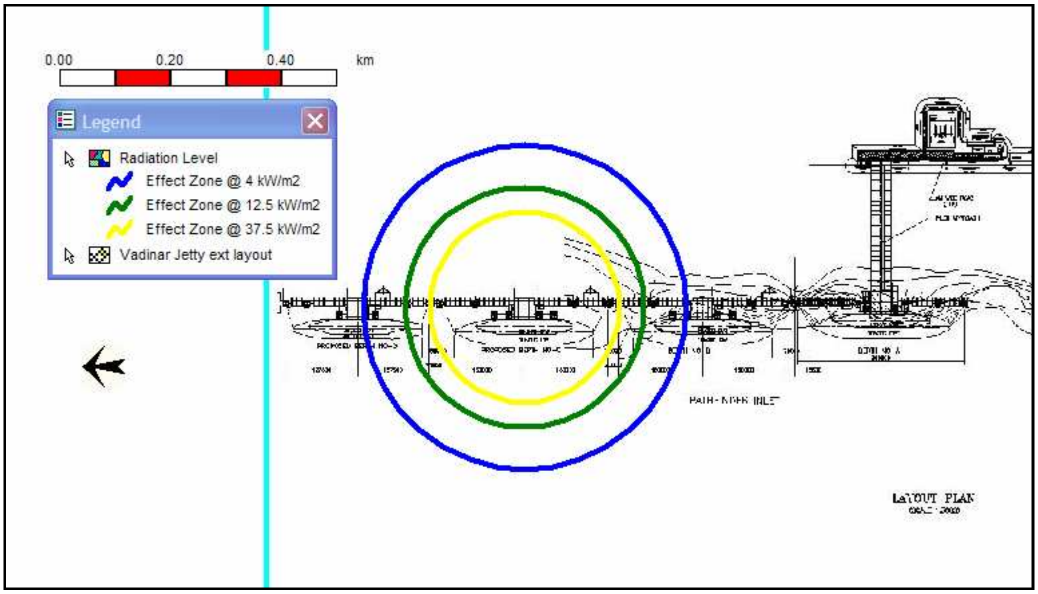
The Figure E.1 Overall Individual Risk Contour Plot results for the marine product jetty expansion project demonstrates that the 1 x 10^{-4} per year fatality risk contour goes offsite to the east by 370m, to the west by approximately 570m from the berth and north by 280m.

Based on a comparison of the IR contour results with the defined Risk Criteria the following conclusions may be drawn:

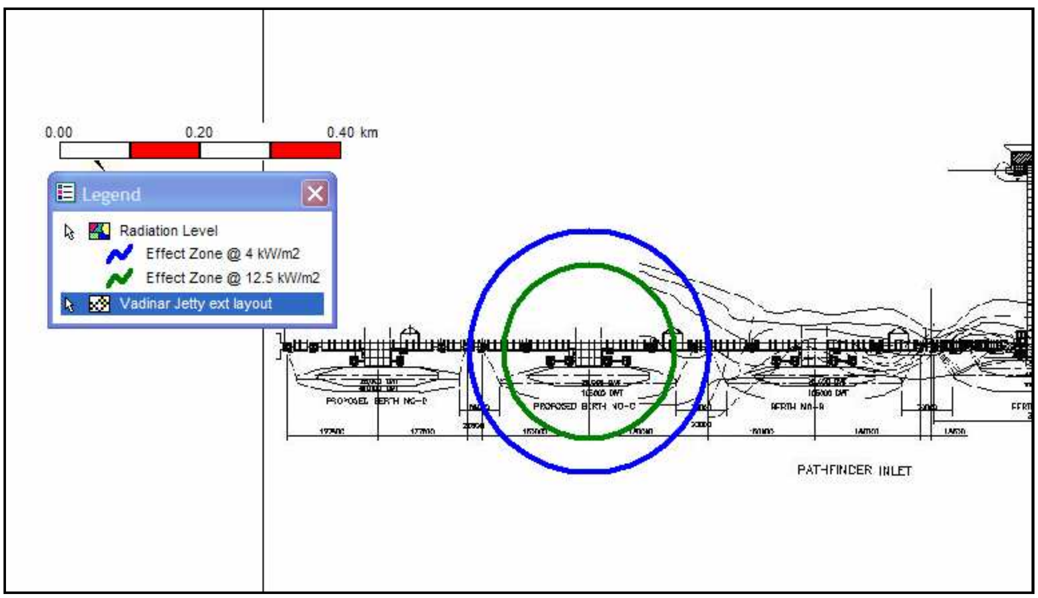
1. The berths C and D are not under tolerable risk region, which is 1 x 10^{-3} per year according to Corporate Risk Criteria of Essar.
2. The following table indicates the Jet fire and Pool fire consequences for the scenarios considered on the berth (C/D) for Naphtha due to leak from the product pipelines. Naphtha gives the maximum consequence of all the materials handled at the berths C & D due to its low flash point.

Leak size	**Damage Distance for Jet fire (3D) (m)**		**Damage distance for Pool fire (3D) (m)**		**Frequency of Leak (/Avg yr)**	**Contribution %**
	12.5Kw/m^2	**37.5Kw/m^2**	**12.5Kw/m^2**	**37.5Kw/m^2**		
14mm	26.14	21.04	16.84	12.09	2.361E-01	92.22
60mm	95.28	75.96	44.62	-	1.449E-02	5.06
175mm	215.09	170.27	127.21	-	5.680E-03	2.21
Total					**2.56E-01**	**100**

From the above risk results it can be concluded that the minimum safe distance between the berths should be 27 meters.



Jet fire from Large leak in pipeline near berth C for Naphtha



Pool fire from Large leak in pipeline near berth C for Naphtha

E.3 Recommendations

E.3.1 Onsite Risks

To ensure that risks are ALARP, all practicable risk reduction measures should be considered and hence additional measures are suggested below. Note that these measures are necessarily general, and essentially relate to ensuring that best-practice is adopted.

Taking into consideration the current risk level of the pipelines near the berths:

- It is suggested to install ESDs on all the lines at safe distance from Berth A, so that the facility downstream is isolated in case of an event/emergency. The consequence of an event is reduced substantially by installation of ESDs and thereby reducing the risk to bring it into ALARP

- It is recommended to rise the height of the breather valve on the underground slop tank as the 20kl trucks are loaded nearby

- It is recommended to provide passive fire protection for all the structures, pipelines and equipments on the berths as they are exposed to Jet Fire hazard

- Key prevention measures are to be taken to minimize the leak frequency and ignition potential within the facility in general. Measures to minimize the leak frequency range between design details, such as for dropped objects and maintenance access, and operational procedures and inspection schedules. Specific ignition controls are to be finalized, while it should be noted that best practice measures relating to hazardous area classification should be adopted and that ignition sources should be minimized in all areas as far as is practicable

- Leak detection and isolation are key control measures, although their primary influence will be in limiting the potential for escalation. The more rapid the isolation occurs the greater the benefit in terms of risks to personnel, although the influence will not be substantial given that the majority of major hazards will have immediate impacts to personnel. In addition to the above, measures to protect building occupants against fire loads and to limit the potential for escalation in general will be key aspects in reducing risks to ALARP

- In addition to the above, measures to protect building occupants against fire loads and to limit the potential for escalation in general will be key aspects in reducing risks further

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1 INTRODUCTION

1.1 General

Vadinar Oil Terminal Limited (VOTL) was set up as a SPV to develop, operate and maintain Marine Oil Terminals, Port facilities, associated tankage and dispatch facilities for meeting the crude oil and product movement requirements of Essar Oil Limited's (EOL) State of art Greenfield Oil Refinery at Vadinar in Gujarat. VOTL is part of the diversified Essar Group which has investments in core infrastructure sectors such as steel, oil and gas, power, shipping & logistics and telecom.

Vadinar Oil Terminal Limited (VOTL) maintains and operates the Marine and Offshore Oil terminals as well as all crude oil and refined petroleum product handling and storage facilities for Essar Oil Ltd's Refinery at Jamnagar. The fully integrated and automated Marine and Offshore Terminal facilities consist of Single Point Mooring (SPM) unit for receiving crude oil imports from the ships, Product Jetty for export of finished petroleum products, State of the art Marine Terminal Control Building, Crude Oil Tanks, Intermediate Product Tanks, Finished Product Tanks, Road Gantry, Rail Gantry and all interconnected pipe lines and pumps. The Marine and Offshore terminal facilities have been set up within the Port Limits of Kandla Port Trust (KPT).

DNV has been requested to carry out Quantitative Risk Assessment (QRA) to assess potential risks associated with the berth C and D of marine product jetty expansion project and give conclusions and recommendations to reduce risk levels if any.

1.2 Scope and Objectives of Project

The specific objectives of the study are to:

- Identify the hazards associated with the Marine Product Jetty (Berth C & D)
- Model and appraise the risks associated with all flammable and toxic hazards resulting from potential loss of containment accident scenarios
- Identify onsite risk posed by the facility and its associated operations as a tool to obtain and document satisfactory onsite safety
- Perform a risk assessment to confirm that risk can be reduced consistent with the ALARP principle according to the project's risk acceptance criteria.
- Ensure that the QRA covers the local regulatory and internal corporate HSE requirements of Vadinar Oil Terminal Limited (an Essar Group Company).
- Recommend risk reducing measures to ensure that all risks are ALARP.

The QRA aims at modelling and appraising risks associated with all flammable and toxic hazards originating from the Marine Product Jetty Expansion Project. The boundaries of the Project are described as follows:

- 32" Onshore Process Pipelines
- Slop Storages
- Storage tank on the Ship

1.3 Risk Assessment Consultant

Vadinar Oil Terminal Limited has commissioned Det Norske Veritas to carry out the Quantitative Risk Assessment Study for marine product jetty expansion project, based on Final Design and Layout. The Quantitative Risk Assessment consultant's registered address and correspondence is:

Registered Address:
Det Norske Veritas As
Emgeen Chambers,
10, C.S.T. Road,
Mumbai, 400098
India
Tel: +91 22 26676532
Fax: +91 22 2665 4584/2665 2820
Contact Person : Venkata Emani (Project Manager)

Contact Address:
Det Norske Veritas As,
Vatika Business Centre,
3rd Floor, NSL ICON, Road No. 12,
Banjara Hills, Hyderabad,
India
Tel: +91 40 4431 1287
Fax: +91 40 4431 1100
Contact Person : Venkata Emani (Project Manager)

1.4 Layout of Report

The risk assessment is summarized within this main report, in the following sections:

- The description of the facilities is given in Section 2.
- The methodology applied in the failure case definition, frequency analysis and consequence analysis is summarized in Section 3. The detailed methodology is given in Appendix II.
- The summary of risks is presented in Sections 4. More detailed analysis is presented in Appendix III.
- Conclusions and recommendations are given in Section 6.

- The summary of the analysis presented in Section 1-6 is supported by the detailed analysis covered in the following appendices:

  i. Project design data as well as assumptions made by DNV are given in study basis as Appendix V

  ii. The methodology for the Process Risk Analysis is detailed in Appendix II

  iii. The failure cases defined for analysis are defined in Appendix III

2 PROCESS DESCRIPTION

2.1 Present Facilities

The existing facility is a T-shaped jetty consisting of a single Berth 'A' located at Vadinar Port in the Pathfinder inlet within the conservancy of Kandla Port Trust (KPT) in water depths of about 15-17 mtrs. The jetty and approach trestle are of piled construction. The breasting dolphins & four mooring dolphins are equipped with fenders & bollards. The jetty is designed to handle vessels of capacity 25,000 to 100,000 dwt. The jetty is provided with 3 state of art loading arms (2 x 12" & 1 x 16") capable of handling Naptha, ATF, SKO, Gasoline, HSD & Fuel Oil. The jetty is being used to export the refined products from Essar Oil Refinery (EOL). The loading rate for white oils is 4000 cum/hr and Fuel Oil is 2500 cum/hr. The jetty is provided with firewater pumps, fire hydrants, tower monitors, Oil pollution prevention equipment etc. of international standards confirming to OCIMF & ESID regulations.

Berths C & D will be in the same line as those of the existing berths. All the existing product lines from existing Berths will be extended to the new berth. The berths are designed to handle vessels of capacity 25,000 to 100,000 dwt. The jetty will be equipped with 4 x 16" state of art loading arms for handling ATF, SKO, Naptha, Gasoline, HSD, Crude Oil and Black Oil.

The Marine Terminal control building located at a distance from the existing berth will house the DCS/ ESD & F&G hardware for the existing and future berths.

2.2 Proposed Facilities

The existing EOL refinery is expanding from 10.5 MMTPA to 32.0 MMTPA. In view of this expansion, two more berths – Berth "C" & "D" are planned to be constructed north of and in line with the existing and under-construction berths. The berths will be similar to the existing berths. The new berths will have connecting walkways from the existing berth for personnel movement. Vehicular access will not be available to Berth B, C & D.
There will be pipelines with valves, drains, vents and flanges interconnected between berths and the product tanks at the EOL refinery. There will be a slop oil tanks of 5- 10 KL for each berth.

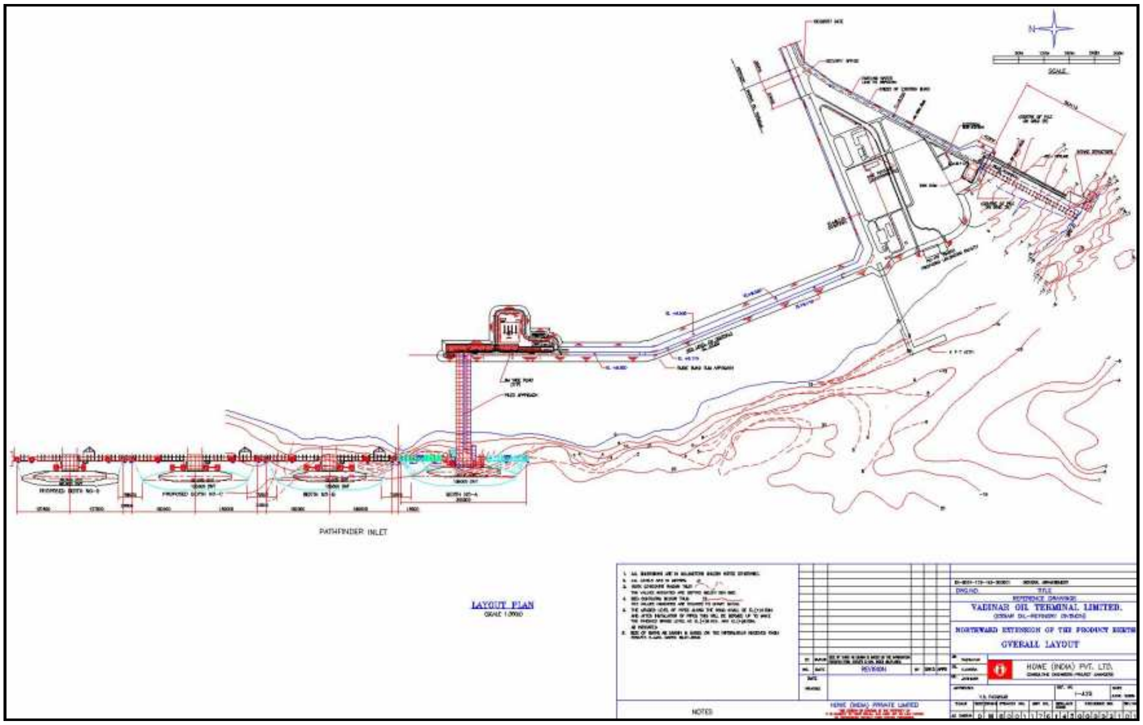


Figure 2-1: Overall layout of the marine product jetty expansion project

3 INTRODUCTION TO QRA METHODOLOGY

The following sections provide a very broad overview of the methodology adopted for the analysis. The key input data and assumptions made within the analysis are listed in Appendix I, while the approach and methodology are detailed in Appendix II.

A standard QRA methodology has been applied for this study where the analysis of hazards and risks involves a step-wise approach as follows:

1. Compile and assess data. Prepare a quantitative description of the relevant hazardous portions of the project
2. Generate failure case scenarios and quantify rates of release of hazardous substances
3. Select relevant failure data and estimate failure frequencies
4. Calculate the consequences of failure cases
5. Calculate the risk to people, using data on frequency, meteorological conditions and population distribution
6. Compare risk with Risk Acceptance Criteria
7. Evaluate mitigation options and risk reduction measures

3.1 Case Definition

The risk analysis is conducted on a sectional basis, grouping the processes within the facility into a series of isolatable sections where the various release sources will have similar characteristics, and hence consequences. For each of the sections, or release scenarios, representative release sizes and locations are considered.

The key parameters determining the behavior of the release in each case, and the subsequent consequences, are the representative release rate, the duration of the release, and the release velocity. These parameters are derived from initial discharge modeling conducted within the PhastRisk v 6.53.1 consequence modeling software based on the representative inventory, temperature and pressure. The approach adopted in deriving the parameters is adapted according to the release phase and whether the release driver is pumped flow, pressure or inventory, where: Process conditions are taken from the available PFDs and Heat & Material Balances. Where the conditions vary within a section (release scenario), those associated with the main inventory are used; where there is no main inventory, the stream with the highest pressure is taken. The section volume is derived from the vessel volumes (taken from the Equipment List), together with estimates of line lengths associated with each section (from the P&IDs and Plot Plans) and the estimated fill fraction of each vessel. The time to detection and isolation of a release event has been standardized at 3 minutes for all release events.

In the case of storage tank failures, all piping, fittings and connections associated with the tanks are included in the process release cases. The only additional scenario modeled for the storage tanks are catastrophic failures due to tank roof collapse. Tank roof collapse can occur as a result of a leak into the secondary containment which, if ignited, can lead to the loss of the tank roof. This scenario ultimately results in an ignited pool inside the tank walls. Therefore, the catastrophic tank failure case selected for the storage tank scenarios is that of full tank pool fire due to tank roof collapse.

3.2 Frequency Analysis

3.2.1 Process Leaks

In line with the DNV world-wide recommended approach, the selected historical failure frequencies used in this study are based on the UK HSE Offshore Hydrocarbon Release database. The HCRD records cover leaks from October 1992 to March 2003 (inclusive).

Within DNV further research and work has been done by John Spouge, who analyzed the UK HSE database data. The leak database file was downloaded from the HSE website on 19 January 2004. The matching equipment populations were provided in a spreadsheet by HSE on 21 January 2004. The data covers leaks of hydrocarbon from all UK offshore installations. Details of the process leak frequency analysis are provided in Appendix III.

4 CONSEQUENCE ANALYSIS

For each defined release event, fire calculations are conducted within DNV's consequence modeling software tool Phast v 6.53.1. These consequence results are used in the risk model PhastRisk, to calculate risk to personnel. A detailed description of the

methodology applied in the consequence analysis for process releases is provided in Appendix II.
The consequence results are input into the risk model in groups of hazard type, which depend upon the type of release and when ignition occurs, as summarized in Table 4-1. It should be noted that:

- Jet fires are conservatively treated as horizontal, and effectively unobstructed, in all cases.
- Liquid releases may result in different consequences according to the process and release conditions. These are generally determined by whether there is a significant initial flash (if the liquid is pressurized or the temperature is above the boiling point of the liquid) or whether the release will be predominantly liquid (if the liquid is stabilized or cryogenic).

Table 4-1: Consequences considered

Release Type	Hazard Type	
	Immediate Ignition	**Delayed Ignition**
Flashing liquid	Jet fire	Flash fire
Liquid release (Atmospheric Conditions)	Pool fire	Pool fire

5 ONSITE RISK RESULTS

This section presents the onsite risk results estimated in this QRA. As discussed in Section I.4 of Appendix I, the risk acceptance criteria proposed by Essar (which is equivalent to UK HSE criteria) is a measure of the acceptability of the risk. The onsite risk acceptance criteria are applied to workers of jetty project, including those in berths and buildings.

It must further be emphasized that the risk results presented herein are incremental and are intended to quantify only those risks associated with potential hazards originating from the marine product jetty expansion project.

5.1 Individual Risk Results

The individual risk contour as shown in Figure 5-1 shows the individual risk distribution on the berths. The figure presents the combined risk from all pipelines and tank storage (slop tanks and ship) hazards modelled for the berths C & D. The risk is expressed as risk of death on average per year. The largest contour as shown in gray colour represents a risk level of 10^{-9}/avg. year while the smallest contour (shown in red) represents an individual risk of 10^{-3}/avg. year. The risk contour is a line of equal risk; therefore, within the confines of that contour, the risk is greater.

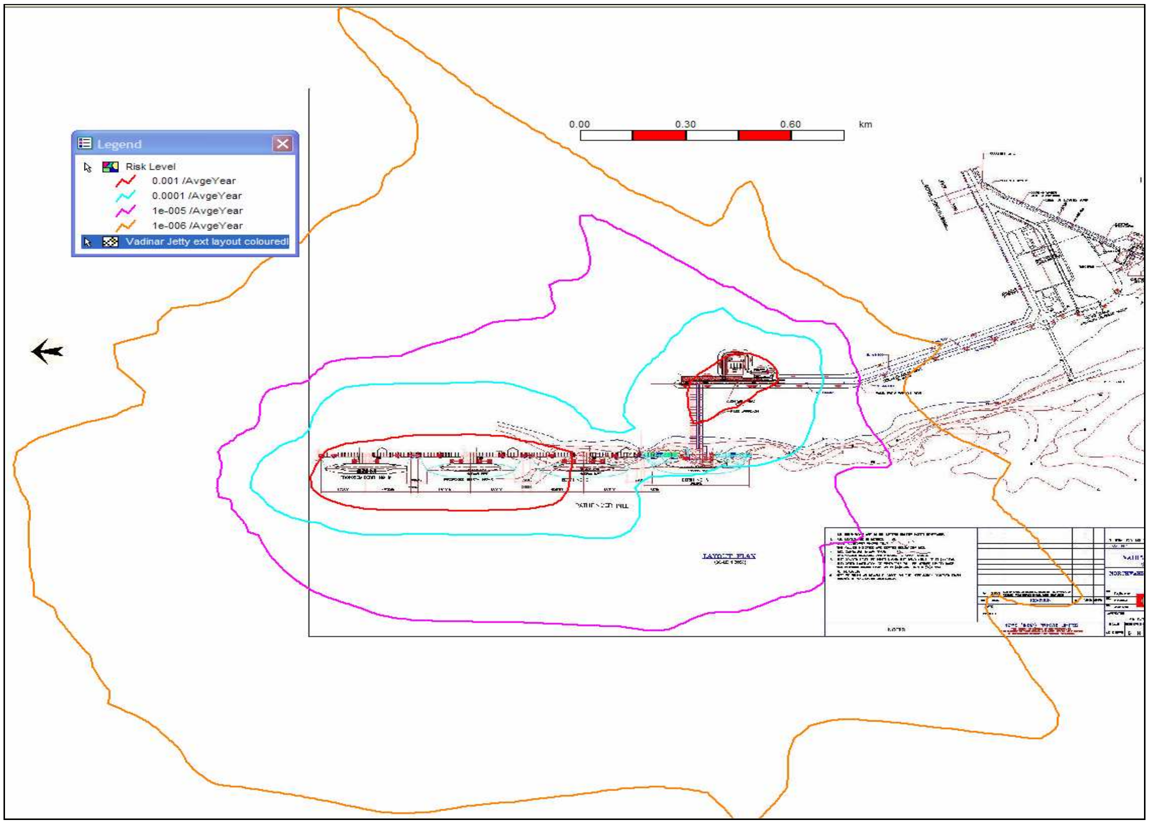


Figure 5-1: **Individual Risk Contour on the New Onshore Terminal**

According to the risk acceptance criteria for this jetty project (ref. Appendix I, Section I.4), a risk of 10^{-3} fatalities/avg. year is the maximum tolerable limit. The location-specific individual risk to workers is depicted in the above figure. The red contour is for 10^{-3} fatalities/avg. year which is the tolerable limit.

As seen in Figure 5-1, the maximum risk within the facility is 10^{-3} (red contour) fatalities/avg. year. These locations include process pipeline areas on the jetties and Admin Building. These results represent the risk to a hypothetical individual standing at that location 24 hours per day, 365 days per year.

The most exposed individuals will be workers on the berths C and D, and near process pipeline areas which are exposed to a risk level above 10^{-3} fatalities/avg. year. The location-specific individual risk for the most exposed worker will therefore be in the range of 10^{-3} fatalities/avg. year which is falling outside the acceptable limits of Risk Acceptance of Essar.

5.2 Societal Risk Results

The F-N curve for onsite populations is shown in above Figure 5-2 and presents the societal risk for all onsite personnel from the fire and explosion hazards associated with marine product expansion jetty project. The societal risk is presented in terms of cumulative frequency (F) of occurrence of events that lead to more than a number (N) of fatalities. No offsite populations have been included in the F-N curve presented below.

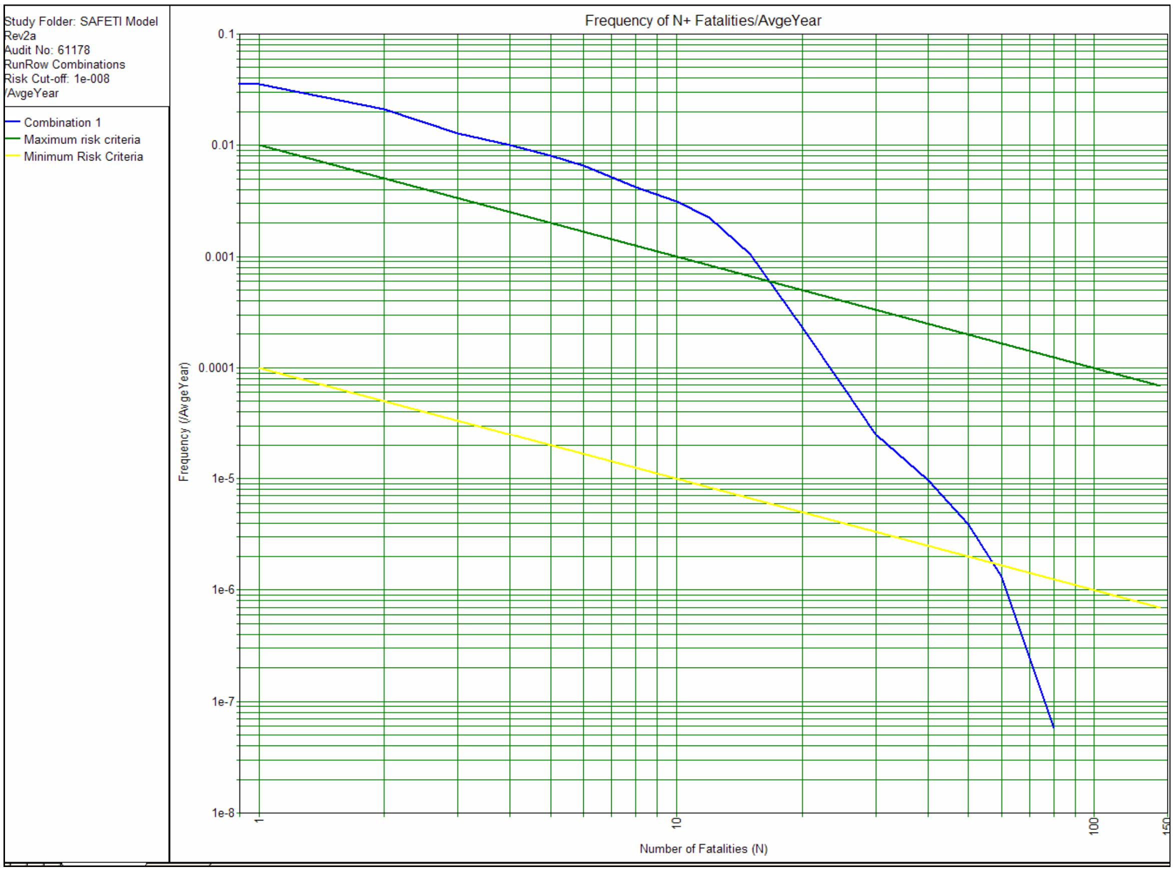


Figure 5-2: F-N Curve for Onsite Population

The green and yellow lines show the proposed intolerable and tolerable risk criteria, respectively. The blue line shows the combined risk for onsite personnel for both daytime and night time. As seen in the F-N curve, the onsite societal risk falls in the intolerable region in the medium fatality range. The greatest number of onsite fatalities from any event is 80, with a frequency of 6.0E-08 per average year.

The high fatality range is caused by high pressure oil releases from process pipeline during daytime when there is high population in the site. These events represent the highest pressure process sections and as such have the potential for very large hazard zones.

6 ESCALATION POTENTIAL

The Oil Process Pipeline is the most susceptible to escalation due to impacts from fire event. This section presents representative, Jet Fire and Pool Fire events in the area which present significant hazards to process equipment and steel structures in the Oil Pipeline Area. Jet and pool Fire results are presented in the form of radiation contours of 4.0, 12.5 and 37.5 kW/m^2.

6.1 Escalation Risk due to Flammable Events

In general, all unprotected equipment and steel structures within a radiation level of 37.5 kW/m^2 for a long duration or to 100kW/m^2 for 30 minutes or within the fire itself for a shorter period of time are likely to fail. A significant number of fires from small (14mm) and medium (65mm) liquid leaks will have durations that are long enough to cause damage if impinged directly by the flame; very few of these, however, actually have hazard zones large enough to impact neighbouring equipment. As documented in Appendix II, event duration is based on a 3-minute detection and isolation time followed by the time needed to release the entire inventory within an isolatable section.
Most potential release locations within facility area are within 10 to 20 meters of neighbouring process equipment or steel structure.

6.2 Active and Passive Fire Protection

Although the application of cooling water via installed spray systems or fire monitors can reduce the risk of escalation or asset loss by protecting storages and equipment from radiation, it will not protect from direct jet flame impingement.

In the case of jet fires, passive protection tends to be more effective, as water sprays (especially installed sprinklers) are usually brushed aside by the pressure of the jet. Therefore, in order to reduce escalation potential in the berth area and reduce the risk of damage to equipment and structures from jet fire events, the application of passive fire protection to key equipment items in this area is recommended.

Fire protection against jet fires means using materials that are effective against thermal load and also against dislodgement by water sprays from monitors or fire hoses.
Given the scale of fires identified in some events, full height fire protection for structures is recommended where large pool fires or jet fires are realistic – vessel structural steel supports and piperack structures. All skirts on vessels should have full height fire protection to prevent escalation and toppling, as most of these are within jet fire hazard zones. Fire insulation should be designed as the primary protection for these structural elements rather than active water sprays.

Passive protection is a problem on valves which require regular inspections. For normal control valves and battery limit isolation valves, water spray cooling using firewater monitors may be adequate in the event that they are exposed to fire.

7 CONCLUSIONS

7.1 Onsite Risks

The worst case Location-specific individual risk to workers within the Marine Product Jetty facility (including workers outside) appears to be in the range of 1 x 10^{-3} fatalities/avg year. This level of individual risk does not fall within the proposed tolerable individual risk criteria for onsite personnel as per Corporate Risk Criteria of Essar.

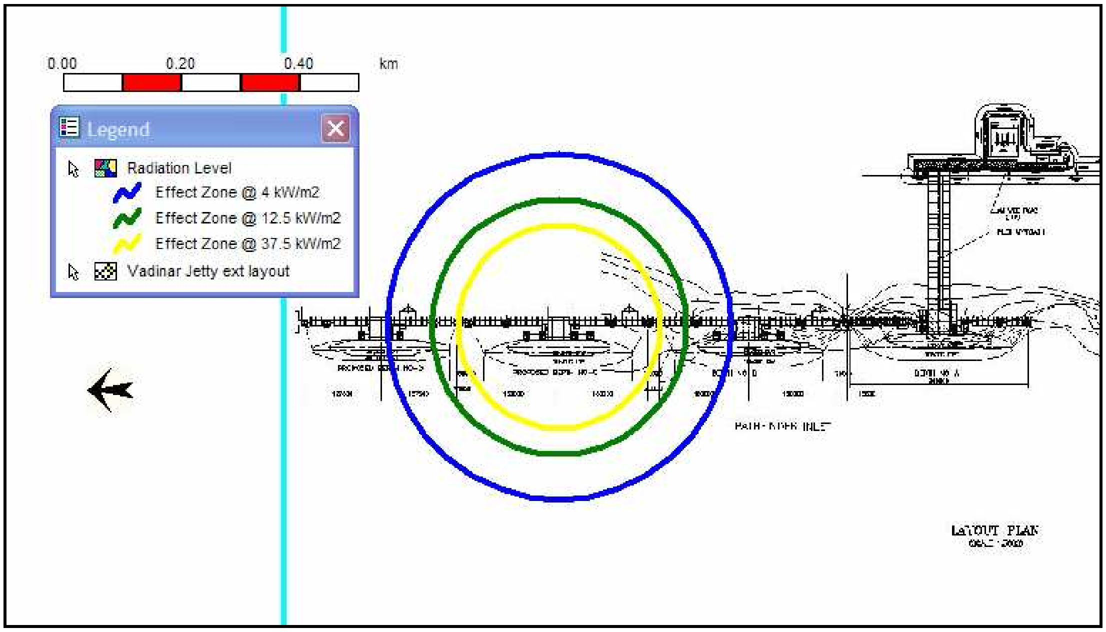
The worst case individual risk to workers within the facility appears to be in the range of 1 x 10^{-3} fatalities/avg year near the Admin building and on the two jetties.

The Figure 5-1 Overall Individual Risk Contour Plot results for the marine product jetty expansion project demonstrates that the 1 x 10^{-4} per year fatality risk contour goes offsite to the east by 370m, to the west by approximately 570m from the berth and north by 280m.
Based on a comparison of the IR contour results with the defined Risk Criteria the following conclusions may be drawn:

1. The berths C and D are under intolerable risk region, which is 1 x 10^{-3} per year according to Corporate Risk Criteria of Essar.
2. The following table indicates the Jet fire and Pool fire consequences for the scenarios considered on the berths due to leak from the product pipelines.

Leak size	Damage Distance for Jet fire (3D) (m)		Damage distance for Pool fire (3D) (m)		Frequency of Leak (/Avg yr)	Contribution %
	12.5Kw/m^2	37.5Kw/m^2	12.5Kw/m^2	37.5Kw/m^2		
14mm	26.14	21.04	16.84	12.09	2.361E-01	92.22
60mm	95.28	75.96	44.62	-	1.449E-02	5.06
175mm	215.09	170.27	121.79	-	5.680E-03	2.21
Total					**2.56E-01**	**100**

From the above risk results it can be concluded that the minimum safe distance between the berths should be 27 meters.



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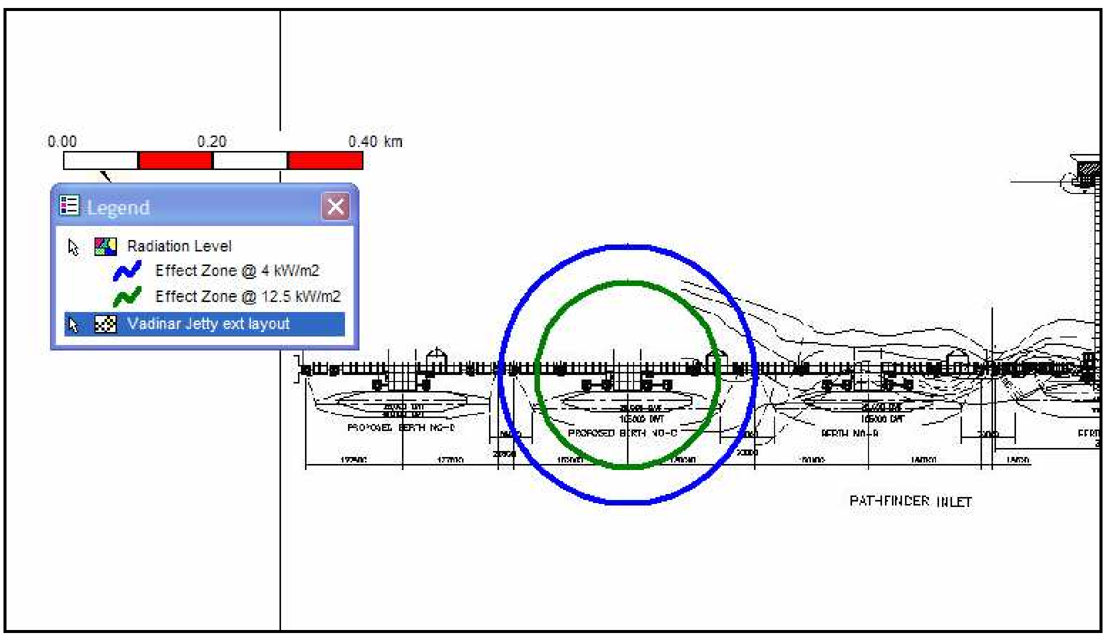

Pool fire from Large leak in pipeline near berth C for Naphtha

7.2 Escalation Potential

The berth area is exposed to events having the potential to cause escalation. This area is exposed to flammable hazards due to process pipeline.

Jet fires have both the length and the duration to cause failure of steel support structures. The escalation risk is estimated to be between 10^{-6} and 10^{-5} per year for the majority of the process area. Key assumptions in this initial analysis are that jet and pool fires result in potential escalation if vessels/structures are exposed to 37.5 kW/m^2 for a long duration or to 100kW/m^2 for 30 minutes. Drainage and fire fighting systems are not accounted for as a mitigation measure against escalation.

8 RECOMMENDATIONS

8.1 Onsite Risks

To ensure that risks are ALARP, all practicable risk reduction measures should be considered and hence additional measures are suggested below. Note that these measures are necessarily general, and essentially relate to ensuring that best-practice is adopted.

Taking into consideration the current risk level of the pipelines near the berths:

- It is suggested to install ESDs on all the lines at safe distance from Berth A, so that the facility downstream is isolated in case of an event/emergency. The consequence of an event is reduced substantially by installation of ESDs and thereby reducing the risk

- It is recommended to rise the height of the breather valve on the slop tank as the 20kl trucks are loaded nearby

- It is recommended to provide passive fire protection for all the structures, pipelines and equipments on the berths as they are exposed to Jet Fire hazard

- Key prevention measures are to be taken to minimize the leak frequency and ignition potential within the facility in general. Measures to minimize the leak frequency range between design details, such as for dropped objects and maintenance access, and operational procedures and inspection schedules. Specific ignition controls are to be finalized, while it should be noted that best practice measures relating to hazardous area classification should be adopted and that ignition sources should be minimized in all areas as far as is practicable.

- Leak detection and isolation are key control measures, although their primary influence will be in limiting the potential for escalation. The more rapidly that isolation occurs the greater the benefit in terms of risks to personnel, although the influence will not be substantial given that the majority of major hazards will have immediate impacts to personnel. In addition to the above, measures to protect building occupants against fire loads and to limit the potential for escalation in general will be key aspects in reducing risks to be as low as reasonably practicable. Recommendations in this respect are listed separately in Section 8.3.

- In addition to the above, measures to protect building occupants against fire loads and to limit the potential for escalation in general will be key aspects in reducing risks further

8.2 Escalation Potential

Best practice is a pre-requisite for demonstrating that risks are ALARP, irrespective of the actual risk values derived, noting also that the risk results suggest that all practical risk reduction measures should be considered. Hence, in addition to the above recommendations, measures to protect against the potential for jet and Pool fire escalation may be initiated.

8.3 General Recommendations (Ref//1//)

Layout of Port Terminals handling hydrocarbons should be done in accordance with Standard Engineering Practices/Requirements. A good layout provides adequate access for fire fighting, escape routes in case of fire and also provisions for segregation of facilities in the event of emergency.
The following fire protection facilities shall be provided depending upon size and nature of risk of installation:

- Fire Water System
- Foam System
- Halon/ its proven equivalent / Clean Agent Fire Extinguishing System
- DCP Protection System
- First Aid Fire Fighting Equipment
- Portable & Mobile Fire Fighting Equipment
- Fire / smoke / Gas Detection and Alarm System
- Fire Alarm/ Communication System

Design Criteria for Fire Protection

- It is assumed that in case of fire on ship tanker, ship will be towed to open sea after stopping the loading/unloading process
- One single largest risk shall be considered for providing fire protection facilities
- All facilities shall be covered with Hydrant System
- Tower mounted water cum Foam monitors shall be provided for protection to loading/unloading arms/first aid to tankers

- Water curtains shall be provided for segregation of loading / unloading arms/piping manifold and ship tanker in the event of fire on either of these facilities
- Manual/ automatic below deck fixed water spray system or pile fire-proofing to protect berth structure and installations shall be provided for a height of 9ft
- For ports terminals handling ships of less than 50,000 tonnes capacity one set of fire water Pumps shall be provided which will cater to both tower mounted monitors as well as hydrant service and water curtains, and for Port terminal handling ships of 50,000 tonnes or larger two sets of Fire water Pumps shall be provided for:
- Tower mounted water cum foam monitors.
- Hydrant Service and water curtains.
- Halon / its equivalent or clean agent fire extinguishing system shall be provided for control room / computer room.
- Requirement of foam compound storage is given in **Table 8-1.**
- Minimum requirements for portable and wheeled fire extinguishers for marine terminal is given in **Table 8-2.**

Table 8-1: Foam Compound Requirement

Sr. No.	Installation Size	Basis of Foam Requirement	3% Foam Compound Requirement
1	Barge Berth at wharf of jetty	2 X 2400 lpm Foam Monitors	8640 litre
2	Tanker Berth at wharf of jetty handling ships of less than 20000 tonnes deadweight capacity.	2 X 300 lpm Foam Monitors	10800 litre
3	Tanker Berth at a wharf or jetty handling ships of 20,000 tonnes & above but less than 50,000 tonnes dead weight	2 X 3000 lpm tower Foam Monitors + 1 base Monitor 1 X 1500 lpm	10800 litre 2700 litre 13,500 litre
4	Tanker Berth at a wharf jetty handling ships of 50,000 tonnes & above but less than 1,00,000 tonnes dead wt.	2 X 5000 lpm Tower Foam Monitor + 2 X 2400 lpm base Foam Monitor	26640 litre
5	Tanker Berth at wharf or jetty handling ships of 1,00,000 tonnes dead wt. and larger	2 X 6000 lpm Tower Foam Monitors + 2 X 2400 lpm base Foam Monitors.	30240 litre

Table 8-2: Minimum Requirement for Portable and Wheeled Fire Extinguisher for Terminals Handling Crude Oil & Petroleum Products

Sr. No.	Installation	Requirement of Fire Extinguisher
1	i) Barge berth at a wharf or Jetty	2 X 10 Kg. DCP Extinguisher
	ii) Barge berth at a wharf or Jetty handling ships or less than 20.000 DCP tonnes capacity	2 X 50 kg wheeled DCP extinguishers. 2 X 10 kg DCP Extinguishers.
2	Tanker berth at a wharf or Jetty handling ships of 20.000 tonnes and above but less than 50,000 tonnes capacity	4 X 10 kg DCP Extinguishers 2 X 75 kg wheeled DCP Extinguisher.
3	Tanker berth at a wharf or Jetty handling ships of 50,000 tonnes upto less than 100000 Tonnes capacity	6 X 10 kg. DCP Extinguishers of 4 X 75 wheeled DCP Extinguishers.
4	Tanker berth at a wharf or Jetty handling ships of 100000 Tonnes and larger	6 X 10 kg. DCP Extinguishers of 4 X 75 wheeled DCP Extinguishers.

Design Flow Rate

- The fire water system at port Terminal shall be designed to meet the fire water flow requirements of a single largest risk at a time
- Fire water flow rate for Port terminal protection shall be aggregate of the following:
  - Water flow for Tower mounted water/ foam monitors for protection of loading / unloading arms / piping manifold and ship tanker.
  - Water flow for area segregation by providing water curtains between ship tanker and loading / unloading arms and Hydrant service.
- Design Flow rate shall vary with type of product and size of ships handled. Refer **Table 8-3** (for POL products) for water flow design requirements.

Table 8-3: Fire Water Design Requirement for Port Terminals Handling Oil and Petroleum Products (Excluding Liquefied Hydrocarbon Gases)

FIRE WATER DESIGN REQUIREMENT FOR PORT TERMINALS HANDLING OIL AND PETROLEUM PRODUCTS (EXCLUDING LIQUEFIED HYDROCARBON GASES)		
Sr. No.	**Installation**	**Fire Water Rate**
1	Barge berth at a wharf or Jetty	Fire mains/monitors with a fire water supply of 288 M^3/hr (One monitor + Four hydrants)
2	Tanker berth at a wharf or jetty handling ships of less that 20,000 deadweight capacity	Fire mains/monitors with a fire water supply of 410 M^3/hr tonnes (2 monitors X 3000 lpm + 50m3)
3	Tanker berth at a wharf or jetty handling Handling ships of 20,000 tonnes and above but less than + 50,000 tonnes.	Fire mains/monitors with a fire water supply of 820 M^3/hr^2 monitors X 3000 lpm + 2 deadweight jumbo Nozzles X 3000 lpm + 100 M^3/hr.
4	Tanker berth at a wharf of Jetty handling ships of 50,000 tonnes and above but less than 100,000 tonnes deadweight	i) 600 M^3/Hrs for water/Foam monitors (2 tower monitors X 5000 lpm)
		ii) 600 M^3/Hrs for hydrant & water curtain service. (2 Jumbo Nozzles X 5000 lpm)
5	Tanker berth at wharf or Jetty handling ships of 100000 tonnes deadweight or larger capacity.	I) 720 M^3/hr for water/Foam monitors (2 tower monitors X 6000 lpm)
		ii) 720 M^3/hr for hydrant & water curtain service. (2 Jumbo Nozzles X 6000 lpm)

Material Specifications

The piping material specification shall be as given below: In case of sea water service, the fire water main pipes shall be cement lined or poly glass lines or glass reinforced internally.

i) Pipes : Carbon Steel as per IS:3589/IS:1239

ii) Isolation : Valves Cast steel (rising stem type) With indication for close / open positions

iii) Hydrant Stand post : Carbon Steel / Stainless Steel

iv) Outlet Valves / Landing Valves : Gunmetal / Stainless Steel

v) Monitors : Carbon Steel/Aluminium alloy / Gun Metal

vi) Fire Hose : Reinforced rubber lined as per IS : 636 Type (B)

vii) Foam : Piping Stainless Steel / Galvanised Iron

viii) In case of underground mains the isolating valves shall be located in RCC/brick masonry chamber.

ix) The above fire water mains and the hydrant standpost shall be painted with corrosion resistant "Fire Red" paint.

x) Water monitor and hose box shall be painted "Fire Red" as per shade 641 of IS : 5.

xi) Fixed water spray system shall be provided at all jetties handling ships of more than 20000 tonnes deadweight for segregation of loading arms and ship.

xii) High expansion foam has an expansion ratio of 1: 200 to 1 : 1000 is used for protection of Hydrocarbon gases stored under cryogenic conditions and for warehouse protection.

Safety Equipment in Fire Station
The following Safety equipment shall be provided in Fire Station of each Port Terminal:

HOSES

- Fire hoses shall be stored in a central hose station in the oil installation. The hoses shall be of 15 mtrs. Standard length and shall be provided with gun metal /stainless steel male and female couplings of instantaneous pattern.
- The number of hoses stored in an oil installation shall be 30% of the number of hydrant outlets. The minimum No. of hoses stored in an installation, however, shall not be less than 10. The hose station shall be located at convenient and easily accessible location in the oil installation.

NOZZLES

Following minimum quantities of fire fighting nozzles shall also be stored in the central hose stations.

i) Jet nozzles with branch pipe as per IS: 903 - 4 nos.

ii) Fog nozzles pipe as per IS: 952 - 4 nos.

iii) Universal nozzles as per IS: 2171 - 4 nos.

iv) Foam branch pipe as per IS: 952 - 4 nos.

v) In addition, HAZCHEM nozzle and high flow long range multi purpose nozzles may also be considered.

ACCESSORIES

Following minimum quantities of accessories shall be provided:

vi)	Sand Scoops	-4 nos
vii)	Safety helmets	-10 nos
viii)	Water curtain nozzles	-2 nos.
ix)	Stretcher	-2 nos.
x)	First Aid Box with Anti snake serum	-2 nos. (min)
xi)	11 KVA rubber hand gloves	-2 pairs
xii)	Explosimeter	-1 no.
xiii)	Fire Proximity suit	-2 no.
xiv)	Resuscitator	-2 nos.
xv)	Electrical siren (3 km range)	-1 no.
xvi)	Hand operated siren	-1 no.(min)
xvii)	Water jel blanket	-2 nos.
xviii)	Red/Green flags	-1 set
xix)	Positive Pressure type self contained breathing apparatus with spare cylinder	-2 no.
xx)	H2S Gas Detectors	-As per need

The DCP powder shall be 25 % of the total required for the portable DCP fire extinguishers and also 2000 kg in case of DCP tender.

First Aid Fire Fighting Equipment

The first aid Fire Fighting Equipment shall be provided at Vadinar Port Terminal as below:

	Description	Norms/criteria to determine the quantity needed
I)	Dry Chemical powder fire extinguishers 10 kg capacity.	Locate in Hydrocarbon pump area, LPG/OIL manifold area, loading areas, substations, workshops, laboratory, power station buildings etc. The number to be determined based on the travelling distance of 15m in above areas (at least one fire extinguisher for every 250 m^2 area)
ii)	Dry Chemical Powder fire extinguishers 50/75 kg capacity	Loading arms areas. The number to be determined based on the max. travelling distance of 50m in above areas (at least one fire extinguisher for every 750 m^2 area).

Further you may refer to Table 8-2.

9 GLOSSARY

ALARP	As Low As Reasonably Practicable
Barg	Bar Gauge
Deg C	Degrees Centigrade
DNV	Det Norske Veritas
ESD	Emergency Shut-Down
ESDV	Emergency Shut-Down Valve
F & G	Fire and Gas Detection
HC	Hydrocarbon
HCRD	Hydro Carbon Release Database (UK HSE)
IR	Individual Risk
IRPA	Individual Risk Per Annum
JF	Jet Fire
Kg/s	Kilogrammes per second
KJ	Kilo Joules, a measure of thermal dose
KW/m^2	Kilo Watt per Square Metre, a measure of heat flux or radiant heat
LFL	Lower Flammable Limit
LSIR	Location Specific Individual Fatality Risk per year
MAH	Major Accident Hazard
mm	Millimetre
MMSCFD	Million Standard Cubic Feet Per Day
NG	Natural Gas
P&ID	Piping and Instrumentation Diagram
PLL	Potential Loss of Life
Psi	Pounds per square inch, a measure of (over) pressure
QRA	Quantitative Risk Analysis
UK HSE	UK Health and Safety Executive
UFL	Upper Flammable Limit
VCE	Vapour Cloud Explosion

10 REFERENCES

//1// OISD –STD-156, Fire Protection facilities for Port Handling Hydrocarbons

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DNV Energy Regional Offices:

Americas and West Africa
Det Norske Veritas Ltda
Rua Sete de Setembro
111/12 Floor
20050006 Rio de Janeiro Brazil
Phone: +55 21 2517 7232

Asia and Middle East
Det Norske Veritas Sdn Bhd
24th Floor, Menara Weld
Jalan Raja Chulan
50200 Kuala Lumpur
Phone: +603 2050 2888

Europe and North Africa
Det Norske Veritas Ltd
Palace House
3 Cathedral Street
London SE1 9DE
United Kingdom
Phone: +44 20 7357 6080

Nordic and Eurasia
Det Norske Veritas AS
Veritasveien 1
N-1322 Hovik
Norway
Phone: +47 67 57 99 00

Offshore Class and Inspection
Det Norske Veritas AS
Veritasveien 1
N-1322 Hovik
Norway
Phone: +47 67 57 99 00

Cleaner Energy & Utilities
Det Norske Veritas AS
Veritasveien 1
N-1322 Hovik
Norway
Phone: +47 67 57 99 00