COCHIN PORT TRUST

ENVIRONMENTAL IMPACT ASSESSMENT STUDY FOR MULTI-USER LIQUID TERMINAL PROJECT (MULT) AT PUTHUVYPEEN, COCHIN PORT

VOLUME- II RISK ANALYSIS REPORT

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PROJECT DESCRIPTION

1.1 GENERAL

The Cochin Port is a natural all weather port. The marine facilities of the port are located along the Mattancherry Channel and the Ernakulam Channel. The on-shore facilities are mainly located on the Willingdon, Vallarpadam and Puthuvypeen Islands. Certain onshore facilities are also located on the shores of Ernakulam and Mattancherry/Fort Cochin. A Risk Analysis and Disaster Management Plan Report for the Cochin Port were prepared by TATA AIG Risk Management Services Ltd. in January 2002 and the same is being updated by WAPCOS Limited, A Government of India Undertaking in the Ministry of Water Resources. The facilities under the jurisdiction of the Cochin Port Trust are listed as follows:

Navigation Channels:

- **Outer Channel** of 13.10 Km length and 260/280 m width witha maintained depth of 15.95/17.4 m**.**
- **Inner Channels**
  - Ernakulam Channel of 5.032 Km length and 200 m widthwith maximum depth of 12.5 m**.**
  - Mattancherry Channel of 2.60 Km length and 183 m width with maximum depth of 10.00 m.

Berthing Facilities:

- Cochin Oil Terminal
- South Tanker Berth
- North Tanker Berth
- Fertilizer Berth (Q10)
- South Coal Berth
- Multi Purpose Berth (BTP & NCB combined)
- Ernakulam Wharf (Q5, Q6 and Q7,Q8 & Q9)
- Mattancherry Wharf (Q1 to Q4)
- Ro-Ro Terminals at Willingdon Island and Bolghatty

Storage Facilities:

- Mattancherry Wharf consisting of Warehouses, Overflow sheds and Transit sheds
- Ernakulam Wharf consisting of Warehouses,Overflow sheds and Transit sheds
- Container Freight Station

Facilities at Vallarpadam SEZ

- International Container Transhipment Terminal (ICTT)

Facilities at Puthuvypeen SEZ

- LNG Regasification Terminal (LNG) of M/s. Petronet LNG Ltd.
- Shore Tank Farmlinked to the SBM of M/s BPCL-KR.for crude oil storage
- Proposed LPG storage Terminal of IOCL.
- Proposed Multi – User Liquid Terminal for handling LPG, Bunker Oil and POL.

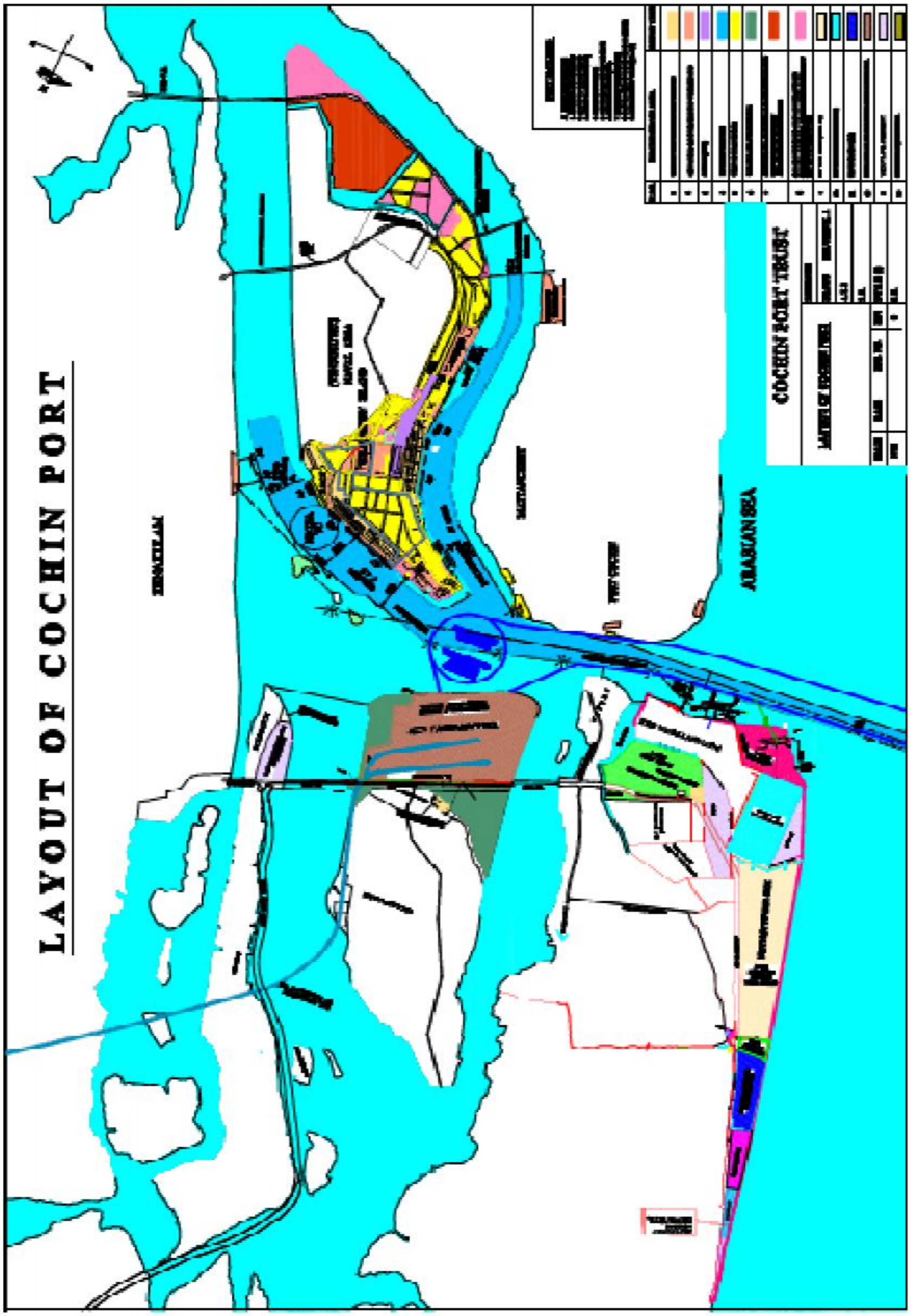
Proposed Facilities at Willingdon Island

- International Ship RepairFacilityat port workshop
- International Cruise Terminal at extended BTP
- Desalination plant
- Waste to energy treatment plant
- General Cargo Terminal (GCT)
- Bridge between W/Island andEdaKochi

Cochin Port Trust as part of expansion programme have envisaged “Setting up a Multi-User Liquid Terminal Project (MULT) at Puthuvypeen” in the notified Special Economic Zone (SEZ) for handling bunkers and other POL cargo (excluding crude oil) and LPG. The berthing facilities to be provided by Operator are as follows:

- A main berth for handling bunker fuel and other POL cargo and LPG
- A Barge loading berth in the vicinity for loading of bunker fuel and other POL cargo into barges.

The Layout map of Cochin Port Trust is given in Figure-1.1.


LAYOUT OF COCHIN PORT
COCHIN PORT TRUST
ARABIAN SEA

1.2 PORT AREA

The total land area of Willingdon Island under the port's jurisdiction is 953 acres, of which the northern portion measures 583 acres and south end reclamation area measures 370 acres. In addition, 115.25 ha of Port area at Vallarpadam island and 285.8413 ha of Port area at Puthuvypeen island have been notified as port based Special Economic Zones.

1.3 HINTERLAND LINKAGES

With the strategic location of Cochin Port on the South-West Coast of India and at the commanding position at the cross roads of East-West Ocean trade, the port is a natural gateway to the vast industrial and agricultural produce markets of the South-West India. It is connected to its hinterland through a network of roads, railways and waterways. The details are given in the following paragraphs:

Road

Cochin is connected to other states via the national highway network. The main North-South highway is NH-07, which runs through the centre of the country from Varanasai to Kanyakumari. This highway is connected to Cochin through NH-47, which runs inland from Trichur and joins at Salem. The NH-47 also connects at Edappally with the NH-17 which runs northwards along the coast to Mumbai.

The port area located at Willingdon island is connected to the mainland by four bridges, two each on Ernakulam Channel and on Mattancherry Channel. Bridges constructed on the Ernakulam Channel and Mattancherry Channel links the port to the NH-47 and NH-49 (Cochin-Madurai).

NH connectivity to ICTT at Vallarpardam comprises of four lane road and bridges with a route length of 17.2 Km from Kalamassery to Vallarpardam. At present, two lane connectivity has been completed and commissioned in February 2011 and other shall be completed by September 2013.

Rail

Cochin has direct access to the southern and national rail network allowing connections to all major industrial and population centres. The rail connections are also extended up to the quay sides. Rail connectivity with a route length of 8.86 Km from Edappally to Vallarpardam has been commissioned in February 2011.

Inland Water Transport

Cochin is located on a series of interconnecting waterways, canals and lagoons which allow movement through waterway vessel to Alleppey and Quilon. The main linkages are provided by the West Coast Canal, the Udyogamandal Canal and the Champakkara Canal which has been declared as National Waterway No. III. Of these, West Coast Canal is the most significant in terms of potential capacity.

1.4 CARGO HANDLED AT THE PORT

The cargo traffic handled at Cochin Port increased from 13.02 million tonnes in 2002-03 to 20.09 million tonnes in 2011-12, registering an average annual growth rate of 5.43.%. The year-wise growth in the cargo traffic handled at Cochin Port vis-à-vis that handled at all the major ports of the country together with the percentage share of traffic handled at Cochin Port from 2002-03 to 2011-12 is given in Table-1.1.

Table-1.1: Cargo traffic handled at Cochin Port from 2002-03 to 2011-12

Year	Traffic Handled (million Tonnes)		% Share of traffic handled by Cochin Port
	Cochin Port	All major ports in the country	
2002-03	13.02	313.55	4.15
2003-04	13.57	344.80'	3.94
2004-05	14.10	383.75	3.67
2005-06	13.89	423.57	3.28
2006-07	15.26	463.78	3.29
2007-08	15.75	519.16	3.03

Year	Traffic Handled (million Tonnes)		% Share of traffic handled by Cochin Port
	Cochin Port	**All major ports in the country**	
2008-09	15.49	530.53	2.92
2009-10	17.43	560.97	3.11
2010-11	17.87	569.91	3.14
2011-12	20.09	516	3.89
Average Annual Growth Rate (%)*	**5.43**	**15.48**	

Source: Major Ports of India – A Profile, IPA – Various issues.

The broad commodity composition of traffic handled at Cochin Port from 2002-03 to 2011-12 is given in Table-1.2.

Table - 1.2: Commodity composition of traffic handled at Cochin Port

Year	Traffic Handled(MT)					
	Liquid Bulk	**Dry Bulk**		**Break Bulk**	**Container**	**Total**
		Mechanical	**Conventional**			
2002-03	9.5	0.45	0.57	0.43	2.07	13.02
2003-04	10.1	0.34	0.51	0.5	2.12	13.57
2004-05	10.42	0.48	0.46	0.42	2.32	14.10
2005-06	9.84	0.59	0.58	0.39	2.49	13.89
2006-07	10.75	0.52	0.74	0.3	2.95	15.26
2007-08	11.58	0.27	0.58	0.14	3.18	15.75
2008-09	10.76	0.27	0.81	0.13	3.52	15.49
2009-10*	12.40	0.33	0.64	0.13	3.93	17.43
2010-11*	12.48	0.61	0.29	0.07	4.42	17.87
2011-12*	14.24	0.67	0.36	0.11	4.71	20.09

*Dry Bulk Mech incl:Rock PH,Sulphur&Cement

During the year 2011-12, Cochin Port handled 20.09 million tonnes of cargo traffic, as against 17.87 million tonnes handled during the preceding year. The commodity-wise break-up of the traffic handled at Cochin Port during2011-12 is given in Table-1.3.

Table- 1.3: Commodity-wise break-up of the traffic handled at Cochin Port during 2011-12

S.No.	Commodity	Traffic Handled during 2011-12 (million tonnes)	Percentage share from the Total
I.	**Liquid Bulk**		
1.	Crude Oil	10.03	49.93
2.	POL Products	3.98	19.81
3.	Other Liquids	0.23	1.14
	Total (I)	**14.24**	**70.88**
II	**Dry Bulk**		
4.	Fertilizer incl.FRM	0.43	2.14
5.	Coal	0.03	0.15
6.	Other Dry Bulk	0.57	.2.84
	Total (II)	**1.03**	**5.13**
III	**Break Bulk**	0.11	**0.55**
IV	**Containers**	4.71	**23.44**
	Grand Total (I to IV)	**20.09**	**100%**

1.5 STORAGE FACILITIES OF COCHIN PORT

For the storage of the cargo, extensive facilities have been provided at the Cochin Port.

1. Mattancherry Wharf is served by a covered area of 35,463 sqm consisting of four warehouses.
2. Ernakulam Wharf excluding Q10 berth, has a covered area of 32,146 sqm including a Container Freight Station of 10732 sq. m.
3. In Willingdon island, 14 tank farms in an area of 412640 sqm with a total capacity of 329467 KL are located. .

The storage facilities available at Cochin Port are detailed in Table-1.4.

Table-1.4: Storage facilities available at Cochin Port

S. No.	Location		Quantity (No. / KL)	Total Storage Area(Sq.M)
1	**Mattancherry Wharf**			
	a.	Warehouses	4 No.	10876
	b.	Overflow Sheds	4 No.	6754
	c.	Transit Sheds	4 No.	17.463
	d.	Sheds for Hazardous cargo	2 No.	370
				35,463
2	**Ernakulam Wharf**			
	a.	Warehouses	1 No.	2977
	b.	Overflow Sheds	3 No.	5982
	c.	Transit Sheds	3 No.	10,800
	d.	Cement Godown	1 No.	1115
	e.	Warehouse at EDC Building	1 No.	540
	f.	Container Freight Station	1 No.	10,732
				32,146
3	**Q 10 Berth**			
	a.	Rock Phosphate Silo	1 No.	5,000 m^3
	b.	Sulphur and Potash Silo	2 No.	10,000 m^3
4	**Tank Farms**			
	a.	Parrisons Infra Structure Ltd.	17260 KL	14300
	b.	HHA Tank Terminal Ltd.	59100 KL	39100
	c.	Konkan Storage Systems (Cochin) Pvt. Ltd.	50940 KL	33840
	d.	Ganesh Benzo Plast Ltd.	30250 KL	4270
	e.	Ganesh Medicament Ltd.		3170
	f.	Ganesh Anhydride Ltd.		4170
	g.	Ruchi Infrastructure Pvt. Ltd.	11000 KL	2000
	h.	Vijayalakshmy Cashew Co. Ltd.	2400 KL	900
	i.	IMC. Ltd.	6000 KL	2020
	j.	Indian Oil Corporation Ltd.	47117 KL	24120
	k	FACT Ltd.		46670
	l.	Liquid Ammonia Tank	10000 KL	
	m.	PhosphoricTank	19500 KL	
	n.	Sulphuric Acid Tank	16000 Kl	

S. No.		Location	Quantity	Total Storage
		(Under construction)		
	o.	Tropicana Liquid Storage Ltd(Construction not started).	-	12100
	p.	B.R. Petrochem (P) Ltd.	29900 KL	12000
	q.	Ruchi Infrastructure Pvt. Ltd. SER area	30000 KL	15800
		Total (Tank Farms)	**329467 KL**	**412640 Sq. M**

1.6 BERTHING FACILITIES OF COCHIN PORT

The berthing facilities of the Cochin Port are provided along Ernakulam Channel and Mattancherry Channel on either side of the Willingdon Island. The various facilities are briefly described in the following sections:

Cochin Oil Terminal (COT)

The COT is located in the Ernakulam Channel, opposite to Q8 berth. Although it has been designed for receiving up to 1,15,000 DWT size crude tankers, in view of the draft restrictions, tankers upto a draft of 12.5 m with parcel size of about 82,000 t are loaded at this terminal. The COT comprises of 4 breasting dolphins, one central platform and four mooring dolphins, two on either side of the platform. The structure has been located on vertical as well as raker piles. The mooring dolphins and central portion consisting of platform and breasting dolphins have been interconnected through walkways, 4 nos. marine unloading arms, each of 300 mm diameter with a rated discharge of 1500 tph has been provided at the central platform.

The COT is being used for handling of crude oil and products. One 762 mm diameter (for crude oil) and two 406 mm diameter (for products) including thesubmarine portion have been provided for connecting the COT to the refinery pipelines at shore.The crude pipeline has a capacity limiting to maximum discharge of 2500 tph and an average discharge of 2000 tph.

South Tanker Berth (STB)

This jetty situated adjacent to NTB is mainly used to service product tankers of size up to 18,000 DWT with an LOA of 170 m and 9.14m draft. This jetty is connected to the Ernakulam shore through a 270 m long approach trestle and oil transfer takes place through marine loading arms and flexible hoses. The jetty is provided with oil pipelines for handling products like Naphtha, MS, FO and SKO/HSD. The average discharge rate is 800 tph in case of Naphtha/MS/SKO/Kerosene and 500 tph in case of FO. One 320 mm diameter bunker pipeline is also provided.

North Tanker Berth (NTB)

This jetty was constructed in the Ernakulam Channel and commissioned in 1955. The jetty was upgraded in 1966 to receive crude tankers of size 30,000 DWT with LOA of 213 m with a loaded draft of 9.14 m. The Jetty is connected to Ernakulam shore by a 270 m long approach trestle. To handle crude and products, pipeline system comprising of various sizes has been provided. Marine loading arms and hoses are provided for transferring oil between the berth and the tanker using tanker's own derrick.

Fertilizer Berth (Q10)

It is an open piled jetty 278 m long, located at the south east of Q9 wharf. Two mooring dolphins, one on either side of the berth and an approach trestle of 36.3 m length and 7.5 m width, at the south eastern end, have been provided. This berth is allotted for handling the FACT traffic exclusively, which consists of fertilizer raw material i.e. rock phosphate and sulphur. In addition to this a 300 mm diameter pipeline has been provided to handle phosphoric acid. A barge jetty is provided adjacent to the Q10 berth, for transportation of the fertilizer raw material for FACT, by barges.

Ernakulam Wharf (Q5, Q6 & Q7,Q8 and Q9)

The Ernakulam Wharf consists of five berths Q5 to Q9. The berths Q5 to Q8 were commissioned in 1964 and Q9 was commissioned in 1972. These berths are made up of concrete monoliths of size 11.00 m x 11.00 m. These monoliths were sunk through the subsoil and found at the levels varying from -23 m to -28 m with reference to chart datum. These monoliths have been spaced 15.4 m from centre to centre and gap between monoliths closed with RC sheet piles. The total length of the Ernakulam Wharf is 917 m. The original quay structure was designed as general cargo berth for a dredged depth of -11.00 m. The Q5 to Q9 berths are being utilized for handling general cargo and fertilizers.

The berths Q8 and Q9 were upgraded to a 414 m long full fledged container terminal after carrying out suitable modificationsto the structure. These berths have been modified for a dredged depth of -13.2m. The modifications of the berths consisted of complete replacement of the superstructure at these berths and providing an RCC platform, supported over bored cast-in-situ piles, behind the quay wall. The RCC platform, acts as a relieving platform relieving the excessive lateral earth pressure on the monoliths.

As the Container operations have been shifted to the new Container Transhipment Terminal at Vallarpadam, these berths are now being utilized for handling General Cargo.

Multi Purpose Berth (Boat Train Pier & North Coal Berth Combined)

This Boat Train Pier (BTP) berth has been constructed as multi-purpose jetty. The berth structure consists of a central platform connected to land through three no. of gangways. The total length of the platform is 200 m.

The North Coal Berth (NCB) is located on the Mattancherry Channel. This was constructed for handling coal vessels. North Coal Berth and was commissioned in 1959 and its length is 182.88 m. The permissible draft at these berths is 9.14

m. The berth is constructed using pre-cast concrete piles and the main berth consists of a 105 m long RCC platform supported over 500 mm square pre-cast piles. This platform is connected to the shore by three gangways, one at the centre and two on either sides. The North Coal Berth is used for handling POL products for Indian oil. This berth is also being used for general cargo vessels with a maximum capacity of 35,000 DWT, passenger vessels and for maintenance of dredgers.

Mattancherry Wharf (Q1 to Q4)

The Mattancherry Wharf consisting of four berths namely Q1, Q2, Q3 and Q4 is the first Wharf constructed during 1930s, using the steel sheet piles. The length of the original steel pile quay was 457.60 m. During 1940s the wharf was extended on both sides, using monoliths, increasing the quay length to 670 m. Subsequently, a structure using reinforced cement concretesupported over concrete screw piles was constructed in 1951 for berthing of vessel. The length of this structure is 577 m. It was subsequently extended on both sides by 33.15 m to provide a total wharf frontage of 643.30 m for berthing of the vessels. The quay structure has been designed for a dredged depth of -9.75 m in front. The berths Q1 to Q3 are being used for handling of general cargo whereas the Q4 was mainly used for handling of defence cargo. Presently Q4 is being converted to handle liquid cargo in bulk.

The Mattancherry Wharf, was in a distressed condition and one of the berths (Q4) collapsed in Nov. 2005. The reconstruction of this wharf for a length of 250m, covering Q4 berth was taken up for a capacity addition of 1.15MMTPA. The reconstruction of berth structure was completed and berthing of ships in the new berth has commenced with effect from 20th June 2010.

South Coal Berth

The South Coal Berth located on the Mattancherry Wharf. It was constructed for handling coal vessels. South Coal Berth was commissioned in 1953. The length of the South Coal Berth is 192.02 m. The permissible draft at the berth is 9.14 m.The berth is constructed using pre-cast concrete piles. The main berth consists of a 105 m long RCC platform supported over 500 mm square pre-cast piles. This platform is connected to the shore by three gangways one at the centre and two on either sides.The South Coal Berth is being used for handling liquid ammonia, for which a 200 mm diameter marine unloading arm and a 300 mm diameter pipeline is provided connecting the storage tank.

Liquid Ammonia Jetty

This is a barge loading jetty located south of the South Coal Berth. This jetty is an open piled construction using 500 mm square RCC piles. This jetty is 59 m long by 4.5 m wide. It is connected to the shore by a 39 m long and 4 m wide approach on pre-cast piles. This jetty was being used for transportation of liquid ammonia for FACT by barges.

Ro-Ro Facility

Cochin Port had devised a barge movement facility through NW 3 between Willingdon Island and Bolghatty to service Roll on-Roll off(Ro-Ro) vessels and Lift on-Lift off (Lo-Lo) barges for clearance of containers in the scenario of increased movement of containers due to commissioning of International Container Transshipment Terminal at Vallarpadam (ICTT).

On behalf of Inland Waterway Authority of India(IWAI) Cochin Port had taken up the construction of terminals at Bolghatty and Willingdon island for facilitating Ro-Ro/Lo-Lo barge movements, as deposit work at a cost of Rs 16 crores.

Construction of the terminals were completed and formally inaugurated on 23rd April 2010. For the operation of Ro-Ro ferry/Lo-Lo barge service, work order was issued to M/s Lots Shipping Ltd. on 05/06/2010. The Ro-Ro vessels arrived at Willingdon Island (Ernakulam Channel) on 16/02/2011 and the operations commenced on 24/02/2011.

1.7 INTERNATIONAL CONTAINER TRANSSHIPMENT TERMINAL (ICTT) AT VALLARPADAM ISLAND

The ICTT project has facilities for handling mother container ships of 8000 + TEU capacity. This State of Art terminal with 1800m berth and supporting handling equipments,which is to have an annual throughput of 3 million TEUs is to be implemented in three phases. This BOT project was awarded to M/s India Gateway Terminal Pvt Ltd (IGT), a subsidiary of M/s Dubai Port World (DPW). The phase-I of the terminal with a capacity of 1 million TEUs had been commissioned in February 2011.

1.8 FACILITIES AT PUTHUVYPEEN SEZ

Captive LNG Port and Re-GasificationTerminal

The comprehensive LNG project comprisingof the LNG Port Project and LNG Re-gasification project, is being implemented by M/s Petronet LNG Ltd. (PLL). The LNG Port project includes the design, finance, construction, operation and maintenance of a jetty and mooring facilities, approach trestle, other associated offshore works and ancillary facilities, capable and sufficient for handling LNG of 5 MMTPA. The LNG Re-gasification project includes the design, finance, construction, operation and maintenance of storage tanks and other onshore facilities required for the import, re-gasification and dispatch of LNG and related activities/services.

Puthuvypeen, the site for the LNG Terminal, is an accreted area west of Vypeen peninsula and north of the entrance channel to Cochin Port. Puthuvypeen is accessible by road through the mainland from Cochin. Alternate route is inland waterway by which one has to travel by ferry from either Ernakulam or Fort Cochin and reach the ferry jetty at Vypeen.

LNG Jetty/ Berth

A dedicated LNG unloading Jetty has been built as a part of the LNG terminal facility. The jetty is havingsingleberthing facility so that only one unloading operation is possible at a time. The Jetty is provided with process and safety equipment required for the LNG unloading operation only. Facilities for supplying bunker fuel and water to the ship are not provided. Here, the predominant wind is from north-west and south-west and hence, the jetty has been aligned in west-south-west direction.

The length of the LNG berth is approximately 376.5 m and is designed for catering to the needs of LNG carriers ranging from 65000 to 216000 cu. m.

The LNG berth comprises offive breasting dolphins and seven mooring dolphins for berthing and mooring of the LNG vessels. ACentral UnloadingPlatform is provided between the breasting dolphins to accommodate LNG unloading arms, vapour recovery arms, access gangway and other utilities. The breasting dolphins, mooring dolphins and service platform are connected by a walkway for movement of personnel.

Unloading Platform

The Unloading Platform provided at the middle of the berthing jetty is in two levels of dimension 43.5 m x18.5 m, lower deck and 25.0 m x 10.5 m, upper deck.The platform is located off centre to take into account the manifold offsets of the LNG tankers.

The unloading arms

Four unloading arms have been installed at the Jetty for the following services:

- Two arms dedicated for unloading LNG only from the ship.

- One arm dedicated for return vapour from the on-shore storage tanks to the ship during the LNG unloading operation.
- One dual purpose arm that could be used for unloading LNG or returning LNG vapour from the Terminal storage tanks to the ship as required.

The LNG product from the ship will be unloaded through 32" diameter insulated line running from the unloading arms manifold to the onshore LNG Storage Tanks. This line is sized to handle 12,000 m^3/hrof LNG product for the normal unloading process which is expected to take approximately 15 hours and includes the cool down time for the unloading arms and the ship's piping. Drain pump will be provided that will be located close to the jetty / onshore interface to drain the jetty portion of the unloading line or the entire unloading system in case of an emergency/maintenance purposes. The pump is designed to transfer drained LNG from the unloading lines into the LNG Storage Tanks or the LNG tank send out pump discharge system.

SBM Project for handling of crude oil

BPCL-Kochi Refineries a subsidiary of BPCL, has installed a Single Buoy Mooring (SBM) facility in the open sea at Vypeen within Kochi port limits. CPT had provided on lease 70 hectares at Puthuvypeen for setting up the Shore Tank Farm for storage of crude oil, handled at SBM.The SBM and supporting facilities areinstalled and maintained by BPCL-KR while all the operations required in connection with the vessel operations are done by CPT.

Multi-User Liquid Terminal (MULT) Project at Puthuvypeen

Presently, development of MULT is envisaged for handling bunkers and other POL cargo (excluding crude oil) and LPG with a capacity of 4.10 MMTPA. The berthing facilities to be provided by the Concessionaire shall comprise the following:

- A main berth for handling bunker fuel and other POL cargo and LPG.
- A Barge loading berth in the vicinity for loading of bunker fuel and other POL cargo into barges.

These berths shall be operated by the Concessionaire to be selected on Design, Build Finance, Operate and Transfer (DBFOT) basis.

LPG Import Terminal

The proposed LPG import terminal is to be located at Puthuvypeen SEZ situated at eastern side of Arabian Sea. The LPG brought in tanker ships will be unloaded using two nos of 10'' dia marine unloading arms in the proposed jetty of Cochin Port Trust and pumped to LPG Mounded Bullets. The LPG from the jetty will be pumped to LPG import terminal through 20" dia. transfer pipeline. The total designed storage capacity of the terminal is 15400 tons and that of the road tanker loading facility is approximately 128 trucks in a day. Four vessels are designed for propane storage and four vessels for butane storage service.

1.9 MECHANICAL EQUIPMENT

For handling of the cargo at the port different mechanical equipments have been provided which include quay cranes, mobile equipment such as forklift trucks, tractors trailers, mobile cranes, high reach-stackers etc.

1.10 PORT CRAFTS

The port has a number of dredgers, tugs, mooring launches, pilot launches, water barges, floating cranes, fire float and other miscellaneous crafts. The details are given in the following sections.

Dredgers

The port has one (1) self-propelled hopper grab dredger and 1 no. non-propelled grab dredger. These are utilized to carry out maintenance dredging in the berthing areas and at the berths. Maintenance dredging of the navigational channel is carried out byengaging outside dredging agencies.

Tugs

Port has 4 nos. tugs out of which 2 nos. are of 30 t bollard pull capacity each and the remaining is of 45 t bollard pull capacity each. In addition there are 2 nos. of hired tugs.

Launches

Port has 13 nos. of mooring launches and 2 nos. of pilot launches. Besides there are 2 more launches. These are of lengths varying between 9.0 m and 17.0 m with horse power ranging from 55 to 150.

Miscellaneous Crafts

These include one water barge, Jalaprabha; one 200 t capacityfloating crane – Periyar; and auxiliary/pollution control craft- Venad.

1.11 MAINTENANCE FACILITIES

For repairs and maintenance of the port structure and equipment, facilities have been provided at the port, which include maintenance workshops, small dry dock, a slipway, workshop jetty and electrical repair shops.

1.12 UTILITIES

Electric Supply

Cochin Port is a Licensee of Kerala Electricity Board for the distribution of Power Supply in Willingdon Island area. Port was drawing power from KSEB through the 110 KV substation. The total load on 110 KV line has been envisaged to be increased more than the permissible limit as per regulations. In order to meet the requirement as per regulation and also to provide quality power to the consumers, one 110 KV substation with 40 transformers of various capacities were installed. Standby Power Supply is available through 3 nos. of Diesel Generator sets of 11kV with 3.125 MVA, 440V with 625 KVA and 440V with 530 KVA networks. Apart from the above, port maintains about 1000 street lights and 10 nos. of high mast lighting systems.

Water Supply

The Cochin Port Trust receives the fresh water supply from the Kerala Water Authority (KWA) and then internal distribution of water in the port area is undertaken. About 4000 KL of water is required for domestic consumption and another 500 KL of water is required for the supply to vessels. Due to acute shortage of water at the port, water supply from the shore installations has been restricted only to passenger vessels coming at the Port.

Presently, port receives water supply from one 225 mm diameter line and one 300 mm diameter line which are also being shared by Navy.

Fire fighting

Port does not have a fixed fire fighting system covering the entire operational area. However, COT, NTB and STB as well as new administration building have been provided with fire fighting system (i.e. COT automatic and other two manual). Besides this, the port has 5 mobile fire tenders. Hazardous liquid storage tank farms have been provided with fire fighting system by the respective user agencies like IOC, FACT etc. COT has been provided with three 500 m^3/hour capacity pumps, STB/NTB with two 500 m^3/hourcapacity pump.

1.13 OUTLINE OF THE REPORT

The document for the Environmental Impact Assessment Study for development of Multi-User Liquid Terminal (MULT) at Puthuvypeen, Cochin Port has been presented in following four volumes:

Volume-I	Environmental Impact Assessment (EIA) study and Environmental Management Plan (EMP)
Volume-II	Risk Analysis Report for Cochin Port
Volume-III	Integrated Disaster & Safety Management Plan
Volume-IV	Hazard and Operability Study (HAZOP)

The present document (Volume-II) outlines the Risk Analysis Report for proposed Multi-User Liquid Terminal Project at Cochin Port. The contents of the document are organized as follows:

Chapter 1: The chapter gives an overview of the project description of the proposed Multi-User Liquid Terminal Project.

Chapter 2: Summaries the Risk Analysis, Risk Estimation, Hazard Analysis and details of the statutory clearances and permissions required pertaining to safe operations of the proposed project.

Chapter 3: Outlines the review of earlier Risk studies, Risk Identification in solid container and break bulk cargo handling, identification of risks for storage and transportation of bulk cargoes, Risk Identification of berths handling liquid products etc.

Chapter 4: Provides an overview on anticipated Risk Analysis for LPG import Terminal at Puthuvypeen Island, preliminary Hazard Analysis, Credible Scenarios and Consequence Analysis.

Chapter 5: Outlines the Risk Analysis for LNG regasification plant near Vypeen Island and process description. Possibility of accidental release of LNG from piping or equipment and Consequence Analysis

Chapter 6: Summaries the Risk Analysis study conducted for International Container Transshippment Terminal (ICTT).

Chapter 7: Outlines the Risk Analysis Study for Multi-User Liquid Terminal (MULT) at Puthuvypeen

Chapter 8: Summarizes the Risk and Failure Probability

CHAPTER-2

CHAPTER – 2
RISK ANALYSIS

2.1 GENERAL

The terms, 'hazard' refers to sources of potential harms, whereas risk considers frequency and severity of damage from hazards. Hazard denotes a property or a situation that in particular circumstances could lead to harm. Risk on other hand, is a function of the probability of a hazard occurring and the magnitude of the consequences. Risk therefore, represents the likelihood of a potential hazard being realized. Risk Estimation involves, identifying the probability of harm occurring from an intended action or accidental event. Risk Evaluation determines the significance of estimated risks, including risk perception. The Risk Analysis study is a combination of risk estimation and risk evaluation.

In the proposed project, the cargo to be handled includes LPG, Bunkers and other POL product excluding crude oil. LPG and POL Products are hazardous materials as per "Manufacture Storage and Import of Hazardous Chemical Rules," 1989. The handling of these products may result in fire, explosion and toxic hazards. In order to minimize damages to existing structure in the Cochin Port due to likely failure cases, the risk analysis study has been carried out to quantify zone of influence of various failure cases and a disaster management plan has been prepared to control the spread of incident effectively.

The first stage in any risk analysis study is to identify the potential accidents that could result in the release of hazardous material from its normal containment. This is achieved by a systematic review of the facilities together with an effective screening process. The chemical hazards can be classified as follows:

* Flammable
* Reactive
* Toxic

Potential accidents associated with any installation can be divided into two categories:

1. Possibility of failure associated with each mechanical component like tanks, pipes, pumps or compressors. These are generic failures and can be caused by mechanisms like corrosion, vibration or external impact (mechanical or overpressure)
2. Likelihood of failure caused by specific operating circumstances e.g. human error.

In the next stage of the study, based on the failure data, consequence analysis for each identified failure is conducted. For flammable materials, effective zone for the various possible outcomes of such a release is estimated. The next step is to assess its impact.

The final and the most significant, stage in risk analysis is the assessment of what the calculated risk levels portray. Risk assessment is a process by which results of risk analysis are used to make judgements either through relative risk ranking or risk reduction strategies or through comparison with risk targets.

2.2 STATUTORY CLEARANCES

The statutory clearances and permissions required pertaining to safe operations are given in Table 2.1.

Table-2.1: Statutory Clearances/Permissions for the Terminal pertaining to Safety

S. No.	Clearance	Authority	Under	Clause applicable
1.	Consent to Establish	Kerala State Pollution Control Board	Water (Prevention and Control of Pollution) Act 1974, Air (Prevention and Control of Pollution) Act 1981, Environment (Protection) Act, 1986, applicable	Several clauses

S. No.	Clearance	Authority	Under	Clause applicable
			rules framed thereunder, Water (Prevention and Control of Pollution) Cess Act 1977.	
2.a	CRZ Clearance	Kerala Coastal Zone Management Authority (notified by Ministry of Environment and Forests.	Declaration of Coastal Stretches as Coastal Regulation Zone (CRZ), and imposing restrictions on industries, operations and processes in the CRZ Notification, 2011	4.0 Regulation of Permissible Activities in the CRZ Area
2.b		Ministry of Environment and Forests (MoEF)		
3.	Environmental Clearance	State EIA Authority (Kerala Expert Appraisal Committee) State MoEF	EIA Notification, 1994, amended 2006, 2009, 2011	Schedule I, 7(e), Category B, 5 million TPA of cargo handling capacity and/or ports/ harbours ^{3}10,000 TPA of fish handling capacity[1]
4.	PESO[2] Approval	Petroleum and Explosives Safety Organization (PESO)	Petroleum Rules, 2002, amended 2005	Chapter II, Part II, Importation by Sea Chapter III, Part II, 44 Loading and Unloading of Bulk Petroleum

[1] Combined capacity of the Terminal is less than 5 MMTPA (4.52 MMPTA = 3.02 MMPTA bunker (ultimate handling capacity) + 0.6 MMTPA LPG + 0.9 MMTPA crude)

[2] Formerly 'Chief Controller of Explosives'

The siting and layout of the Jetty will be governed by the following statutes/ guidelines:

- The Petroleum Rules, 2002 (2005)
- Standard for Fire Fighting system - OISD Standard – 156

The Petroleum Rules administered by the PESO is of statutory applicability, whereas the OISD guidelines are safety, operational philosophy and design guideline generally followed by hydrocarbon installations under the administrative control of the Ministry of Petroleum and Natural Gas. (Some OISD guidelines have been given statutory status under the amended. Petroleum Rules, 2002, where adherence to these OISD standards is a prerequisite for setting up and operation of an installation seeking permission from CCoE, therefore enforceable under the Rules. These OISD standards are OISD -105, 116, 117, 118, 141 and 156.).

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In addition, following guidelines and industry standards have been referred for conducting the Risk Assessment:

1. Liquefied Gas Handling Principles on Ships and in Terminals – Mc Guire and White (3rd edition) – SIGTTO
2. International Safety Guide for Oil Tankers and Terminals (4th edition) – ICS, OICMF, NAPH
3. Liquefied Gas Fire Hazard Management (1st edition) – SIGTTO
4. A guide to Contingency Planning for Marine Terminal Handling Liquefied Gases in Bulk (1st edition) – ICS, OCIMF, SIGTTO
5. A Risk Based Approach for the Evaluation of Firefighting Equipment on Liquified Jetties – SIGTTO

6. A guide to Contingency Planning for the Gas Carrier alongside and within Port limits – (2nd edition) – ICS, OCIMF, SIGTTO

2.3 COMPONENTS OF RISK ASSESSMENT

The normal components of a risk assessment study are:

- Hazard identification and specification (Identification of Maximum Credible Loss Scenarios).
- Consequence calculations.
- Failure frequency estimation.
- Risk review
- Recommendations on risk mitigation measures.

2.4 FAILURE CASE IDENTIFICATION AND DEFINITION

The first stage in any risk assessment study is to identify the potential accidents that could result in the release of the hazardous material from its normal containment. This is achieved by a systematic review of the facilities together with an effective screening process.

Chemical hazards are generally considered to be of three types :

- Flammable
- Reactive
- Toxic

Where there is the potential for confined gas releases, there is also the potential for explosions. These often produce overpressures which can cause fatalities, both through direct action on the body or through building damage.

Potential accidents associated with any plant, section of a terminal/plant or pipeline can be divided into two categories:

- There is a possibility of failure associated with each, mechanical component of the facility/terminal (vessels, pipes, pumps or compressors). There are generic failures and can be caused by such mechanisms as corrosion, vibration or external impact (mechanical or overpressure). A small event (such as a leak) may escalate to a bigger event, by itself causing a larger failure.

- There is also a likelihood of failures caused by *specific* operating circumstances. The prime example of this is human error, however it can also include other accidents due, for example, to reaction runaway or the possibility of ignition of leaking tank gases due to hot work.

The first class of accident requires consideration of each component under its normal operating conditions. Both classes may also require consideration of some components under abnormal conditions. In principle, an essential first stage in failure case identification of such a facility is therefore every significant mechanical component in the plant which could fail, together with its operating conditions, contents and inventory.

The range of possible releases for a given component covers a wide spectrum, from a pinhole leak up to a catastrophic rupture (of a vessel) or full bore rupture (of a pipe). It is both time-consuming and unnecessary to consider every part of the range; instead, representative failure cases are generated. For a given component these should represent fully both the range of possible releases and their total frequency.

As a part of the study, the following typical types of failures were considered:

For Vessel/storage tank:

- Rupture (full bore)
- Large leaks (20% mm equivalent diameter)

- Medium and Small leaks (due to corrosion, impact and other such cases).

For pipelines:

- Full bore rupture
- Large, Medium and Small leaks

Failures of other components are dealt with in a similar manner giving releases which are representative of accidents to that type of component.

For risk assessment study, 20% equivalent to the pipe diameter has been considered for estimating area of leakage.

2.5 RISK ESTIMATION

The release of hazardous chemicals poses fire, explosion or/and toxic hazard. Chemical release would be due to leakage from gaskets/flange joint, rupture of pipeline due to over pressure, corrosion or external mechanical impact or liquid hammer, malfunctioning of equipment or isolation valves, failure of pressure relief system, failure of unloading hose, etc. These basic causes of failures may be due to human error, lapse in control system, design error, poor/wrong material of construction, poor maintenance, wrong operating procedure etc.

The magnitude of risk depends upon following parameters:

- Inherent flammable/toxic properties of chemical; for example, propane is highly flammable but it is relatively non-toxic.
- Physical state. For example, gaseous chemical releases are more dangerous than liquid chemical releases (except saturated liquids).
- Chemicals released at high temperature and pressure could pose severe risk. For example, consequences arising out of ammonia release from a storage vessel under pressure and at atmospheric temperature is more severe than the same release from a storage tank under refrigerated conditions and at atmospheric pressure.
- Rate of release is proportional to the area of leakage.
- Inventory of the chemicals; high inventory would pose high risk.

2.6 PRELIMINARY HAZARDS ANALYSIS (PHA)

Preliminary Hazards Analysis (PHA) is a broad based study carried out to identify potential hazards associated with various process operations, types of chemicals, and associated activities carried out at any facility. The objective of Preliminary Hazards Analysis is to further direct greater depth of analysis and suggest remedial measures for hazard potential areas. The PHA is always better done in the early stages of the project so that requisite time is available to implement recommendations and it is economical to implement in the beginning rather than modifying the system subsequently after commissioning the facility.

The areas identified for carrying out PHA are given below:

- Areas where large quantities of hazardous chemicals are stored or processed.
- Areas where operating temperatures and pressures could be particularly high.
- Areas where flammable inventories exist. At times the flammable inventories may not be hazardous in itself but even a minor fire in the vicinity may be sufficient to cause knock-on effect resulting in release of hazardous chemicals.
- Specific operations associated with the high probability of failure.
- Areas where destructive and dangerous chemical reactions could take place resulting in major heat evolution, release of toxic products in reaction, polymerization, etc.
- Areas where potentially corrosive material is stored and handled and where pipeline or tank failure due to corrosion would result in major release of the corrosive or toxic chemical.
- Areas where passive or active safety systems are associated with a generally high failure rate.

Ranking of Chemical hazards

National Fire Protection Association (NFPA) ratings of the chemicals handled by the port are given in Table 2.2. The explanation of NFPA classification is given in Table 2.3.

Table- 2.2: Degree of hazards associated with various cargo

CHEMICAL	**N_f**	**N_h**	**N_r**
High Speed Diesel	2	0	0
Crude Oil	3	1	0
Gas Oil	2	0	0
SKO	2	0	0
Naphtha	3	1	0
Motor Spirit	3	1	0
Sulphur	1	1	0
Phosphoric Acid	0	2	0
Ammonia	1	3	0
LNG	4	1	0
Coal	1	0	0

N_f = Number of flammability
N_h = Number of health hazard
N_r = Number of reactivity

Table 2.3: Explanation of NFPA classification

CLASSIFICATION	**DEFINITION**
Health Hazard Nh	
4	Materials which on very short exposure could cause death or major residual injury even though medical treatment were given.
3	Materials which on short exposure could cause serious temporary or residual injury even though medical treatment were given.
2	Materials which on intense or continued exposure could cause temporary incapacitation or possible residual injury unless medical treatment is given.
1	Materials which on exposure would cause irritation but only minor residual injury even if no treatment is given.
0	Materials which on exposure under fire conditions would offer no hazard beyond that of ordinary combustible material.
Flammability Hazard Nt	
4	Materials which will rapidly or completely vapourise at atmospheric pressure and normal ambient temperature, or which are readily dispersed in air and which will burn readily.

CLASSIFICATION	DEFINITION
3	Liquids and solids that can be ignited under almost all ambient temperature conditions.
2	Materials that must be moderately heated or exposed to relatively high ambient temperatures before ignition can occur.
1	Material that must be preheated before ignition can occur.
0	Materials that will not burn.
Reactivity Hazard Nr	
4	Materials which in themselves are readily capable of detonation or of explosive decomposition or reaction at normal temperature and pressures.
3	Materials which in themselves are capable of detonation or explosive reaction but require a strong initiating source or which must be heated under confinement before initiation or which react explosively with water.
2	Materials which in themselves are normally unstable and readily undergo violent chemical change but do not detonate. Also materials which may react violently with water or which may form potentially explosive mixtures with water.
1	Materials which in themselves are normally stable, but which can become unstable at elevated temperature and pressures or which may react with water with some release of energy but not violently.
0	Materials which in themselves are normally stable, even under fire exposure conditions and which are not reactive with water

Safety Data Sheets of chemicals

1. Ammonia

A. <u>Health Hazards</u>

1. Acute Effect

Persons who are directly sprayed or splashed with liquid ammonia or strong aqueous ammonia solution may suffer very serious injuries but the effects are limited to the immediate vicinity of the release. Liquid anhydrous ammonia produces skin burns on contact.

Gaseous ammonia, however, may form a cloud which spreads over a large area and affects population within. Ammonia can cause burning of eyes, conjunctivitis, swelling of the eye lids and lips, burning of throat, coughing and in more severe cases of exposure, difficult breathing, temporary blindness and severe eye damage.

The toxic effects of gaseous ammonia are thus most relevant and have been considered. Examination of case histories lead to the conclusions that:

- Emphasis should be placed on injury to the respiratory system by exposure to gaseous ammonia.
- Survivors who later suffer permanent lung damage would probably have died without prompt medical treatment.

Literature values for lethal concentrations to human being are based on animal experiments, and as laboratory animals do not receive veterinary care after exposure, it is reasonable to define the lethal toxicity as the critical irreversible effect. The experimental results show that the LD_{50} (for 30 minutes) for ammonia is 11500 ppm. Effect of ammonia at various concentrations is given in Table -2.4.

Table - 2.4: Effect of Ammonia at Various Concentrations

Ammonia concentration in air (ppm)	Effects
5.0 20 – 50 100 (minimum)	Least perceptible odour Readily detectable odour Upper respiratory tract excluding nose and throat.
500 (minimum)	Deep lung irritation
1700	Coughing, bronchial spasms
2000 – 3000	Dangerous, less than hall an hour exposure may be fatal.
5000 – 10000	Serious edema, strangulation, asphyxia, rapidly fatal.
>10000	Immediately fatal.

2. Chronic Effect

Chronic irritation to the eyes, nose and upper respiratory tract may result from repeated exposure to the vapours. Threshold Limit Value (TLV) of 25 ppm in air has been set as a maximum safe concentration for daily eight hours of exposure. For risk assessment study, only acute effects are taken into consideration.

B. Fire Hazards

Ammonia and air mixture is flammable. Since the Lower Flammability Limit is 15% by volume which is very high, it is treated as non-flammable under normal conditions likely to be encountered.

C. Chemical Hazards

In presence of moisture, it is corrosive to copper, zinc and copper alloys and galvanized surfaces.

2. Naphtha

A. Health Hazards

a) Vapour Inhalation

The lower boiling point of naphtha exhibits inhalation effects of nausea, giddiness and narcosis. A 10% vapour concentration will induce narcosis within an hour. Chronic exposure will induce symptoms of central nervous system depression and neurobehavioral disorders.

b) Eye Contact

Naphtha is known to be non-irritating to the eyes. It is solvent and the variable nature of solvents would be expected to be irritant and cause conjunctivitis.

c) Skin Contact

The solvents will remove fat from the skin, resulting in redness (erythema) and irritation. Naphtha solvent will permeate the skin and cause systemic disease. In the case of solvent, bone marrow damage and liver damage have been reported as a result of the persistent practice of cleaning hands with the solvent. Dermatitis may be expected.

d) Swallowing

Naphtha solvents are not particularly toxic by ingestion, but will cause gastro-intestinal disturbance and there is a risk of aspiration of the liquid into the lungs if vomiting takes place. Aspiration of liquid solvent into the lungs causes chemical pneumonitis and pulmonary edema.

B. Fire Hazards

They are highly inflammable. Especially naphtha vapours on release, are heavy and can travel long distance and flash back when it encounters a source of ignition.

C. Chemical Hazards

It can react with strong oxidizing agents such as concentrated oxygen and liquid chlorine.

3. BENZENE

A. Health Hazards

a) Eyes

Moderate to severe irritant. Contact with liquid or vapor may cause irritation.

b) Skin

Moderate to severe irritant. May cause skin irritation with prolonged or repeated contact. Practically nontoxic if absorbed following acute (single) exposure. Liquid may be absorbed through the skin in toxic amounts if large areas of skin are exposed repeatedly.

c) Ingestion

The major health threat of ingestion occurs from the danger of aspiration (breathing) of liquid drops into the lungs, particularly from vomiting. Aspiration may result in chemical pneumonia (fluid in the lungs), severe lung damage, respiratory failure and even death. Ingestion may cause gastrointestinal disturbances, including irritation, nausea, vomiting and diarrhea, and central nervous system (brain) effects similar to alcohol intoxication. In severe cases, tremors, convulsions, loss of consciousness, coma, respiratory arrest, and death may occur.

d) Inhalation

Excessive exposure may cause irritation to the nose, throat, lungs and respiratory tract. Central nervous system (brain) may get affected and cause headache, dizziness, loss of balance and coordination, unconsciousness, coma, respiratory failure, and death. Effects to the blood (including decreased platelet and white blood cell counts), cardiovascular system, nervous system, retina, lungs, gastrointestinal system, spleen, and kidneys have been reported from large, acute (short) and repeated or prolonged exposures.

B. Fire Hazards

Benzene is highly flammable and its vapour/air mixtures may be explosive. It has Low flash point

C. Chemical Hazards

. As a volatile liquid, benzene rapidly evaporates and is a common air pollutant, although generally present in very low concentrations. Therefore, most exposures are from inhalation.

4. TOLUENE

A. Health Hazards

a) Eyes

Causes severe eye irritation with redness and pain

b) Skin

Causes irritation and it may be absorbed through skin.

c) Ingestion

Swallowing may cause abdominal spasms and other symptoms that parallel over-exposure from inhalation. Aspiration of material into the lungs can cause chemical pneumonitis, which may be fatal.

d) Inhalation

Inhalation may cause irritation of the upper respiratory tract. Symptoms of overexposure may include fatigue, confusion, headache, dizziness and drowsiness. Peculiar skin sensations (e. g. pins and needles) or numbness may be produced. Very high concentrations may cause unconsciousness and death.

B. Fire Hazards

Its vapour is explosive when exposed to heat or flame and It has a flsh point below 73 ^{0}F.

C. Chemical Hazards

Toluene is clear, colourless flammable liquid with a sweet, pungent odourIt emits acid smoke and irritating fumes when heated.

5. LNG <u>(Methane)</u>

A. Health Hazards

a) <u>Vapour Inhalation</u>

Methane is a simple asphyxiant at high concentrations.

b) <u>Eye Contact</u>

No information is available on the effects on the eyes.

c) <u>Skin Contact</u>

Liquefied methane causes frost bite on skin contact.

d) <u>Fire Precautions</u>

Do not extinguish burning gas if the flow cannot be shut off at once.

B. Fire Hazards

LNG (Methane) should be handled wearing safety goggles and mechanical exhaust is required. The vapour may travel a considerable distance to a source of ignition and flash back.

C. Chemical Hazards

It is practically inert and does not demonstrate physiological or toxicological effects.

6. Crude Oil

A. Health Hazards

- Goggles or face shield, rubber gloves and boots should be used as personal protective equipment. If exposed, it may irritate eyes and skin.
- If eyes are affected they should be flushed with water for at least 15 minutes.
- If skin affected it should be wiped off and washed with soap and water.
- The vapours are non irritating to the eyes and throat.
- Liquid or solid if spilled on clothing and allowed to remain may cause smarting and reddening of the skin.

B. Fire hazards

The flash point should be 20-90°F and the fire extinguishing agents are Dry chemical powder, foam or carbon dioxide. Water may be ineffective, hence it is not used and the burning rate is 4 mm/min.

C. Chemical Hazards

Sulfur compounds in this material may decompose to release hydrogen sulfide gas which may accumulate to potentially lethal concentration in enclosed spaces. Vapor concentration of hydrogen sulfide above 50ppm or prolonged exposure at lower concentration may saturate human odor perceptions so that smell of gas may not be apparent.

7. Diesel

A. Health Hazards

- Goggles or face shield should be used as personal protective equipment. When exposed, if liquid is ingested an increased frequency of bowel movements will occur.

Treatment of exposure:

- Ingestion: do not induce vomitting.
- Skin: wipe off, wash with soap and water
- Eyes: wash with copious amount of water for atleast 15 min.

Threshold limit value: For No single TLV is applicable.

Vapors (Gas) cause a slight smarting of the eyes or respiratory system if present in high concentrations. This effect is temporary.

B. Fire Hazards

- Flash point (1-0) 100°F .{2-0) 125°F .
- Flammable limits in air is 1.3-6.0 vol. %.
- The fire extinguishing agents are dry chemical powder, foam or carbon dioxide. Water may be ineffective. The ignition temperature is (1-0) 350-625°F (2-D) 490-545°F. The burning rate is 4 mm/min.

8. Kerosene

A. Health Hazards

Protective gloves, goggles or face shield should be used as personal protective equipment. When exposed, ingestion causes irritation of gastrointestinal tract, pulmonary tract irritation secondary to exhalation of vapours. Aspiration causes severe lung irritation with coughing, gagging, dyspnea, substernal distress and rapidly developing pulmonary edema, signs of bronchopneumonia and pneumonitis appear later, minimal central nervous system depression.

Treatment of exposure:

- Ingestion: do not lavage or induce vomitting, call physician.
- Aspiration: enforce bed rest, administer oxygen, call physician.
- Skin: wipe off and wash with soap and water.
- Eyes: wash with plenty of water.

Vapors (Gas) cause a slight smarting of the eyes or respiratory system if present in high concentrations. The effect is temporary.

B. Fire hazards

- Flash point is 100°F.
- Flammable limits in air is 0.7%-5% by volume.
- The fire extinguishing agents are dry chemical powder, foam, carbon dioxide. Water may be ineffective.

9. Phosphoric Acid

A. Health Hazards

Protective gloves, goggles or face shield should be used as personal protective equipment. When exposed, burns on mouth and lips, sour acid taste, severe gastrointestinal irritation, nausea, vomitting, bloody diarrhea, difficult swallowing, severe abdominal pains, thirst, acidemia, difficulty in breathing, convulsions, collapse, shock, death.

Treatment of exposure:

- Ingestion: do not induce vomitting, give water, milk or vegetable oil.
- Skin or Eyes: flush with water for at least 15 min
- . Threshold limit value: 1.0 mg/m^3

B. Fire hazards

Non explosive in presence of open flames and sparks.

C. Chemical Hazards

Reacts with metals to liberate flammable hydrogen gases.

10. Sulfur

A. Health Hazards

Safety goggles with side shields, approved respirator, heat resistant gloves, leather heat-resistant clothing should be used as personal protective equipment. When exposed, can cause eye irritation and it may rarely irritate skin.

Treatment of exposure:

- Eyes: wash eyes carefully for atleast 15 min with plenty of water.
    - Skin: Treat molten sulfur burns with petroleum jelly or mineral oil.
- Inhalation: remove victim from exposure, if breathing has stopped give artificial respira.tion. administer oxygen if needed, consult physician.

B. Fire hazards

- Flash point is 405°F.
- Fine dust of sulfur dispersed in the air is a potential hazard. When sulfur dust mixes with oxygen, it forms sulfur dioxide, which when ignited causes explosion
- Dust suspended in air is readily ignited by fumes or static electricity and can cause destructive fires
- Fires caused by sulfur are hard to put out because once they spread the presence of oxygen only serves to increase the fire.
- The ignition temperature is 450^{o}F.

C. Chemical Hazards

It is a reactive element that given favorable circumstances combines with all other elements except gases, gold, and platinum. In the presence of moisture and oxygen, it becomes sulfur dioxide, which forms an acidic and corrosive solution and thus causes corroding of metals.

11. Urea

A. Health Hazards

Goggles or face shield, dust mask should be used as personal protective equipment. When exposed, may irritate eyes. Treatment of exposure:

- Eyes: wash eyes with water.

B. Fire hazards

It is not flammable in air. Water is a fire extinguishing agent. In fire it melts and decomposes generating ammonia.

C. Chemical Hazards

- Hygroscopic. Absorbs moisture from air
- Reacts violently with Gallum perchlorate.
- Reacts with chlorine to form chloramines

12. LPG

A. Health Hazards

- **Eyes** : May cause mild, short-lasting discomfort to eyes. Rapid release of gases which are liquids under pressure may cause frost burns of exposed tissues (skin, eye) due to evaporative cooling.
- **Skin :** Negligible irritation to skin at ambient temperatures. Rapid release of gases which are liquids under pressure may cause frost burns of exposed tissues (skin,eye) due to evaporative cooling.
- **Chronic Exposure** : Chronic Effects And/Or Target Organ Data: May cause central nervous system disorder (e.g., narcosis involving a loss of coordination, weakness, fatigue, mental confusion and blurred vision) and/or damage.
- Over exposure of LPG can cause lightheadedness and drowsiness
- Greater exposure to LPG can cause unconsciousness and death

B. Fire hazards

- Contact with strong oxidizing agents can cause fire and explosion
- Auto ignition temperature is 405 -450 ^{o}C

2.7 FIRE AND EXPLOSION INDEX

Fire and Explosion Index analysis, is a step by step evaluation of the realistic fire, explosion and reactivity potential of processes, equipments and its contents. The F & EI is used for any operation in which flammable, combustible or reactive material is stored, handled or processed. The F & EI is calculated by evaluating the loss potential of chemicals stored in the facility. The Fire and Explosion Index is a number which indicates, damage potential due to the fire and explosion of a particular unit and comparison is based on numerical value that represent the relative level of significance of each hazard. It is a product of three attributes, Material Factor, General Process hazards and Special Process hazards.

The material factor is the starting value in computation of F & EI. Material Factor (MF) is a measure of intrinsic rate of potential energy released from fire or explosion produced by combustion or other chemical reaction. The material factor is considered for the most hazardous material or mixture of material present in the unit in sufficient quantity actually to present the hazard. The MF is obtained from flammability factor and Reactivity factor i.e., Nf and Nr. respectively given for various chemicals by National Fire Protection Association (NFPA).

Process hazards that contribute to the magnitude of losses have been quantified as penalties, which provide factors for computation. Every penalty may not be applicable to a specific situation and same may have to be modified. The General Process Hazards (GPH) and Special Process Hazards (SPH) are taken into account as penalties which are applied to Material Factor.

The Fire and Explosion Index (F & EI) is defined as:

F & EI = MF x (GPH) (SPH)

The degree of hazard is identified based on F & EI range as per the criteria given in Table-2.5. The summary of Dow's Index for various chemicals is given in Table-2.6.

Table-2.5: Degree of hazards associated with F&EI

F & EI RANGE	DEGREE OF HAZARD
0-60	Light
61-96	Moderate
97-127	Intermediate
128-158	Heavy
>159	Severe

Table 2.6: Summary of Dow's Index for various chemicals

CHEMICAL	MF	GPH	SPH	UHF	F & EI	RATING
HIGH SPEED DIESEL	10	2.1	2.7	5.67	56.7	Light
SKO	10	2.1	2.7	5.67	56.7	Light
NAPHTHA	16	2.1	2.1	3.1	104	Intermediate
MOTOR SPIRIT	16	2.1	2.1	3.1	104	Intermediate
AMMONIA	4	2.1	3.4	7.14	28.5	Light
LNG	21	2.1	3.95	8.29	1174	Severe

The Dow's Index for various operations at the Cochin Port Trust is given in Tables-2.7 to 2.11.

Table-2.7: Dow's Fire and explosion index for Ammonia unloading system

MA TERIAL FACTOR			4
GENERAL PROCESS HAZARDS	PENALTY	PENALTY USED	
BASE FACTOR A. EXOTHERMIC CHEMICAL REACTIONS (FACTOR .30 to 1.25)	1.00	1.00	-
B. EXOTHERMIC PROCESSES (FACTOR .20 to .40)		-	
C. MATERIAL HANDLING &. TRANSFER (FACTOR .25 to 1.05)	'	0.50	
D. ENCLOSED OR INDOOR PROCESS UNITS (FACTOR .25 to .30)		-	
E. ACCESS	0.35	0.35	
F. DRNNAGE AND SPILL CONTROL (FACTOR .25 to .50)		0.25	
GENERAL PROCESS HAZARDS (FACTOR FI) **2. SPECIAL PROCESS HAZARDS**			2.10

BASE FACTOR	1.00	1.00	
A. TOXIC MATERIALS) (FACTOR 0.20 to 0.80)		060	
B. SUB-ATMOSPHERIC PRESSURE (500 mm Hg)	*0.5e*		
C. OPERATION IN OR NEAR FLAMMABLE RANGE INERTED NOT INERTED			
1. TANK FARMS STORAGE FLAMMABLE LIOUIDS	0.50		
2. PROCESS UPSET OR PURGE FAILURE	0.30		
3. ALWAYS IN FLAMMABLE RANGE	0.80		
D. OUST EXPLOSION (FACTOR .25 to 2.00)			
E. PRESSURE OPERATING PRESSURE psig RELIEF SETTING psig			
F. LOW TEMPERAI1JRE (FACTOR .20 to .30)		0.30	
G. QUANTITY OF FLAMABLE UNSTABLE MATERJAL QUANTITY lbs.he = BTU lb		.	
1. LIQUIDS, GASES AND REACTIVE MATERJALS IN PROCESS			
2. LIQU1DS OR GASES IN STORAGE			
3. COMBUSTIBLE SOLIDS IN STORAGE. DUST IN PROCESS			
H. CORROSION AND EROSION (FACTOR .10 to .75)		0.50	
I. LEAKAGE - JOINTS AND PACKING (FACTOR .10 to 1.50)		1.00	
J. USE OF FIRE HEATERS.		-	
K. HOT OIL HEAT EXCHANGE SYSTEM (FACTOR .15 to 1.15)			
J. ROTATING EQU1PMENT	0.50		
SPECIAL PROCESS HAL'\RDS FACTOR (1'2)			3.40
UNIT HAZARD FACTOR (Fr x F2 - 1'3)			7.14
FIRE AND EXPLOSION INDEX (F3 x MF = F &. El)			28.50
FIRE & EXPLOSIVE INDEX (RATINGS)			Light

Table-2.8: Dow's Fire and explosion index for HSD/Kerosene unloading system

MATERIAL FACTOR			10
GENERAL PROCESS HAZARDS	PENALTY	PENALTY USED	
BASE FACTOR	1.00	1.00	-
A. EXOTHERMIC CHEMICAL REACTIONS (FACTOR .30 to 1.25)			
B. EXOTHERMIC PROCESSES (FACTOR .20 to .40)		-	
C. MATERIAL HANDLING &. TRANSFER (FACTOR .25 to 1.05)		0.50	
D. ENCLOSED OR INDOOR PROCESS UNITS (FACTOR .25 to .30)		-	
E. ACCESS	0.35	0.35	
F. DRNNAGE AND SPILL CONTROL (FACTOR .25 to .50)		0.25	
GENERAL PROCESS HAZARDS (FACTOR FI)			2.10
2. SPECIAL PROCESS HAZARDS			
BASE FACTOR	1.00	1.00	
A. TOXIC MATERIALS) (FACTOR 0.20 to 0.80)		-	
B. SUB-ATMOSPHERIC PRESSURE (500 mm Hg)	0.50	-	
C. OPERATION IN OR NEAR FLAMMABLE RANGE INERTED NOT INERTED	0.30	-	
1. TANK FARMS STORAGE FLAMMABLE LIOUIDS	0.80	-	
2. PROCESS UPSET OR PURGE FAILURE		-	
3. ALWAYS IN FLAMMABLE RANGE		0.20	
D. OUST EXPLOSION (FACTOR .25 to 2.00)			
E. PRESSURE OPERATING PRESSURE psig RELIEF SETTING psig			
F. LOW TEMPERAI1JRE (FACTOR .20 to .30)		0.30	
G. QUANTITY OF FLAMABLE UNSTABLE MATERJAL QUANTITY lbs.he = BTU lb		.	
1. LIQUIDS, GASES AND REACTIVE MATERJALS IN PROCESS			
2. LIQU1DS OR GASES IN STORAGE		0.20	

3. COMBUSTIBLE SOLIDS IN STORAGE. DUST IN PROCESS		0.50	
H. CORROSION AND EROSION (FACTOR .10 to .75)			
I. LEAKAGE - JOINTS AND PACKING (FACTOR .10 to 1.50)			
J. USE OF FIRE HEATERS.		-	
K. HOT OIL HEAT EXCHANGE SYSTEM (FACTOR .15 to 1.15)			
J. ROTATING EQU1PMENT	0.50		
SPECIAL PROCESS HAL'\RDS FACTOR (1'2)			2.70
UNIT HAZARD FACTOR (Fr x F2 - 1'3)			5.67
FIRE AND EXPLOSION INDEX (F3 x MF = F &. El)			56.70
FIRE & EXPLOSIVE INDEX (RATINGS)			Light

Table- 2.9: Dow's Fire and explosion index for Naphtha unloading system

MA TERIAL FACTOR			16
GENERAL PROCESS HAZARDS	PENALTY	PENALTY USED	
BASE FACTOR A. EXOTHERMIC CHEMICAL REACTIONS (FACTOR .30 to 1.25)	1.00	1.00	-
B. EXOTHERMIC PROCESSES (FACTOR .20 to .40)		-	
C. MATERIAL HANDLING &. TRANSFER (FACTOR .25 to 1.05)	0.50	0.50	
D. ENCLOSED OR INDOOR PROCESS UNITS (FACTOR .25 to .30)		-	
E. ACCESS	0.35	0.35	
F. DRNNAGE AND SPILL CONTROL (FACTOR .25 to .50)	0.25	0.25	
GENERAL PROCESS HAZARDS (FACTOR FI)			2.10
2. SPECIAL PROCESS HAZARDS BASE FACTOR	1.00	1.00	
A. TOXIC MATERIALS) (FACTOR 0.20 to 0.80)		0.40	
B. SUB-ATMOSPHERIC PRESSURE (500 mm Hg)	0.50	-	
C. OPERATION IN OR NEAR FLAMMABLE RANGE INERTED NOT INERTED	0.30	-	
1. TANK FARMS STORAGE FLAMMABLE LIOUIDS	0.80	-	
2. PROCESS UPSET OR PURGE FAILURE		-	
3. ALWAYS IN FLAMMABLE RANGE		0.20	
D. OUST EXPLOSION (FACTOR .25 to 2.00)			
E. PRESSURE OPERATING PRESSURE psig RELIEF SETTING psig			
F. LOW TEMPERAI1JRE (FACTOR .20 to .30)		-	
G. QUANTITY OF FLAMABLE UNSTABLE MATERJAL QUANTITY Ibs.he = BTU lb		-	
1. LIQUIDS, GASES AND REACTIVE MATERJALS IN PROCESS		-	
2. LIQU1DS OR GASES IN STORAGE			
3. COMBUSTIBLE SOLIDS IN STORAGE. DUST IN PROCESS			
H. CORROSION AND EROSION (FACTOR .10 to .75)		0.20	
I. LEAKAGE - JOINTS AND PACKING (FACTOR .10 to 1.50)		0.50	
J. USE OF FIRE HEATERS.		-	
K. HOT OIL HEAT EXCHANGE SYSTEM (FACTOR .15 to 1.15)			
J. ROTATING EQU1PMENT	0.50		
SPECIAL PROCESS HAL'\RDS FACTOR (1'2)			3.10
UNIT HAZARD FACTOR (Fr x F2 - 1'3)			6.51
FIRE AND EXPLOSION INDEX (F3 x MF = F &. El)			104.00
FIRE & EXPLOSIVE INDEX (RATINGS)			Intermediate

Table- 2.10: Dow's Fire and explosion index for LNG unloading system

MATERIAL FACTOR			21
GENERAL PROCESS HAZARDS	PENALTY	PENALTY USED	
BASE FACTOR A. EXOTHERMIC CHEMICAL REACTIONS (FACTOR .30 to 1.25)	1.00	1.00	-
B. EXOTHERMIC PROCESSES (FACTOR .20 to .40)		-	
C. MATERIAL HANDLING &. TRANSFER (FACTOR .25 to 1.05)		0.50	
D. ENCLOSED OR INDOOR PROCESS UNITS (FACTOR .25 to .30)		-	
E. ACCESS	0.35	0.35	
F. DRNNAGE AND SPILL CONTROL (FACTOR .25 to .50)		0.25	
GENERAL PROCESS HAZARDS (FACTOR FI) **2. SPECIAL PROCESS HAZARDS** BASE FACTOR	1.00	1.00	2.10
A. TOXIC MATERIALS) (FACTOR 0.20 to 0.80)		0.20	
B. SUB-ATMOSPHERIC PRESSURE (500 mm Hg)	0.50	-	
C. OPERATION IN OR NEAR FLAMMABLE RANGE INERTED NOT INERTED		-	
1. TANK FARMS STORAGE FLAMMABLE LIOUIDS	0.50	-	
2. PROCESS UPSET OR PURGE FAILURE	0.30	-	
3. ALWAYS IN FLAMMABLE RANGE	0.80	-	
D. OUST EXPLOSION (FACTOR .25 to 2.00)		-	
E. PRESSURE OPERATING PRESSURE psig RELIEF SETTING psig		0.45	
F. LOW TEMPERAI1JRE (FACTOR .20 to .30)		0.30	
G. QUANTITY OF FLAMABLE UNSTABLE MATERJAL QUANTITY lbs.he = BTU lb		.	
1. LIQUIDS, GASES AND REACTIVE MATERJALS IN PROCESS		-	
2. LIQU1DS OR GASES IN STORAGE		-	
3. COMBUSTIBLE SOLIDS IN STORAGE. DUST IN PROCESS		0.50	
H. CORROSION AND EROSION (FACTOR .10 to .75)		1.50	
I. LEAKAGE – JOINTS AND PACKING (FACTOR .10 to 1.50)		-	
J. USE OF FIRE HEATERS.		-	
K. HOT OIL HEAT EXCHANGE SYSTEM (FACTOR .15 to 1.15)			
J. ROTATING EQU1PMENT	0.50		
SPECIAL PROCESS HAL'\RDS FACTOR (1'2)			3.95
UNIT HAZARD FACTOR (Fr x F2 – 1'3)			8.29
FIRE AND EXPLOSION INDEX (F3 x MF = F &. EI)			174.00
FIRE & EXPLOSIVE INDEX (RATINGS)			**Severe**

Table- 2.11: Dow's fire and Explosion Index for various operations at Port

S.No.	Activity	F&EI	Category
1.	Ammonia Unloading System	28.50	Light
2.	HSD/Kerosene Unloading system	56.70	Light
3.	Naphtha Unloading System	104.0	Intermediate
4.	LNG Unloading System	174.0	Severe

2.8. CONSEQUENCE ANALYSIS

Consequence analysis is basically a quantitative study of the hazard due to various failure scenarios to determine the possible magnitude of damage effects and to determine the distances upto which the damage may be affected. The reason and purpose of consequence analysis are manifolds like:

- For computation of risk.
- For evaluating damage and protection of other plants.
- To ascertain damage potential to public and evolve protection measures.
- For preparation of effective emergency planning, both onsite and offsite.
- For formulating safe design criteria of equipment and protection systems.

The results of consequence analysis are useful for getting information about all known and unknown effects that are of importance when some failure scenarios occur and to get information about how to deal with possible catastrophic events. It also gives the plant authorities, workers and the public living outside in the vicinity of the plant an understanding of hazard potential and remedial measures.

Modes of Failure

There are various potential sources of large/small leakages, which may release hydrocarbon to the surrounding atmosphere. This leakage may be in the form of a small gasket failure in a flanged joint or snapping of loading arm, a guillotine failure of a pipeline or any other source of leakage.

Damage Criteria

The damage effects are different for different types of failure scenarios .The physical effects of ignition of hydrocarbon vapours, e.g. blast wave, thermal radiation and BLEVE due to release of LPG from the containment are discussed below:

Hydrocarbon vapours released accidentally will normally spread out in the direction of the wind. If it comes into contact with an ignition source before being dispersed below the lower flammability limit (LFL), a flash fire is likely to occur and the flame may travel back to the source of leak. Any person caught in the flash fire is likely to suffer from severe burn injury. Therefore, in consequence analysis, the distance to LFL value is usually taken to indicate the area, which may be affected by flash fires. Any other combustible material within the flash fire is likely to catch fire and may cause secondary fires. In the area close to the source of leakage of hydrocarbon there is a possibility of Oxygen depletion since the LPG vapour is heavier than air. A minimum of 19.5% Oxygen in air is considered essential for human lives.

Thermal radiation due to pool fire, jet flame or fire ball may cause various degrees of burn on human bodies. Also its effects on inanimate objects like equipment, piping, building and other objects needs to be evaluated. The damage effects with respect to thermal radiation intensity is elaborated in Table – 2.12.

Table- 2.12: Damage due to Incident Thermal Radiation Intensity

Incident Thermal Radiation Intensity, KW/m^2	Types of damage	Casualty Probability
37.5	Sufficient to cause damage to process equipment	1.00
12.5	Minimum energy required for piloted ignition of wood, melting of plastic tubing etc.	0.50
4.5	1st degree burn	0.00
1.6	Will cause no discomfort to long exposure	0.00
0.7	Equivalent to solar radiation	0.00

In the case of fireball the effect will be similar to that of thermal radiation. Those who are located within fireball distance are likely to suffer fatal burn injury. Those who are beyond fireball diameter will be subjected to different levels of thermal radiation, which has been mentioned above in Table-2.12.

In the event of dispersion of LPG vapour cloud, the cloud comes into contact with an ignition source between its upper and lower flammability limit an explosion may occur. The resultant blast wave may have damaging effect on the equipment, buildings, structures etc. The collapse of buildings & structures may cause injury or fatality. Damaging effect of blast overpressures are illustrated in the Table – 2.13.

Table-2.13: Damage Effects of Blast Overpressure

Blast Overpressure (bar)	Damage Type	Casualty Probability
0.30	Major damage to structures (assumed fatal to the people inside structure)	0.25
0.17	Eardrum rupture	0.10
0.10	Repairable Damage	0.10
0.03	Glass Breakage	0.00
0.01	Crack of Windows	0.00

In case of transient fires like fire ball, doses of thermal radiation (total incident energy) is also used to estimate threshold damage levels on human bodies. Table-2.14 shows the damage effects due to various dose levels.

Table- 2.14: Physiological Effects of Thermal Dose Level

Dose Threshold (KJ/m^2)	Effect
375	Third degree burn
250	Second degree burn
125	First degree burn
65	Threshold of pain, no reddening or blistering of skin is caused
1st Degree Burn	Involves only epidermis. Sunburn is an example. Blisters may occur.
2nd Degree Burn	Whole epidermis along with some portion of dermis is affected.
3rd Degree Burn	Involves whole of epidermis and dermis. Sub-cutaneous tissues may also be affected.

Dispersion and Stability Class

In calculation of effects due to release of hydrocarbons, dispersion of vapour plays an important role as indicated earlier. The factors which govern dispersion are mainly Wind Velocity, Stability Class, Temperature as well as surface roughness. One of the characteristics of atmosphere is stability, which plays an important role in dispersion of pollutants. Stability is essentially the extent to which it allows vertical motion by suppressing or assisting turbulence. It is generally a function of vertical temperature profile of the atmosphere. The stability factor directly influences the ability of the atmosphere to disperse pollutants emitted into it from sources in the plant. In most dispersion problems relevant atmospheric layer is that nearest to the ground. Turbulence induced by buoyancy forces in the atmosphere is closely related to the vertical temperature profile.

2.9. HAZARDS OF LPG SPILLAGE/ESCAPE FROM CONTAINMENT

General

When LPG is released from pipeline, a fraction of LPG vapourizes immediately and the other portion forms a pool if the released liquid quantity is more. LPG from the pool vapourizes rapidly entrapping some liquid as droplets as well as considerable amount of air, forming a gas cloud. The gas cloud is relatively heavier than air and forms a thin layer on the ground. The cloud flows into trenches and depressions and in this way travels a considerable distance.

As the cloud formed in the area of spill moves downwind under influence of wind, it gets diluted. A small spark within the flammability limit can cause flash fire, explosion and if the liquid pool still exists and remains in touch of cloud under fire it can ignite the whole mass of liquid. However in case of non existence of any source of fire there will be no occurrence of hazardous event and the cloud may get diluted to such a level that the mixture is no longer explosive. But it can cause asphyxiation due to displacement of oxygen. Different types of combustion reactions associated in case of release of LPG from the containment are listed in the following sections.

Jet Fire

Escaping jet of LPG from piping, if ignited, causes a jet flame. The jet flame direction and tilt depend on prevailing wind direction and velocity. Damage, in case of such type of jet fires, is restricted within the plant boundary. However, the ignited jet can impinge on other vessels and equipment carrying LPG and can cause domino effect.

Pool Fire

The liquid pool, if ignited, causes a "Pool Fire". In the pool fire, LPG burns with long smoky flame throughout the pool diameter radiating intense heat, which creates severe damage to the adjoining buildings, structures, other vessels and equipment causing secondary fires. The flame may tilt under influence of wind and may get propagated / blown several pool diameters down wind. Damage, in case of such fires, is restricted within the plant area and near the source of generation except causing a phenomena, called BLEVE. However, in case of plants having a good layout, maintaining safe separation distances and other precautionary measures, the damage is minimum.

Vapour Cloud Explosion

Clouds of LPG vapour mixed with air (within flammability limit) may cause propagating flames when ignited. In certain cases flame may take place within seconds. The thermal radiation intensity is severe depending on the total mass of LPG in the cloud and may cause secondary fires. When the flame travels very fast it explodes causing high overpressures or blast effects causing heavy damage at considerable distance from the release point. Such explosions are called unconfined vapour cloud explosion and is most common cause of such industrial accidents.

Boiling Liquid Expanding Vapour Explosion (BLEVE)

This phenomenon occurs when pressure inside a storage vessel increases above the design pressure due to a fire in the adjacent area. Due to impingement of flame or due to radiant heat, temperature in the vapour portion of the storage vessel increases rapidly compared to the portion filled with liquid. Increase in temperature weakens the shell. With the rise in vapour pressure and inadequate vapour space for expansion, the shell of storage tank bursts causing fragments of the shell flying like projectiles with release of whole mass of pressurized boiling liquid. The released liquid flashes and atomizes immediately often resulting in a large fire ball in contact with an ignition source. Although the fire ball lasts only a few seconds, its effect is devastating due to flame contact and intense thermal radiation. This phenomenon is called BLEVE. The effect of BLEVE extends beyond the plant boundary in case of catastrophic failure of large pressurized storage vessels but occurrence of such phenomena is very rare.

CHAPTER-3

CHAPTER – 3

REVIEW OF EARLIER RISK STUDIES

3.1 INTRODUCTION

Tata AIG Risk Management Services Ltd. (TARMS) had carried out Risk Assessment Study for Cochin Port Trust. The study was completed in January 2002. The objectives of the study were:

- Hazard identification
- Evaluation of the consequences/Impact Assessment
- Risk contours and Quantitative Hazard Analysis
- Quantitative Risk Assessment

3.2 OBJECTIVES OF THE STUDY

The objectives have been briefly described in the following sections:

Hazard Identification

a) Identification of potential physical hazards which could trigger loss causing events, such as fire and explosion and leakage of toxic-flammable materials from operations like loading, unloading, transportation and storage areas.

b) Identifying the Maximum Credible Loss Scenarios (MCLS) for the vulnerable areas in both process operations and storage areas.

c) Estimation of DOW's INDEX (fire and explosion index) for various identified MCLS.

d) Chemicals Hazard Ranking based on NFPA guidelines.

e) Identification of the most hazardous situation with the worst damage potential.

Evaluation of the Consequences/Impact Assessment

The consequence analysis was carried out using model PHAST (Process Hazard Analysis Software Tool). The consequence analysis established minimum distances to specified hazard criteria:

a) Thermal radiation

i) 37.5 kW/m^2 - intensity at which damage is caused to process equipment.

ii) 12.5 kW/m^2 - intensity for which buildings should be normally designed to withstand.

iii) 4.5 kW/m^2 - intensity sufficient to cause pain to personnel unable to reach safety cover in 20 seconds, though blistering of skin (first degree burn) unlikely.

b) Vapour dispersion

Vapour dispersion envelopes are determined for half (1/2) of the Lower Flammability Level (LFL) for the released gases. Incident overpressure levels to establish distances were assessed as:

i) 3 PSI (Pound per Square Inch) - heavy machines (3000 Ib) in industrial building suffer little damage. Steel frame building distorted and pulled away from foundation.

ii) 2 PSI - partial collapse of walls and roofs of houses.

iii) 0.3 PSI - safe distance.

c) Toxic release

Toxic gas dispersion envelop are determined for the Threshold Limit Value (TLV), IDLH or LC_{50} level of the gases released.

The worst credible accident scenarios were considered for consequences analysis based on the past accident information and engineering judgement.

Risk Contours and Quantitative Hazard Analysis

Risk Contour of scenarios were plotted on site plan for assessing the magnitude and severity of the impact of various failure scenarios in terms of damage to property and injury to personnel.

The credibility of the probable accident situation, quantification of hazard through consequence analysis and estimation of frequencies of these events form this part of the analysis have been established. This information enables the management to take necessary preventive actions.

Quantitative Risk Assessment

Risks have been reviewed and recommendation submitted for overall safety improvements based on the above evaluation.

3.3 RISK IDENTIFICATION

The Risk identification has been divided into two parts on the basis of nature of operation at the berth. The Part A covers the solid /container/ bulk/ break bulk cargoes handling. This part covers the container terminal at Vallarpadam, Fertiliser berth of FACT (excluding Phosphoric Acid and Ammonia), Quay 1, Quay 2, Quay 3, Quay 4, Quay 5, Quay 6, Quay 7 and Quay 8. The Part B covers liquid chemicals and fuel handling facilities, i.e. ammonia and phosphoric acid of FACT, HSD and gas oil, crude oil at terminal at Puthuvypeen, Liquefied Natural Gas at Petronet LNG Ltd, HSD and gas oil, crude oil at terminal at Ernakulam Channel, POL products at Cochin Oil Terminal, POL products at NTB and STB of IOCL.

In addition to specifically classified hazardous substances such as flammable petroleum products and flammable/toxic fertilizers/FRMs, various IMO class cargo is handled in the port at Q5, ICTT and CFS. IMO class cargoes pose specific risks depending on the class; their handling and storage requirements are also specific, and to be strictly followed. Information of IMO class cargoes accompanies the shipment, has to be declared by the consigner. Storage/handling of such cargo is the joint responsibility of the consignee and the port. Section 3.8 deals in the risks and indicative recommended measures for handling of IMO class cargo in the port.

The ICTT handles classified defense cargoes, all of which are containerized and adequately packed for the purpose of container transportation through vessels. While no information about contents of the containers is provided by the defense forces, it is surmised that the cargoes are packed, labeled and transported in a manner so that they do not loose confinement, and retain their form and function while keeping the container safe.

3.4 PART- A: SOLID CONTAINER BREAK BULK CARGOES

Identification and control of risks in handling container cargoes

The material such as coir products, tea, rubber, rubber products, dry fruits, cotton, food grains, other food stuffs, timber, machinery, iron, steel, cement etc., which were handled at the Quay 7, Quay 8 and Quay 9 berths at Ernakulam Wharf, are now being handled at the Container Terminal at Vallarpadam.

Almost all the above materials are combustible materials with least fire hazards. Since, they are handled in containers' the possibility of material encountering a source of ignition is unlikely. Even if a container somehow catches fire, the fire may not spread rapidly as all other materials stored in the vicinity are also in the closed containers and will not come directly in contact with fire.

Therefore, accidents at the Container Terminal may not lead to off-site implications. The most common accidents involve slips and falls, falling loads (containers), failure of lifting and transportation devices also contribute to serious accident i.e. failure of grab, ropes of gantry cranes, failure of straddle carrier, toppling of forklift, derailment of wagons, collision of tractor- trailers within the premises etc. These have potential to cause fatal accidents to the persons associated with the operations and present in the vicinity at the time of the accident. Moreover, by adhering to safety rules and procedures, the rate of such accident could be minimized considerably.

Recent surveys of crane accidents in a number of countries indicate that most fatal and serious injuries occur when workers are crushed between moving parts of machines and fixed objects or struck by falling loads, when persons erecting or dismantling cranes fall from a height or when the driver or another person comes into contact with an overhead line or other live conductor. Overturning of tower or mobile cranes is not uncommon; these accidents are very costly and can also result in serious or fatal injuries.

Port workers may be exposed to dangerous gases, vapours, fumes and dusts that escape from broken or inadequately packaged containers in poorly ventilated spaces. Skin or eye contact with corrosive substances may cause chemical burns. Contact with certain hides or skins may cause anthrax, while some cargoes may harbour venomous animals. Accidents have sometimes been caused by fumigated grain, by oxygen deficiency or by the fermentation of organic matter holds. Finally, the introduction of the fork-lift truck into ships holds and port warehouses has created a distinct health hazard as a result of the presence of noxious exhaust gases and fumes in poorly ventilated areas.

Dry bulk cargoes and break bulk cargoes

The bulk products i.e. coal, fertiliser rock phosphate, potash, sulfur, iron scrap, different ores, common salt, clinker, etc are handled at fertiliser berth, Quay 3, Quay 4, Quay 5 and Quay 6.

After unloading, these products are transported to stackers and silos with help of conveyors/ road-trucks. Coal is stored in open in long stacks known as windrows.

Coal

Coal is unloaded from the ship by grab crane and transported to two stacked areas, each of 20,000 tonnes capacity, by road trucks. Thereafter, from the stacked area, it is transported to various destinations by rail.

Rock Phosphate, sulfur, urea

They are unloaded by grab crane and transported to silos by belt conveyors.

General cargo, especially fertilizer and fertilizer raw material may pose handling and storage problems due to huge variety in the properties of Fertilizer (FERT) and Fertilizer Raw Material (FRM). Therefore, it is important that these be handled and stored properly. General cargo including fertilizer and FRM is being handled in the following berths in the port:

- South Coal Berth
- Ernakulam Wharf (Q5, Q6 & Q7)
- R.G.C.T (Q8 & Q9)
- Multi Purpose Berth (Boat Train Pier & North Coal Berth Combined)
- Mattancherrv Wharf (Q1 to Q3)
- Fertilizer Berth (Q10)

Table-3.1 lists the precautions to be taken while handling FERT/FRM in the port:

Table-3.1: Handling Precautions for Fert/FRM

Transportation of goods	• Cover any loads of fertilizer products whilst in transit
Drift of dust from storage areas and/or facilities	• Keep fertilizer products covered and/or sealed • Clean up spillages promptly • Personnel responsible for storage areas and/or facilities to will ensure that the drift of dust beyond the perimeter is kept to a minimum.
Storage areas - Floors	• Keep floor surfaces swept clean of fertilizer to prevent tracking by people and/or vehicles beyond the perimeter. • Sweep up and dispose of spillages in a timely and appropriate manner
Cross contamination of product	• Keep each fertiliser product will in a separate storage container and/or position within the facility and/or area.
Confusion of Product	• Maintain an accurate storage manifest/register. • Ensure all storage bays and bins are clearly labelled. • Ensure all storage, loading and blending plant and equipment is cleaned from all residues when changing from one product to another. • Do not store product in bags that are not correctly stamped
Personal Protective Equipment	• Personnel must be provided with appropriate PPE when using fertiliser products.

Appropriate warning safety signage and information	• Managers must ensure that appropriate safety warning signs and/or information is displayed/available regarding nature of hazards and risk control measures.
Housekeeping and/or routine maintenance	• All personnel are responsible for implementing sound housekeeping practices in storage areas and arranging regular routine maintenance for all equipment used.
Plant & equipment	• Conduct regular inspection & testing of equipment and infrastructure to identify maintenance requirements
Training	• Personnel will undergo appropriate training.
Appropriate records &/or documentation	• All relevant records and documentation to be kept and maintained e.g. training records, risk assessments, maintenance schedules, MSDS's etc.

General provisions

- Ensure that the storage facility is appropriately secured,
- FERT/FRM materials are not to be stored in contact with ground surfaces,
- Storage areas/facilities are to weather-proofed and able to exclude runoff from other areas,
- Do not store in close proximity to heat sources such as open flames, steam pipes, radiators or other combustible materials such as flammable liquids,
- In case of fire flood the area with water,
- If augers are used to move the material ensure that any residue(s) in the immediate area is cleaned up, and
- Dispose of empty bags in the appropriate manner.

Field Usage

- Keep FERT/FRM covered to avoid unnecessary expose to open air.
- Do not store dry urea with dry ammonium nitrate.

The majority of FRM/FERT to be handled and stored at the facility are not hazardous but it is highly desirable that MSDS of all the FERT/FRM are sought from the supplier such that MSDS is received at least fifteen days in advance to help train the personnel as well as in taking the necessary special precautions (if any) for handling and storage of FERT/FRM.

A brief summary of major fertilizers is presented in below in order to provide an idea about the fertilizers and the precautions to be taken while handling them. The brief summary given below is NOT intended for practical use. Detailed MSDSs must be referred to whenever the need arises.

Iron Sulphate
Physical Iron sulphate is a liquid that is grey in colour. It is fully soluble in water. Fire It may not catch fire by itself. Wear full protective suit and Self Contained Breathing Apparatus (SCBA) for fire fighting as oxides of sulphur may get emitted due to fire. Use water spray and carbon dioxide to extinguish fire. Health It may enter human body through inhalation of spray fumes and exposed skin. Eyes: Flush immediately with plenty of water for 15 minutes, if condition persists, consult doctor. Skin: Wash thoroughly with water, if condition persists, consult doctor. Ingestion: Do NOT induce vomiting, give large quantities of water, if condition persists, consult doctor. Toxicological Information No data is available *General Precautions:* Use good personal hygiene practices Environmental Information It undergoes ionic dissociation It may be toxic to aquatic life

Do not contaminate land and water with concentrate Reactivity/ Materials to avoid Extremes of temperatures should be avoided Salts of Barium and strontium and highly alkaline substances and reagents should be avoided

Calcium Ammonium Nitrate
Physical It is in powder form. It's soluble in water to an extent of 140 g/100 ml. Fire It may not catch fire by itself, but it may catch fire when in contact with combustible materials. In case the surrounding material catches fire, due to possibility of release of toxic and corrosive nitrous vapours, Self Contained Breathing Apparatus may be used. All types of extinguishing media can be used for surrounding fires. Health Eyes: Irritating to eyes, flush immediately with plenty of water for 15 minutes, if condition persists, consult doctor. Skin: Wash thoroughly with water, if condition persists, consult doctor. Ingestion: Give large quantities of water, if condition persists, consult doctor. Inhalation: Move victim to fresh air; maintain adequate airway & respiration, if breathing problems develop or unconscious, consult doctor Toxicological Information Acute Oral Toxicity: LD_{50} (rat) found to be 2000 mg/kg, not acutely toxic. *General Precautions:* Use good personal hygiene practices Remove contaminated clothing immediately Clean contaminated clothing

Environmental Information Do not contaminate land, water or sewerage with concentrate *Reactivity/ Materials to avoid* Hygroscopic conditions should be avoided Keep away from reducing materials and organic materials

Muriate of Potash
Physical It is a colourless or whitish in granules or powder form fertiliser. It's slightly soluble in water to an extent of 11 g/100 ml. Fire It may not catch fire by itself, but it may catch fire when in contact with combustible materials. The product may reach melting point & decompose to release NH_3, SO_X, PO_X or CN. In case the surrounding material catches fire, use suitable media to extinguish source of fire, Self Contained Breathing Apparatus may be used. Health Eyes: Flush immediately with plenty of water for 15 minutes, if condition persists, consult doctor. Skin: Wash thoroughly with soap & water, if condition persists, consult doctor. Ingestion: If large amount is ingested, give 2-3 glasses of water, induce vomiting, and consult doctor. Inhalation: Move victim to fresh air; maintain adequate airway & respiration, if breathing problems develop or unconscious, consult doctor Toxicological Information Acute Oral Toxicity: LD_{50} (rat) found to be 1500-2600 mg/kg, not acutely toxic. *General Precautions:*

Use good personal hygiene practices

Environmental Information

Do not contaminate land, water or sewerage with concentrate

Reactivity/ Materials to avoid

Hygroscopic conditions should be avoided

Keep away from strong oxidising agents as prolonged contact may cause oxidation of unprotected metals.

Phosphoric Acid, 28 % P_2o_5
Physical It is white solid fertilizer. It's odourless when cold and pungent when hot. It reacts with water to produce heat. It's soluble in water to an extent of 31 g/100 ml. Fire It may not catch fire by itself, but it may catch fire when in contact with combustible materials. The product on reaching very high temperatures may decompose to from hazardous gaseous oxides of nitrogen. Remove containers from fire area, if possible. Self Contained Breathing Apparatus may be used for fire fighting purposes. Use water to extinguish fire. Do not use dry chemicals, CO_2 or halogenated agents to extinguish fire. Health Eyes: It will cause discomfort, Flush immediately with plenty of water for 15 minutes, if condition persists, consult doctor. Skin: It will cause discomfort, Wash thoroughly with soap & water, if condition persists, consult doctor. Ingestion: Mau cause diarrhoea, vomiting or convulsions, Consult doctor. Inhalation: May cause discomfort, Move victim to fresh air, maintain adequate airway & respiration, if breathing problems develop or unconscious, consult doctor Toxicological Information

Acute Oral Toxicity: LD_{50} (rat) found to be 1900-3750 mg/kg, not acutely toxic.

Acute Dermal Toxicity: LD_{50} (rat) > 5000 mg/kg, not acutely toxic

General Precautions:

Use good personal hygiene practices

Environmental Information

Do not contaminate land, water or sewerage with concentrate

Reactivity/ Materials to avoid

It is an oxidizer and may burn vigorously or explode when mixed with combustible materials or ignited.

Rock Phosphate, Ground

Physical

It is a light brown to dark brown or black rock. It's soluble in water.

Fire

It will not catch fire by itself. The product may decompose at high temperatures to release PO_X & SiF_4 gases. Use suitable media to extinguish source of fire.

Health

Eyes: Flush immediately with plenty of water for 15 minutes, if condition persists, consult doctor.

Skin: Wash thoroughly with soap & water, if condition persists, consult doctor.

Ingestion: If large amount is ingested, give 2-3 glasses of water, induce vomiting, and consult doctor.

Inhalation: Move victim to fresh air; maintain adequate airway & respiration, if breathing problems develop or unconscious, consult doctor

Toxicological Information

No information available

General Precautions:

Use good personal hygiene practices

Environmental Information

Do not contaminate land, water or sewerage with concentrate

Reactivity/ Materials to avoid

Keep away from strong acids.

Urea

Physical

It is in white powderish or white crystalline form having ammonia like odour. It's soluble in water.

Fire

It will not catch fire by itself. Reactions with incompatible material may cause explosion hazard. Use full protective clothing and Self Contained Breathing Apparatus for fire fighting. Use suitable media to extinguish source of fire.

Health

Eyes: Flush immediately with plenty of water for 15 minutes, if condition persists, consult doctor.

Skin: Wash thoroughly with soap & water, if condition persists, consult doctor.

Ingestion: Induce vomiting immediately, consult doctor.

Inhalation: Move victim to fresh air; maintain adequate airway & respiration, if breathing problems develop or unconscious, consult doctor

Toxicological Information

Acute Oral Toxicity: LD_{50} (rat) found to be 8471 mg/kg, investigated as reproductive effector.

General Precautions:

Use good personal hygiene practices

Environmental Information

Do not contaminate land, water or sewerage with concentrate

Reactivity/ Materials to avoid

Urea reacts with calcium hypochlorite or sodium hypochlorite to form the explosive nitrogen trichloride.

It is incompatible with sodium nitrite, gallium perchlorate, strong oxidizing agents (permanganate, dichromate, nitrate, chlorine), phosphorus pentachloride, nitrosyl perchlorate, and titanium tetrachloride and chromyl chloride.

Zinc Sulphate

Physical

It is a colourless hazy liquid with little odour. It's completely soluble in water

Fire

It may not catch fire by itself. The product may evolve oxides of sulphur on reaching high temperatures. Use water sprays and/or CO_2 to extinguish fire. Use full protective suit.

Health

Eyes: Flush immediately with plenty of water for 15 minutes, if condition persists, consult doctor.

Skin: Wash thoroughly with water, if condition persists, consult doctor.

Ingestion: If conscious, give large amount of water, do NOT induce vomiting, if condition persists or unconscious, Consult doctor.

Toxicological Information

No information available.

General Precautions:

Use good personal hygiene practices

Environmental Information

Do not contaminate land, water or sewerage with concentrate

Reactivity/ Materials to avoid

High temperatures should be avoided.

Lead, calcium, powered metals such as aluminium and magnesium, strontium salts and strong alkalies & borax should be avoided.

3.5 IDENTIFICATION OF RISKS FOR STORAGE AND TRANSPORTATION OF BULK CARGOES

The dry products are unloaded from the ship by crane and conveyed from berth to storage by belt conveyors. Belt conveyors are vulnerable to fire. It could catch fire by two principal causes, either due to rubber belts or due to combustible material being conveyed. The belts made of rubber are combustible and friction/static charge generator between the conveyor belts and roller, due to belt movement are the common causes of fire.

The risk associated with the belt conveyors are as follows:

- Injuries from nip points. Usually employees are pulled in when their hands, clothing, or tools are caught in the pinch point.
- Injuries from material falling from moving conveyors.
- Injuries and deaths to workers crushed against stationary objects by moving conveyors.
- Injuries to workers who fall from moving conveyors while riding on them or from conveyors that are started while they are standing or working on them.
- Injuries to workers who access unguarded head and tail pullies when the conveyor is in operation.
- Injuries to workers who service moving conveyor belts.
- Injuries to workers who fall while trying to cross over conveyors where there is no crossover bridge.
- Fires from friction, overheating, or static or other electrical sources.
- Explosions of dust raised by combustible materials at transfer points, where belts

are loaded or discharged.

- Hazards to health and vision from irritating or toxic dusts.
- Electrical shock from ungrounded or improperly installed controls or conductors,

These injuries and hazards may be reduced by proper guarding and environmental control measures.

3.6 RISK IDENTIFICATION OF BERTHS HANDLING LIQUID PRODUCTS

The Maximum Credible Loss Scenarios and Worse Case Scenarios have considered in the Risk Analysis Study for existing facilities at Cochin Port are given in Table-3.2.

Table- 3.2: List of Maximum Credible Loss Scenarios and Worst Case Scenarios

Facility No.	Facility	MCLS/WCS No.	Scenario description
1	South Coal Berth Liquid Ammonia Jetty	MCLS 1.1	Release of ammonia in the event of detachment of unloading arm.
1	South Coal Berth Liquid Ammonia Jetty	MCLS 1.2	Flange leak from a flange of the pipeline at the berth
1	South Coal Berth Liquid Ammonia Jetty	MCLS 1.3	Leakage on the pipeline from jetty to the 75.:2001 storage tank
1	South Coal Berth Liquid Ammonia Jetty	MCLS 1.4	Leakage on the pipeline from P990 1A and P990B pump discharge to the barge
1	South Coal Berth Liquid Ammonia Jetty	WCS 1.1	.Guillotine rupture of pipeline
1	South Coal Berth Liquid Ammonia Jetty	WCS 1.2	Catastrophic leakage failure of the storage tank
2	North Coal Berth POL/General Cargo	MCLS 2.1	Unloading arm/hose failure on HSD/SKO/ATF Pipeline.
2	North Coal Berth POL/General Cargo	MCLS 2.2	Unloading arm/hose failure on Naphtha / MS Pipeline.
2	North Coal Berth POL/General Cargo	MCLS 2.3	Failure of 300 NB Flange on each pipeline (HSD/SKO/ATF).
2	North Coal Berth POL/General Cargo	MCLS 2.4	Failure of 300 NB Flange on each pipeline (Naphtha/MS pipeline).

Facility No.	Facility	MCLS/WCS No.	Scenario description
2	North Coal Berth POL/General Cargo	WCS 2.1	Catastrophic failure of pipeline (HSD/SKO/ATF)
2	North Coal Berth POL/General Cargo	WCS 2.2	Catastrophic failure of pipeline (Naphtha/MS pipeline).
3	Cochin Oil Terminal (COT)	MCLS 3.1	Release of crude oil due to detachment of ERS on unloading arm while unloading ship tanker.
3	Cochin Oil Terminal (COT)	MCLS 3.2	Leakage of the transfer pipeline From the jetty to the proposed terminal while unloading the ship tanker
3	Cochin Oil Terminal (COT)	WCS 3.1	Guillotine rupture of the pipeline
4	North Tanker Berth (NTB) and South Tanker Berth (STB)	MCLS 4.1	Unloading arm/rose failure on HSD/SKO Pipeline.
4	North Tanker Berth (NTB) and South Tanker Berth (STB)	MCLS 4.2	Unloading arm/hose failure on Naphtha / MS Pipeline.
4	North Tanker Berth (NTB) and South Tanker Berth (STB)	MCLS 4.3	Failure of 300 NB Flange on each pipeline (HSD/SKO)
4	North Tanker Berth (NTB) and South Tanker Berth (STB)	MCLS 4.4	Failure of 300 NB Flange on each pipeline (Naphtha/MS pipeline).
4	North Tanker Berth (NTB) and South Tanker Berth (STB)	WCS 4.1	Catastrophic failure of pipeline at Booster pump discharge (HSD/SKO).
4	North Tanker Berth (NTB) and South Tanker Berth (STB)	WCS 4.2	Catastrophic failure of pipeline at Booster pump discharge (Naphtha/MS pipeline).
5	Proposed Oil Terminal at Puthuvypeen (MULT)	MCLS 5.1	Detachment of ERS on unloading arm while unloading crude oil
5	Proposed Oil Terminal at Puthuvypeen(MULT)	MCLS 5.2	Detachment of ERS on unloading arm while unloading HSD
5	Proposed Oil Terminal at Puthuvypeen	MCLS 5.3	Leakage of transfer pipeline of crude oil
5	Proposed Oil Terminal at Puthuvypeen	MCLS 5.4	Leakage of transfer pipeline of HSD
5	Proposed Oil Terminal at Puthuvypeen	WCS 5.1	Guillotine rupture of Crude Oil Pipeline while unloading
5	Proposed Oil Terminal at Puthuvypeen	WCS 5.2	Guillotine rupture of HSD Pipeline while unloading

Facility No.	Facility	MCLS/WCS No.	Scenario description
5	Proposed Oil Terminal at Puthuvypeen	WCS 5.3	Catastrophic failure of Crude Oil Storage tank
5	Proposed Oil Terminal at Puthuvypeen	WCS 5.4	Catastrophic failure of Crude Oil Storage tank
6	LNG Terminal at Puthuvypeen	MCLS 7.1 .	Detachment of ERS on unloading arm while unloading LNG
6	LNG Terminal at Puthuvypeen	MCLS 7.2	Leakage of LNG transfer pipe line between the proposed LNG berth and the proposed LNG terminal
6	LNG Terminal at Puthuvypeen	WCS 7.1	Fire on LNG storage tank at the proposed terminal

Facility 1 - South Coal Berth: Liquid Ammonia Jetty

MCLS 1.1 - Release of ammonia from unloading arm

Liquid ammonia, in refrigerated condition is received at the jetty. The ship is brought to the berth with the help of tugs and moored with ropes. Ammonia, with the help of the ship pump is unloaded to the storage tank. The drifting of ship due to breakage of mooring ropes could lead to detachment of unloading arm.

MCLS 1.2 - Leak from a flange of the pipeline at the berth

There are many flange joints for isolation valves, control valve, NRV, Unloading arm, vent drum in the ammonia pipeline at the berth. The probability of leakage from flange joints cannot be ruled out. The causes of flange leakage could be one of the following:

- Overstressing of bolts could cause breakage. Pipe expansion which has not been allowed for, or jammed hangers could bow pipes and cause opening of flanges.
- Sometimes, few bolts will be fitted or some will be left untightened during installation or maintenance. The remainder may be overstressed.
- Corrosion or aging can weaken packings.

For this scenario, flange leak equivalent to 50 mm hole diameter has been assumed. For this scenario, 1 minute time of response has been considered as the berth is manned during unloading operation.

MCLS 1.3 - Leakage of ammonia from the pipeline from the berth to the storage tank 75-2001

In this scenario it is assumed that the pipeline has developed a leak equivalent to 20% of the pipe diameter. The leakage of the pipeline may be due to impact, corrosion, welding failure etc.

MCLS 1.4 - Leakage on the pipeline from P9901A and P990B pump discharge to the barge

There are many flange joints for isolation valves, control valve, NRV, loading arm in the ammonia pipeline at the berth. The probability of leakage from flange joints cannot be ruled out. The causes of flange leakage could be one of the causes explained in MCLS **1.2.**

WCS 1.1 - Guillotine rupture of pipeline

Guillotine failure of the pipeline from the berth to the storage tank is possible only due to severe impact, failure of the structure supporting the pipeline, fire/explosion in the vicinity, natural calamity i.e. earthquake, cyclone etc. In the scenario it is assumed that the pipeline has developed a full bore rupture during unloading operation. Guillotine rupture of the pipeline is so improbable that it can not be treated as Maximum Credible Loss Scenario.

WCS 1.2 - Catastrophic failure of bottom nozzle of the storage tank

In this scenario it is assumed that bottom nozzle of the storage tank has developed a leak before an isolation valve and ammonia leaked out completely.

Facility 2 - North Coal Berth; POL facility of IOCL

MCLS 2.1 Unloading arm/hose failure on HSD / SKO / ATF Pipeline.

MCLS 2.2 Unloading arm/hose failure on Naphtha / MS Pipeline.

The quantity released in this failure is very small due to the Emergency Release System and the hydrocarbon which is present in the arm will loose confinement

MCLS 2.3 Failure of 300 NB Flange on the pipeline (HSD/SKO/ATF).

MCLS 2.4 Failure of 300 NB Flange on the pipeline (Naphtha/MS pipeline).

As physical and flammability profile of SKO is similar to that of ATF, scenarios of SKO and ATF will be similar. Consequence analysis for the MCLD and WC has been carried out for SKO, which will be representative of SKO and conservative for HSD as it is lower in flammability rank than SKO/ATF, It is assumed that the 300 NB flange on the line will fail due to external impact resulting in loss of confinement of hydrocarbon in the area. It is further assumed that the leakage would be detected and stopped within 1 minute, as the jetty will be manned continuously during transfer operation. The hydrocarbon released would form an unconfined pool. The pool would catch fire if there is any source of ignition otherwise there will be pool evaporation resulting in dispersion of vapour cloud.

Pipelines

The cross country section of the pipeline will be buried 6'' underground except around the booster pumping station and suitably protected by coating as well as by cathodic protection.

However failure on the pipeline is still possible due to failure of protection leading to increased corrosion or due to unauthorized drilling in the area leading to puncture which can be intentional or unintentional. Catastrophic failure of the underground pipeline is ruled out. However, as a worst case scenario it is considered for assessment.

WCS 2.1 & 2.2 - CATASTROPHIC FAILURE OF PIPELINE

As already discussed, probability of catastrophic failure of the pipeline is very small. It is only possible due to external impact like missile attack or terrorist activity. The chances of such an occurrence in a peaceful state of Kerala are very remote. However this case has been considered as it is the worst possible scenario possible and this will help the management plan for such contingency.

Facility 3 - Cochin Oil Terminal (COT)

MCLS 3.1 - Detachment of ERS on unloading arm

Crude Oil is unloaded using unloading arms equipped with ERS. In the event of the unloading operations being carried out in bad weather and failure of the mooring ropes, there are chances of the ship drifting during the unloading operation. If this occurs the unloading arm would get detached from the Emergency Release Coupling (ERC) of Emergency Release System (ERS). This would result in the fuel flowing out and spilling on to the berth/water.

MCLS 3.2 - Leakage due to failure of gasket of flange joint

The fuel would be transported from the ship unloading point to the storage area through pipelines. Flanges to the pipelines are located at the berth. In case the gasket of the flange joint fails, fuel would leak from the joint. For leakage, a hole equivalent to 20% of the pipe dia. is considered. Response time for taking necessary measures to stop the leakage is 600 seconds. This could result in pool fire\ jet fire\ PVCE in case the spilled material encounters a source of ignition.

WCS 3.1

In this scenario a guillotine rupture of the pipeline at the time of unloading crude oil has been considered. The guillotine rupture is likely only due to severe impact, structural failure, cyclone/storm, earthquake etc. Therefore the probability of this scenario is extremely remote and cannot be treated as Maximum Credible Loss Scenarios.

Facility 4 - North Tanker Berth (NTB) and South Tanker Berth (STB)

MCLS 4.1 Unloading arm failure on HSD / SKO Pipeline,

MCLS 4.2 Unloading arm failure on Naphtha / MS Pipeline,

The quantity released in this failure is very small because of the ERS system, it is only the hydrocarbon which is present in the arm will loose confinement

MCLS 4.3 Failure of 300 NB Flange on each pipeline (HSD/SKO),

MCLS 4.4 Failure of 300 NB Flange on each pipeline (Naphtha/MS pipeline)

It is assumed that the 300 NB flange on the line will fail due to external impact resulting in loss of confinement of hydrocarbon in the area. It further assumed that the leakage would be detected and stopped within 1 minute, as the jetty will be manned continuously during transfer operation. The hydrocarbon released would form an unconfined pool. The pool would catch fire if there is any source of ignition otherwise there will be pool evaporation resulting in dispersion of vapour cloud.

PIPELINES

The cross country section of the pipeline will be buried 6''underground except around the booster pumping station and suitably protected by coating as well as by cathodic protection.

However failure on the pipeline is still possible due to failure of protection leading to increased corrosion or due to unauthorized drilling in the area leading to puncture which can be intentional or unintentional. Catastrophic failure of the underground pipeline is ruled out.

Two failure scenarios are considered as MCLS for the present study around the booster station because the pipeline is above ground in this region and the pressure in the pipeline is maximum at booster pump discharge.

Following are the WCS selected in this part of the facility for the Risk Assessment Study:

WCS 4.1 & 4.2 - CATASTROPHIC FAILURE OF PIPELINE AT BOOSTER PUMP DISCHARGE

As already discussed, probability of catastrophic failure of the pipeline is very small. It is only possible due to earthquake or external impact like missile attack or terrorist activity. The chances of such an occurrence in a peaceful state of Kerala are very remote. However this case has been considered as it is the worst possible scenario possible and this will help the management plan for such contingency.

Facility 5 - Proposed Oil Terminal at Puthuvypeen (MULT)

An oil terminal for handling crude oil and Class B fuels (HSD, Gas Oil etc.) is proposed at Puthuvypeen. It is located on the northside of the proposed LNG terminal on the same island. The ship parcel size varying from 80,000 DWT to 1,50,000 DWT will be berthed and unloaded at a rate of 3000 t/hr.

WCS 5.3 & 5.4

In these scenarios it is assumed the storage tank of Crude Oil and HSD have failed and complete content that has leaked into the dyke has caught fire subsequently.

Facility 6 - LNG Terminal at Puthu Vypeen

Description of Maximum Credible Loss Scenarios and Worse Case Scenarios

MCLS 7.1 - Detachment of ERS on unloading arm while unloadinq LNG

LNG ship of 78000 t (approx.) parcel size will be unloaded at the dedicated jetty with help of unloading arm. The material of construction of all three unloading arms-LNG unloading arm, LNG vapour return arm and Dual function arm, is SS316L and the diameter is 16''. The leakage of LNG due to detachment of one of these arms while-unloading could lead to release of LNG. The spilled LNG either on concrete surface of berth or on sea water would vapourise and could form a cloud within flammability range. In addition to the fire hazard, the spillage of LNG OF1 metal structure at -160^0 C could result in structural failure. With provision of ERS (Emergency Release System), the probability of release and risk of large quantity spilled is reduced considerably.

ERS ensures that in case of unexpected large drift by the ship away from the normal mooring position, product flow through the unloading arm will first be rapidly shut-off by isolating valves and the arm will be safely decoupled from .the part affixed to the ship's manifold in order to avert physical damage to the transfer system. The decoupling action of the ERS would be achieved by disengaging a collar provided between two isolation valves. Hence, loss of containment of product is limited to the volume held within the collar. In this case, with the diameter of arm 406 mm and with 100 mm width of collar, the volume of spillage would be at the most 10 kg.

MCLS 7.2 - Leakage of LNG Transfer pipe line between the LNG berth and theLNG terminal

A dedicated LNG unloading jetty is located 310 m from the terminal. LNG transfer line between the LNG berth and theLNG terminal will handle LNG at -160°C and 10 kg/cm^2 pumping pressure. The ship pump will be used for unloading. The pipe rack will be located on one side of the road from the jetty. Mechanical impact by a vehicle passing through the approach road or by any other agency could cause rupture of pipeline. The probability of such occurrence is extremely low (refer chapter 6), but from risk assessment study point of view, it can not be ignored. Besides the mechanical impact, corrosion, faulty material of construction of pipeline or gasket failure of flanges, pipeline support, inadequate design factor for expansion could lead to failure of the pipeline and release of LNG.

WCS 7.1 - Fire on LNG storage tank at the terminal

The LNG terminal comprises two refrigerated LNG storage tanks, each of 1,55,000 m^3 capacity. The storage tank will be equipped with two submersible pumps. The average send out rate is 6850 tonnes per day. (2.5 MMTPA) The storage tank will be a double containment type and a failure of storage tank is extremely low because such type of tank has inner as well as outer full integrity shells. In case of failure of inner shell, LNG will be contained by the outer shell. It has outer roof of metal/prestressed concrete. Considering this, the failure of storage tank is extremely low for risk assessment study. The roof fire scenario has been considered. The failure of tank-roof and subsequent ignition will result in pool fire.

ASSUMPTIONS:

1. The roof of the tank fails due to missile flying object.
2. There is no failure of shell and LNG is fully contained.
3. The pool fire takes place on the surface of liquid.

3.7 DISPERSION MODELLING

After release of hazardous chemical, it mixes with air and forms a flammable or toxic cloud which could drift away from the source of release. The flammable cloud could ignite or explode if it encounters source of ignition. The toxic cloud could affect the site as well as population in the vicinity. The parameters influencing dispersion are:

1. Density of cloud

In hazard analysis the clouds which are denser than air are usually of most concern. Clouds which are lighter than air will rise upwards and are therefore likely to disperse faster than denser cloud, which would settle at ground level and affect the population in the vicinity. Ammonia gas is safer as it is lighter than air.

2. Atmospheric Stability

Atmospheric stability is important with regard to the extent to which it suppresses or enhances the vertical movement of the cloud in the atmosphere. This is a function of the vertical temperature profile in the atmosphere. If a volume of air rises, it would normally be expected to cool as it equals the vertical temperature profile, then turbulence is neither suppressed nor enhanced. Such conditions are termed neutral. If the vertical temperature profile is more marked then turbulence is enhanced and if the profile is less marked then turbulence is suppressed. Neutral conditions correspond to adiabatic rate of decrease in temperature with height of about 1°C per 100 metres.

Stability is defined in terms of the vertical temperature gradient in the atmosphere. It is usually described using the system of categories developed by Pasquill. This system use 6 (or sometimes 7) categories to cover unstable, neutral and stable conditions; the categories are ranges of stability identified by the letters A - F (or sometimes A - G). Neutral stability occurs typically when there is total cloud cover and is designated category 0 (the temperature gradient = diabatic lapse rate). Unstable conditions occur when the sun is shining because the warming of the ground increases connective turbulence; unstable conditions are designated by the letters A - C- with A as the least stable condition. Stable conditions occur on clear, calm nights when the air near the ground is stratified and free from turbulence, and are designated by the letters E and F; sometimes an additional category G is used for exceptionally stable conditions. For the dispersion study D and F stability class have been considered.

3. <u>Surface roughness parameter</u>

Surface roughness determines the amount of turbulence generated by wind of a given velocity as it passes over the ground. The degree of roughness relates to a comparison of the average height of surface .protuberances with the depth of the laminar sub-layer in the air stream.

Since the site is located in industrial zone, 0.17 Surface Roughness Parameter has been considered for the study.

4. <u>Wind speed and surface roughness</u>

These factors are discussed together because they combine to influence local turbulence. The wind usually increases atmospheric turbulence and accelerates dispersion. The surface roughness of the ground induces turbulence in the wind which flows over it, and therefore affects dispersion.

Dispersion Models

Dispersion Modelling aims at estimating the distances likely to be affected due to release of certain quantity of toxic or flammable gas within an acceptable concentration limit. Depending upon the properties of the material released and the release condition; a dense gas dispersion, neutral gas dispersion or a buoyant gas release model is used for estimating the affected areas. Both the models describe the behaviour of material subsequent to its release in the predominant downwind direction, at a particular wind speed and at the existing meteorological conditions such as humidity, temperature, etc. It should be noted that the release rate would depend on release conditions (temperature and pressure), the release/failure point, intervention time, the release area and other factors.

Windspeed and turbulence are significant factors as the amount of air entrainment into the released gas would depend on the velocity at which the cloud is travelling and also turbulence in the surroundings. Varying terrain contours in the area would affect the dispersion. The atmospheric stability class takes into account atmospheric turbulence and is another important consideration in modelling. This in turn depends on several factors such as wind speed, insolation, cloud cover and the time period i.e. day or night. Stable atmospheric conditions led to the least amount of mixing thus resulting in larger areas for gas dispersion and unstable conditions result in maximum mixing of gas with air leading to the dilution of the gas.

Surroundings of the area including building and other structures also have a marked effect on the dispersion of released gas. The dispersion would vary with the size and position of the building relative to the source of release along with the other factors already discussed above.

a) Pool fires and Jet fires

The effects of a pool fire depend upon factors such as flammability, combustibility, the amount of material released, temperature, humidity, the pool size, flame height and tilt of the flame.

The distances for damage due to different intensities for various scenarios of jet fire are given in Table-3.3.

Table – 3.3: Distances for Damage due to Radiations Intensity Due To Jet Fire

S. No.	MAXIMUM CREDIBLE LOSS SCENARIOS	ATMOSPHERIC STABILITY	WINDSPEED m/s	RADIATION DISTANCE (m)		
				37.5 (kw/m^2)	12.5 (kw/m^2)	4 (kw/m^2)
1.	MCLS -1.1	F	1	-	247	288
	MCLS - 1.1	D	3	-	205	246
	MCLS -1.1	D	5	-	186	226
2.	MCLS - 1.2	F	1	-	-	69
	MCLS -1.2	D	3	-	48	58
	MCLS -1.2	D	5	-	45	54
3.	MCLS -1.3	F	1	-	-	69
	MCLS -1.3	D	3	-	48	58
	MCLS -1.3	D	5	-	45	54
4.	MCLS -1.4	F	1	-	-	41
	MCLS - 1.4	D	3	-	31	38
	MCLS - 1.4	D	5	-	27	32
5.	WCS -1.1	F	1	-	288	340
	WCS -1.1	D	3	-	240	288
	WCS -1.1	D	5	175	219	262
6.	WCS -1.2	F	1	-	349	404
	WCS-1.2	D	3	-	288	344
	WCS -1.2	D	5	211	259	313
7.	MCLS - 2.1	F	1	-	98	123
	MCLS - 2.1	D	3	-	83	103
	MCLS - 2.1	D	5	-	78	94
8.	MCLS - 2.2	F	1	-	641	759
	MCLS - 2.2	D	3	419	534	646
	MCLS - 2.2	D	5	407	419	594
9.	MCLS - 2.3	F	1	-	-	54
	MCLS - 2,3	D	3	-	36	45
	MCLS - 2.3	D	5		34	41
10.	MCLS - 2.4	F	1	-	205	242
	MCLS - 2.4	D	3	-	169	205
	MCLS - 2.4	D	5	120	153	186
11.	WCS - 2.1	F	1	-	-	111
	WCS - 2.1	D	3	-	67	82
	WCS - 2.1	D	5	-	62	75
12.	WCS - 2.2	F	1	-	531	631
	WCS - 2.2	D	3	338	425	510
	WCS - 2.2	D	5	323	384	467
13.	MCLS - 3.1	F	1		-	-

S. No.	MAXIMUM CREDIBLE LOSS SCENARIOS	ATMOSPHERIC STABILITY	WINDSPEED m/s	RADIATION DISTANCE (m)		
				37.5 (kw/m^2)	12.5 (kw/m^2)	4 (kw/m^2)
	MCLS - 3.1	0	3	-	-	-
	MCLS - 3.1	D	5	.	-	-
14.	MCLS - 3.2	F	1	-	-	60
	MCLS - 3.2	D	3	-	43	52
	MCLS - 3.2	D	5	-	39	46
15.	WCS - 3.1	F	1	-	302	362
	WCS - 3.1	D	3	-	227	273
	WCS - 3.1	D	5	189	229	275
16.	MCLS - 5.1	F	1	-	-	-
	MCLS - 5.1	D	3	-	-	-
	MCLS - 5.1	D	5	-	-	-
17.	MCLS - 5.2	F	1	-	-	-
	MCLS - 5.2	D	3	-	-	-
	MCLS - 5.2	D	5	-	-	-
18.	MCLS - 5.3	F	1	-	-	70
	MCLS - 5.3	D	3	-	51	62
	MCLS - 5.3	D	5	-	48	57
19.	MCLS - 5.4	F	1	-	-	20
	MCLS - 5.4	D	3	-	-	20
	MCLS - 5.4	D	5	-	15	18
20.	WCS - 5.1	F	1	707	838	984
	WCS - 5.1	D	3	585	706	853
	WCS - 5.1	D	5	542	648	792
21.	WCS - 5.2	F	1	-	99	122
	WCS - 5.2	D	3	-	84	102
	WCS - 5.2	D	5	-	77	92
22.	WCS - 5.3	F	1		-	-
	WCS - 5.3	D	3	-	-	-
	WCS - 5.3	D	5	-	-	-
23.	WCS - 5.4	F	1	-	-	-
	WCS - 5.4	D	3	-	-	-
	WCS - 5.4	D	5	-	-	-

**Reference- Table 3.2,*

A- Extremely Unstable ,
B- Moderately Unstable
C- Slightly Unstable
D- Neutral
E- Stable
F- Highly Stable

The distances for damage due to different intensities for various scenarios of pool fire are given in Table-3.4

Table -3.4: Distances For Damage Due To Various Radiation Intensity For Pool Fire

S. No.	MAXIMUM CREDIBLE LOSS SCENARIOS	ATMOSPHERIC STABILITY	WINDSPEED m/s	RADIATION DISTANCE (m)		
				37.5 (kw/m^2)	12.5 (kw/m^2)	4 (kw/m^2)
1.	MCLS - 1.1	F	1	160	239	364
	MCLS -1.1	D	3	161	239	364
	MCLS -1.1	D	5	182	252	359
2.	MCLS -1.2	F	1	28	45	73
	MCLS -1.2	D	3	34	49	74
	MCLS -1.2	D	5	36	48	68
3.	MCLS 1.3	F	1	.	.	69
	MCLS 1.3	D	3	-	48	58
	MCLS - 1.3	D	5	-	45	54
4.	MCLS - 1.4	F	1	15	25	42
	MCLS - 1.4	D	3	19	27	41
	MCLS - 1.4	D	5	20	27	39
5.	WCS-1.1	F	1	-	288	340
	WCS -1.1	D	3	-	239	288
	WCS -1.1	D	5	172	219	262
6.	WCS -1.2	F	1	*506*	694	972
	WCS -1.2	D	3	*506*	695	973
	WCS -1.2	D	5	516	*706*	993
7.	MCLS - 2.1	F	1	106	195	332
	MCLS - 2.1	D	3	1.09	210	342
	MCLS - 2.1	D	5	140	245	355
8.	MCLS - 2.2	F	1	-	62	111
	MCLS - 2.2	D	3	-	62	111
	MCLS - 2.2	D	5	-	63	145
9.	MCLS - 2.3	F	1	39	67	107
	MCLS - 2.3	D	3	47	84	123
	MCLS - 2.3	D	5	57	89	121
10.	MCLS - 2.4	F	1	-	205	242
	MCLS - 2.4	D	3	-	169	205
	MCLS - 2.4	D	5	121	153	187
11.	WCS - 2.1	F	1	87	162	281
	WCS - 2,1	D	3	96	185	300
	WCS - 2.1	D	5	119	206	306

S. No.	MAXIMUM CREDIBLE LOSS SCENARIOS	ATMOSPHERIC STABILITY	WINDSPEED m/s	RADIATION DISTANCE (m)		
				37.5 (kw/m^2)	12.5 (kw/m^2)	4 (kw/m^2)
12.	WCS - 2.2	F	1	-	61	103
	WCS - 2.2	D	3	-	60	102
	WCS - 2.2	D	5	-	61	135
13.	MCLS - 3.1	F	1	2	4	6
	MCLS - 3.1	0	3	3	4	5
	MCLS - 3.1	D	5	3	4	5
14.	MCLS - 3.2	F	1	6	16	31
	MCLS - 3.2	D	3	6	19	45
	MCLS - 3.2	D	5	6	23	48
15.	WCS - 3.1	F	1	-	69	111
	WCS - 3.1	D	3	-	66	114
	WCS - 3.1	D	5	-	71	152
16.	MCLS - 4.1	F	1	3	4	6
	MCLS - 4.1	D	3	3	4	6
17.	MCLS - 4.2	F	1	3	5	7
	MCLS - 4.2	D	3	4	5	6
18.	MCLS - 4.3	F	1	-	34	51
	MCLS - 4.3	D	3	-	39	63
19.	MCLS - 4.4	F	1	-	32	50
	MCLS - 4.4	D	3	-	46	72
20.	WCS -4.1	F	1	-	216	356
	WCS - 4.1	D	3	-	221	419
21.	WCS - 4.2	F	1	-	177	302
	WCS - 4.2	D	3	-	178	334
22.	MCLS - 5.1	F	1	2	4	6
	MCLS - 5.1	D	3	3	4	5
	MCLS - 5.1	D	5	3	4	5
23.	MCLS - 5.2	F	1	1	4	7
	MCLS - 5.2	D	3	2	5	7
	MCLS - 5.2	D	5	3	6	7
24.	MCLS - 5.3 ’	F	1	.7	18	34
	MCLS - 5.3	D	3	7	20	48
	MCLS - 5.3	D	5	7	22	52
25.	MCLS 5.4	F	1	20	36	64
	MCLS - 5.4	D	3	26	48	72
	MCLS - 5.4	D	5	32	52	71
26.	WCS - 5.1	F	1	-	385	570
	WCS - 5.1	D	3	-	385	570

S. No.	MAXIMUM CREDIBLE LOSS SCENARIOS	ATMOSPHERIC STABILITY	WINDSPEED m/s	RADIATION DISTANCE (m)		
				37.5 (kw/m^2)	12.5 (kw/m^2)	4 (kw/m^2)
	WCS - 5.1	D	5	-	;385	570
27	WCS - 5.2	F	1	140	248	397
	WCS - 5.2	D	3	141	248	397
	WCS - 5.2	D	5	177	295	438
28.	WCS - 5.3	F	1	-	173	269
	WCS - 5.3	D	3	-	174	269
29.	WCS - 5.4	F	1	190	333	542
	WCS - 5.4	D	3	190	333	542
	WCS - 5.4	D	5	228	397	597
30.	MCLS - 7.1	D	1	0.6	1.4	3.8
	MCLS - 7.1	D	5	0.64	2.7	5.2
31.	MCLS - 7.2	D	1	143	295	523
	MCLS - 7.2	D	5	143	295	524
32.	WCS - 7.1	D	1	78	154	270
	WCS - 7.1	D	5	106	188	291

**Reference- Table 3.2,*

A-	*Extremely Unstable*
B-	*Moderately Unstable*
C-	*Slightly Unstable*
D-	*Neutral*
E-	*Stable*
F-	*Highly Stable*

b) Flash fire

In determining the affected distance for flash fire the ½ LEL dispersion distance of the flammable cloud is considered.

The flask fire distances for various scenarios are given in Table-3.5

Table-3.5: Flash Fire Distances

S. NO.	MAXIMUM CREDIBLE LOSS SCENARIOS	ATMOSPHERIC STABILITY	WINDSPEED m/s	FLASH FIRE DISTANCES (m)
1.	MCLS -1.1	F	1	124
	MCLS -1.1	D	3	155
	MCLS -1.1	D	5	155
2.	MCLS -1.2	F	1	42

S. NO.	MAXIMUM CREDIBLE LOSS SCENARIOS	ATMOSPHERIC STABILITY	WINDSPEED m/s	FLASH FIRE DISTANCES (m)
	MCLS -1.2	D	3	50
	MCLS -1.2	0"	5	48
3.	MCLS -1.3	F	1	42
	MCLS -1.3	D	3	50
	MCLS -1.3	D	5	49
4.	MCLS -1.4	F	1	26
	MCLS - 1.4	D	3	30
	MCLS - 1.4	D	5	28
5.	WCS -1.1	F	1	161
	WCS -1.1	D	3	218
	WCS -1.1	D	5	217
6.	WCS -1.2	F	1	425
	WCS-1.2	D	3	451
	WCS -1.2	D	5	392
7.	MCLS - 2.1	F	1	213
	MCLS - 2.1	D	3	13
	MCLS - 2.1	D	5	13
8.	MCLS - 2.2	F	1	407
	MCLS - 2.2	D	3	511
	MCLS - 2.2	0	5	523
9.	MCLS - 2.3	F	1	12
	MCLS - 2.3	D	3	12
	MCLS - 2.3	D	5	12
10.	MCLS - 2.4	F	1	124
	MCLS - 2.4	D	3	163
	MCLS - 2.4	D	5	163
11.	WCS - 2. 1	F	1	12
	WCS - 2.1	D	3	54
	WCS - 2.1	D	5	54
12.	WCS - 2.2	F	1	318
	WCS - 2.2	D	3	396
	WCS - 2.2	D	5	404
13	MCLS - 3.1	F	1	3
	MCLS - 3.1	D	3	5
	MCLS - 3.1	D	5	6
14.	MCLS - 3.2	F	1	25
	MCLS - 3.2	D	3	32
	MCLS - 3.2	D	5	32
15.	WCS-3.1	F	1	169

S. NO.	MAXIMUM CREDIBLE LOSS SCENARIOS	ATMOSPHERIC STABILITY	WINDSPEED m/s	FLASH FIRE DISTANCES (m)
	WCS - 3.1	D	3	172
	WCS - 3.1	D	5	189
16.	MCLS - 4.1	F	1	3
	MCLS -4.1	D	3	6
17.	MCLS - 4.2	F	1	2
	MCLS - 4.2	D	3	4
18.	MCLS - 4.3	F	1	51
	MCLS - 4.3	D	3	63
19.	MCLS - 4.4	F	1	150
	MCLS - 4.4	D	3	168
20.	WCS -4.1	F	1	309
	WCS - 4.1	D	3	230
21.	WCS - 4.2	F	1	780
	WCS - 4.2	D	3	827
22.	MCLS - 5.1	F	1	2.5
	MCLS - 5.1	D	3	5
	MCLS - 5.1	D	5	6
23.	MCLS - 5.2	F	1	2.7
	MCLS - 5.2	D	3	5
	MCLS - 5.2	D	5	7
24.	MCLS - 5.3	F	1	28
	MCLS - 5.3	D	3	37
	MCLS - 5.3	D	5	40
25.	MCLS - 5.4	F	1	4
	MCLS - 5.4	D	3	4
	MCLS - 5.4	D	. 5	5
26.	WCS - 5.1	F	1	432
	WCS - 5.1	D	3	504
	WCS - 5.1	D	5	594
27.	WCS - 5.2	F	1	114
	WCS - 5.2	D	3	102
	WCS - 5.2	D	5	102
28.	WCS - 5.3	F	1	314
	WCS - 5.3	D	3	364
	WCS - 5.3	D	5	405

S. NO.	MAXIMUM CREDIBLE LOSS SCENARIOS	ATMOSPHERIC STABILITY	WINDSPEED m/s	FLASH FIRE DISTANCES (m)
29.	WCS - 5.4	F	1	12
	WCS - 5.4	D	3	103
	WCS - 5.4	D	5	121
30.	MCLS - 7.1	F	1	81
	MCLS - 7.1	D	3	60
	MCLS - 7.1	D	5	41
31.	MCLS - 7.2	F	1	513
	MCLS - 7.2	D	3	602
	MCLS - 7.2	D	5	670
32.	WCS - 7.1	F	1	187
	WCS - 7.1	D	3	115
	WCS-7.1	D	5	80

**Reference- Table 3.2*

A-	*Extremely Unstable*
B-	*Moderately Unstable*
C-	*Slightly Unstable*
D-	*Neutral*
E-	*Stable*
F-	*Highly Stable*

The distance for various radiation intensities in case of explosion for various scenarios are given in Table-3.6.

Table-3.6: Distance for Various Radiation Intensity In Case Of Explosion for Various Scenarios

S. No.	MAXIMUM CREDIBLE LOSS SCENARIOS	ATMOSPHERIC STABILITY	WINDSPEED m/s	RADIATION DISTANCE (m)		
				37.5 (kw/m^2)	12.5 (kw/m^2)	4 (kw/m^2)
1.	MCLS -1.1	F	1	-	-	-
	MCLS - 1.1	D	3		-	-
	MCLS -1.1	D	5	-	-	-
2.	MCLS - 1.2	F	1	-	52	87
	MCLS -1.2	D	3	49	60	89
	MCLS -1.2	D	5	58	47	64
3.	MCLS -1.3	F	1	45	52	87

S. No.	MAXIMUM CREDIBLE LOSS SCENARIOS	ATMOSPHERIC STABILITY	WINDSPEED m/s	RADIATION DISTANCE (m)		
				37.5 (kw/m^2)	12.5 (kw/m^2)	4 (kw/m^2)
	MCLS -1.3	D	3	49	60	89
	MCLS -1.3	D	5	58	46	65
4.	MCLS -1.4	F	1	45	-	-
	MCLS - 1.4	D	3	-	-	-
	MCLS - 1.4	D	5	-	-	-
5.	WCS -1.1	F	1	-	108	217
	WCS -1.1	D	3	151	160	275
	WCS -1.1	D	5	185	193	290
6.	WCS -1.2	F	1	606	661	1351
	WCS-1.2	D	3	566	600	1032
	WCS -1.2	D	5	473	498	807
7.	MCLS - 2.1	F	1	-	-	-
	MCLS - 2.1	D	3	-	-	-
	MCLS - 2.1	D	5	-	-	.
8.	MCLS - 2.2	F	1	206	225	471
	MCLS - 2.2	D	3	330	344	528
	MCLS - 2.2	D	5	339	353	538
9.	MCLS - 2.3	F	1	-	-	-
	MCLS - 2,3	D	3	-	-	-
	MCLS - 2.3	D	5	-	-	-
10.	MCLS - 2.4	F	1	163	179	377
	MCLS - 2.4	D	3	197	207	342
	MCLS - 2.4	D	5	191	200	315
11.	WCS - 2.1	F	1	-	-	-
	WCS - 2.1	D	3	-	-	-
	WCS - 2.1	D	5	-	-	-
12.	WCS - 2.2	F	1	201	233	642
	WCS - 2.2	D	3	307	335	695
	WCS - 2.2	D	5	369	395	726
13.	MCLS - 3.1	F	1	-	-	-
	MCLS - 3.1	0	3	-	-	-
	MCLS - 3.1	D	5	-	-	-
14.	MCLS - 3.2	F	1	23	24	37
	MCLS - 3.2	D	3	34	35	50
	MCLS - 3.2	D	5	34	35	50
15.	WCS - 3.1	F	1	120	132	280
	WCS - 3.1	D	3	197	204	303

S. No.	MAXIMUM CREDIBLE LOSS SCENARIOS	ATMOSPHERIC STABILITY	WINDSPEED m/s	RADIATION DISTANCE (m)		
				37.5 (kw/m^2)	12.5 (kw/m^2)	4 (kw/m^2)
	WCS - 3.1	D	5	207	215	315
16.	MCLS - 5.1	F	1	-	-	-
	MCLS - 5.1	D	3	-	.	.
	MCLS - 5.1	D	5	.	.	-
17.	MCLS - 5.2	F	1	-	-	-
	MCLS - 5.2	D	3	-	-	-
	MCLS - 5.2	D	5	-	-	-
18.	MCLS - 5.3	F	1	24	25	41
	MCLS - 5.3	D	3	33	34	45
	MCLS - 5.3	D	5	34	35	48
19.	MCLS - 5.4	F	1	-	-	-
	MCLS - 5.4	D	3	-	-	-
	MCLS - 5.4	D	5	-	-	-
20.	WCS - 5.1	F	1	285	298	466
	WCS - 5.1	D	3	381	395	584
	WCS - 5.1	D	5	485	503	742
21.	WCS - 5.2	F	1	-	-	-
	WCS - 5.2	D	3	-	-	-
	WCS - 5.2	D	5	-	-	-
22.	WCS - 5.3	F	1	373	400	740
	WCS - 5.3	D	3	340	361	634
	WCS - 5.3	D	5	345	365	625
23.	WCS - 5.4	F	1	203	249	828
	WCS - 5.4	D	3	80	85	142
	WCS - 5.4	D	5	94	98	146

**Reference- Table 3.2*

A-	*Extremely Unstable*
B-	*Moderately Unstable*
C-	*Slightly Unstable*
D-	*Neutral*
E-	*Stable*
F-	*Highly Stable*

3.8 HANDLING OF IMO CLASS CARGO

IMO class cargo is handled in the port on Q5, ICTT and CFS. Carriage of dangerous goods and marine pollutants in sea-going ships is respectively regulated in the

International Convention for the Safety of the Life at Sea (SOLAS) and the International Convention for the Prevention of pollution from Ships (MARPOL). Relevant parts of both SOLAS and MARPOL have been worked out in great detail and are included in the International Maritime Dangerous Goods (IMDG) Code, thus making this Code the legal instrument for maritime transport of dangerous goods and marine pollutants. As of 1st January 2004, the IMDG Code became a mandatory requirement.

Safe Procedure for Handling of IMO Class Cargo

The shipper of dangerous goods should provide a dangerous goods declaration embodying the relevant details listed in section 9 of the general introduction to the IMDG Code and the original or a copy should be placed aboard the ship. Without such a declaration the dangerous goods shall not be accepted for shipments.

Those responsible for the packing of dangerous goods into a freight container or vehicle should provide a signed vehicle packing certificate, stating that the provisions of paragraph 5.4 of the IMDG Code have been met, and the original or a copy should be handed over to the vessel operator. Without such certification, the container or vehicle shall not be accepted for shipment.

Classification of Dangerous Goods

For all modes of transport (sea, air, rail, road and inland waterways) the classification (grouping) of dangerous goods by type of risk involved, has been drawn up by the UNITED NATIONS Committee of Experts on the Transport of Dangerous Goods (UN). Based on this framework of grouping and for the purpose of carriage by sea, IMO Classes comprise the following, which are further subdivided as indicated: Dangerous goods, marine pollutants and material hazardous only in Bulk (MHB).

Dangerous Substances Codes

Modern maritime transportation involves the shipment of more than a million chemical materials. In such a situation it is clear that the characteristics of each of the many different chemical substances must be determined and measures taken accordingly. As a result of this requirement, in 1960 the Inter-governmental Maritime Consultative Organization, known as IMCO for short, categorized the most important dangerous chemical substances in the International Maritime Dangerous Goods – Code, or IMDG-C for short, which classified dangerous substances according to international standards and stated that labels measuring at least 10 cm x 10 cm should be put on all containers carrying this kind of cargo. It listed nine different classes according to the different characteristics which constituted a hazard to life and property. These are given below with their international label and code.

CLASS 1 – EXPLOSIVES

It should be stored away from the Liquid storage tanks and other equipments involved in handling of LPG\LNG. Substances included in this class are Gunpowder, Fireworks, smoke bombs, ammunitions, Dynamite etc.

Class 1.1

This designation is used for explosives that have a mass explosion hazard. In other words, the entire load can explode at once if one device is initiated. Typically high explosives like dynamite, TNT, fall into this category.

Class 1.2

Explosives that don’t have a mass explosion hazard as in the case of 1.1 explosives, but do have a projection hazard.

Class 1.3

Explosives that don’t have a mass explosion hazard, but are a fire hazard, and either a minor blast hazard or a minor projection hazard, or both.

Class 1.4

Explosives that only present a minor explosion hazard which are generally confined to the package, and have no explosion fragments of significant size or range.

Class1.5D

Very insensitive explosives. These explosives can have a mass explosion hazard, but due to their insensitivity, probability of explosion under normal transportation conditions, even in the event of burning, is very small.

Class1.6N

Extremely insensitive explosives. These explosives have no mass explosion hazard. These substances are so insensitive, that the probability of accidental ignition is negligible.

CLASS 2 - GASES

class 2.1 - FLAMMABLE GASES

It should be stored away from the Liquid storage tanks and other equipments involved in handling of LPG\LNG.Substances included in this class are Acetylene, Ethane, Ethylene, Methane, Hydrogen, Lighter Gas etc.

class 2.2 - TOXIC GASES

It should be stored away from any source of heat and foodstuffs. Substances included in this class are Ammonia, Flor, Prussic Acid, Chloride, Carbon Monoxide etc.

class 2.3 - NON-FLAMMABLE COMPRESSED GASES

Store on or under the deck in a cool, well-ventilated place. Containers filled with this kind of gas will expand if heated and there is a high risk of an explosion. Substances included in this class are Argon, Helium, Carbon Dioxide, Coal Gas, Oxygen etc.

CLASS 3 - FLAMMABLE LIQUID

Inflammable liquids are divided into three groups according to the temperature at which, in a vapour state, they explode when heated.

class 3.1- PETROL

Combustion occurs at less than 18°C and should always be stored above the deck.

class 3.2 - FUEL OIL

Combustion occurs between 18°C and 23°C and should be stored above or below the deck.

class 3.3 - FUEL OIL

Combustion occurs between 23°C and 61°C and should be stored below the deck.

CLASS 4 - GASES

class 4.1 - FLAMMABLE SOLID

Substances included in this class are Aluminum Powder, Celluloid, Naphthalene, Red Phosphorus, Films, Naphtha Oil, Dry Fiber etc.

class 4.2 - SPONTENOUSLY COMBUSTIBLE

Should be stored in well ventilated areas and air should be able to circulate between the stored materials. Substances included in this class are Copra, Fish Powder, Hay, Charcoal etc.

class 4.3 - DANGEROUS WHEN WET

Solids which are inflammable when wet or when in contact with water. Should be stored in well ventilated, dry areas and should avoid any contact with water. Substances included in this class are Alkaline Alloys, Barium, Calcium Carbide, Ferro Silicon, Natrium, Magnesium etc.

CLASS 5 - OXIDIZİNG SUBSTANCES

class 5.1 - OXIDIZING AGENT

The substances in this category can create an inflammable environment when brought into contact with oxygen. For this reason they should not be stored next to combustible materials. Substances included in this class are Nitrate, Artificial Fertilizers, Ammonium Sulphate, Barium Chlorate etc.

class 5.2 - ORGANIC PEROXIDE

The substances in this class can be inflammable or explosive. They should be stored in dry cool areas. Substances included in this class are all peroxides.

CLASS 6 - TOXIC

class 6.1 - TOXIC SUBSTANCES

Toxic substances are those which can enter the human body through the mouth and cause death. For this reasons they should be stored away from foodstuffs, drinks, and materials which increase humidity, such as tobacco. Substances included in this class are Arsenic, Aniline, Barium Oxide, Phenol, Nicotine, Lead, Cyanide, Mercury Products etc.

class 6.2 - INFECTIOUS (BIOLOGICAL) SUBSTANCES

These substances contain microbes which can cause illness. They should be stored away from foodstuffs, drinks etc. In case of danger the nearest health authority should be notified. Substances included in this class are Bones, Marrow, Condensed Meat Wastes, Animal Skins, Dehydrated Blood etc.

CLASS 7 - RADIOACTIVE MATERIALS

These materials should be transported in specially sealed containers. The seals must always be completely undamaged. They should preferably be stored away foodstuffs, unprocessed films, pharmaceuticals and chemical substances.

CLASS 8 - CORROSIVES

The substances in this class are solids or liquids possessing, in their original state, the common property of being able, more or less severely to damage living tissue. The escape of such a substance from its packaging may also cause damage to other cargo or the storage tanks. Corrosive substances are apportioned among three categories (packaging groups) according to the degree of danger they present.

CLASS- 9 - MISCELLANEOUS DANGEROUS SUBSTANCES

Class- 9 comprises:

1. Substances and articles not covered by other classes which experience has shown, or may show, to be of such a dangerous character that the provisions of SOLAS

should apply. These include substances that are transported or offered for transport at temperatures equal to or exceeding 1000^oC and in a liquid state, and solids that are transported at temperatures equal or exceeding 2400^oC;

2. Harmful substances not subjects to the provisions of SOLAS, but to which the provisions Annex III of MARPOL apply.

They are divided into two categories according to the degree of danger they present: medium danger (packing group II) and minor danger (packing group III).

CHAPTER – 4

CHAPTER – 4

RISK ANALYSIS FOR LPG IMPORT TERMINAL AT PUTHUVYPEEN ISLAND

4.1 GENERAL

The proposed LPG import terminal is located at Puthuvypeen Special Economic Zone in Vypeen Island in the district of Ernakulam of the state of Kerala. The LPG import terminal is situated at eastern side of Arabian Sea. The Highest tidal level attained is 1.05 M above mean sea level. The LPG brought in tanker ships will be unloaded using two, 10" marine unloading arms in the jetty and pumped to LPG Mounded Bullets using a 20" dia. transfer pipeline. The total designed storage capacity of the terminal is 15400 tons and that of the road tanker loading facility is approx. 128 trucks in a day. Four storage vessels are designed for propane and four for butane service.

4.2 PROCESS DESCRIPTION

LPG Receipt, Storage & Dispatch

LPG brought in tanker ships will be unloaded using marine unloading arms in the jetty and pumped to LPG mounded bullet through a 20" dia. pipeline running from jetty to the terminal using pumps provided in the ship. The storage tanks will be provided with a single liquid inlet/outlet line at the bottom, one vapor inlet/outlet line connected with LPG vapor compressor at top. Two numbers of safety valves have been provided on the top of each storage vessel. All the storage vessels are provided with level gauges. The LPG stored in the storage vessel will be loaded to the road tankers using loading pumps/ compressors. The LPG will be loaded in two nos. of TLF sheds each having eight nos. of loading bays.

LPG Pump House/ Compressors House

Following equipment shall be provided in LPG pump house:

i) LPG Pump - 08 Nos.
Capacity - 90 TPH Type - Centrifugal
Discharge. Press. - 14 kg/cm^2

ii) LPG Vapor compressor : 01 Nos.
Capacity : 100 CFM (Cubic feet per Minute).
Type : Reciprocating
Discharge Pressure : 13 kg/cm^2g (Max)

LPG Pumps

LPG pumps will take liquid LPG from bottom of mounded bullet through suction and deliver it to TLF Sheds for filling in LPG road tankers

LPG Vapor Compressors

One No. LPG vapor compressor have been provided for unloading of sick LPG road tankers.

Air compressor & Air Drying Unit

Two Nos. screw type Air compressors have been provided for supply of compressed air for plant requirement at a pressure of 5-6kg/cm^2. Two nos. of air drying units have been considered of 340 Nm^3/ hr. capacity each. The refrigerated type air drying unit will have 8 kg/cm^2 outlet pressure.

Dry compressed air will be used as instrument air for remote operated valves etc. The air compressor and air drying unit has been considered at a sufficient distance from LPG handling facilities.

4.3 PRELIMINARY HAZARD ANALYSIS

MULT handles LPG, which is highly inflammable and explosive. The hazards involved in the plant are:

- Fire and explosion in storage area due to damage of the pipeline connected with the bulk storage vessels.
- Over turning of LPG road tankers and other transport hazard.
- Flash/Jet fire due to leakage of LPG from LPG transfer pipeline
- Equipment failure/malfunction like relief valve failure, flange gasket failure, pump mechanical seal failure etc. resulting in leakage of LPG to atmosphere.
- Lack of adequate fire protection facilities available at different places of LPG unloading and usage.
- Leakage in LPG transfer line from ship to LPG terminal

Apart from the above, accidents due to operational mistakes, negligence and sabotage are also not ruled out.

4.4 CREDIBLE SCENARIOS

LPG import terminal of M/s IOCL at Kochi mainly poses fire and explosion hazards due to unwanted and accidental release of hydrocarbons. This section deals with listing of various failure cases leading to various hazard scenarios, analysis of failure modes and consequence analysis.

Temperature of the atmospheric air normally decreases with increase in height. The rate of decrease of temperature with height is known as the Lapse Rate. It varies from time to time and place to place. The atmosphere is said to be stable, neutral or unstable according to the lapse rate is less than, equal or greater than dry adiabatic lapse rate i.e. 1^{O}C per 100 metres.

Pasquill has defined six stability classes ranging from A to F

A = Extremely unstable
B = Moderately unstable
C = Slightly unstable
D = Neutral
E = Stable
F = Highly stable

The mode of approach adopted for consequence analysis is to first select the failure cases and then to conduct the consequence analysis of the selected failure cases. The failure cases selected are listed in Table - 4.1.

Table - 4.1: Selected Failure Cases

S. No.	Failure Case	Failure Mode	Consequence
1.	Full bore / 20% CSA failure of LPG outlet line of Mounded Bullets.	Random failure	Dispersion, unconfined vapor cloud explosion, blast effect
2.	LPG Filling pump discharge line full bore failure.	Random failure	Dispersion, unconfined vapor cloud explosion, blast effect
3.	Road tanker failure	Random failure	Dispersion, unconfined vapor cloud explosion, blast effect,
4.	LPG pump mechanical seal failure.	Mechanical seal failure	Dispersion, UVCE
5.	LPG Pump Outlet Line Gasket failure.	Gasket failure	Dispersion, UVCE
6.	Loading Arm Failure.	Random failure	Dispersion, UVCE
7.	Safety valve failure.	Random failure	Dispersion, UVCE
8.	Full Bore Failure of LPG Transfer Line	Random failure	Dispersion, unconfined vapor cloud explosion, blast effect
9.	20% CSA failure of LPG Transfer Line	Random failure	Dispersion, unconfined vapor cloud explosion, blast effect

S. No.	Failure Case	Failure Mode	Consequence
10.	5mm dia hole in LPG transfer line after 1 km from the Jetty	Random failure	Jet fire & explosion
11.	10mm dia hole in LPG transfer line after 1km from the Jetty	Random failure	Jet fire & explosion
12.	15mm dia hole in LPG transfer line after 1km from the Jetty	Random failure	Jet fire & explosion
13.	5mm dia hole in LPG transfer line after 2km from the Jetty	Random failure	Jet fire & explosion
14.	10mm dia hole in LPG transfer line after 2km from the Jetty	Random failure	Jet fire & explosion
15.	15mm dia hole in LPG transfer line after 2km from the Jetty	Random failure	Jet fire & explosion
16.	5mm dia hole in LPG transfer line after 2.5km from the Jetty	Random failure	Jet fire & explosion
17.	10mm dia hole in LPG transfer line after 2.5km from the Jetty	Random failure	Jet fire & explosion
18.	15mm dia hole in LPG transfer line after 2.5km from the Jetty	Random failure	Jet fire & explosion

4.5 CONSEQUENCE ANALYSIS

- **Full Bore/20% CSA Failure of the LPG Outlet Line of Mounded Bullet**

The Mounded Bullets have been provided with a single 300 mm inlet/outlet line. In case, full bore / 20% CSA failure of the outlet line inside the dyke, LPG shall flow out from the Mounded Bullets and spill on the concrete floor provided with a dyke and having a slope leading to a sump and finally to the drain to avoid accumulation of LPG near the vessels. The spillage of the LPG in the liquid form will be short lived as it will gather heat from the atmosphere and the hard substratum and flash in copious translucent vapors. The outflow of LPG will depend on the section of pipeline/vessel that can be isolated from any continues source of LPG, and the holdup between two such ends..Excess flow check valve is provided on the outlet line which will check the flow of LPG. ROV is also provided on the outlet line. If the excess flow check valve fails, LPG shall flow out and in that case ROV is to be closed to avoid larger losses. If the failure is beyond the dyke wall LPG will spill on the ground. However, the failure frequency of full bore and 20% CSA failure of the 300 mm dia. pipeline are 0.03 x 10^{-6} m/year and 1.0 x 10^{-7}/m/year respectively which indicate that chances of such failures are very remote. The consequence of 1 minute spill of LPG due to guillotine / 20% CSA failure outside the dyke may be the following:

- The spill liquid shall evaporate forming vapor cloud which may disperse safely beyond its lower flammability limit (LFL) in the direction of the wind, if not found any ignition source between its upper and lower flammability limits.
- The dispersing vapor cloud may come in contact with an ignition source between its flammability limits. In that event flash fire shall occur and unconfined vapor cloud explosion shall result. Any thing coming within the fire zone shall be severely affected.

In the event of the spilled liquid not catching fire, simultaneous evaporation and spreading on the ground without any physical obstruction of the spill shall occur. The results are given in Table-4.2. The rate of release is taken as 147 kg/sec. The evaporating cloud may disperse safely to LFL value of LPG and it does not come in contact with any ignition source between its flammability limits. The hazard distance to LFL value of LPG has been calculated for various wind speed and stability class of 2B, 3D, 5D (Day) and 2F, 3D, 5D (Night) condition.

Table - 4.2: Maximum hazard distance to LFL of LPG for failure of bullet outlet line

S. No.	Wind Speed (m/sec)	Stability Class (Day/Night)	Distances (meters) (Day/Night)
CASE-I: Full bore failure of Bullet outlet line			
01.	2	B/F	295/307
02.	3	D/D	321/317
03.	5	D/D	323/319
CASE-II: 20% CSA failure of Bullet outlet line			
01.	2	B/F	127/169
02.	3	D/D	139/139
03.	5	D/D	136/135

**references*

A-	*Extremely Unstable*
B-	*Moderately Unstable*
C-	*Slightly Unstable*
D-	*Neutral*
E-	*Stable*
F-	*Highly Stable*

It is evident from the Table-4.2, that the LFL distances can go upto a maximum distance of 323 m in case of bullet outlet line FB failure. In case of 20% CSA failure of Bullet outlet line, the LFL distances may extends upto 169 m respectively. This shows that in case of such failures, LPG vapor may go outside the battery limit..

If the evaporating vapor cloud comes in contact with an ignition source between its flammability ranges, the unconfined vapor cloud explosion shall result. The hazard distances for over pressures of 0.3 bar, 0.1 bar and 0.03 bar are given in Table-4.3.

Table - 4.3: Hazard distances to overpressure due to UVCE for bullet outlet line F.B. / 20% CSA failure

S. No.	Wind Speed m/sec.	Stability Class (Day/ Night)	Max. Distances (m) to overpressure of					
			0.3 Bar		0.1 Bar		0.03 Bar	
			D	N	D	N	D	N
CASE-I: Full bore failure of Bullet outlet line								
01.	2	B/F	341	331	412	413	602	631
02.	3	D/D	389	370	458	441	643	629
03.	5	D/D	451	449	511	509	674	669
CASE-II: 20% CSA failure of Bullet outlet line								
01.	2	B/F	205	208	240	236	335	311
02.	3	D/D	223	223	255	256	343	345
03.	5	D/D	268	267	296	297	371	374

**references*

A- Extremely Unstable	*D*	*Day*
B- Moderately Unstable	*N*	*Night*
C- Slightly Unstable		
D- Neutral		
E- Stable		
F- Highly Stable		

It can be observed from Table-4.3, the maximum distances to 0.3 bar overpressure (heavy damage) may extends upto 451 m and 268 m in the case of full bore/ 20% CSA failure of Bullet outlet line failure respectively, which may go outside the battery limit.

LPG import terminal will also be provided with sufficient nos. of LPG Detectors which will detect the LPG leakage at 20% LFL concentration and will provide alarm to Fire Water Pump House and control room. During operation period, the LPG loading pump can be stopped after getting alarm before reaching the LPG concentration up to LFL concentration level and the remote operated valve on the bullet outlet line can also be closed. So, in normal operating condition, even in case of full bore rupture of the pipeline, very small quantity of LPG which is contained in the pipeline will come out. Thus, the LFL distances will not go beyond the plant premises and no chances of ignition. Even after ignition, the effect of explosion will be limited within the plant premises.

- **LPG Filling Pump Discharge Line Failure**

The LPG pump takes liquid from the Mounded Bullet by suction and pumps it to the TLF shed for filling the tank lorries. The details of the pumps are as follows:

No. of pumps	:	08
Type of pump	:	Centrifugal
Capacity	:	90 TPH
Suction pressure	:	6-8 Kg/cm^{2}g
Discharge pressure	:	14.0 Kg/cm^{2}g (max)
Operating temperature	:	20 - 45^{O}C
LPG pump discharge line size	:	200 mm dia

In case of LPG pump discharge line failure, a portion of the spilling liquid shall flash off and the remaining liquid shall fall and spread on the ground unrestricted if no dyke wall is provided.

Following scenario has been envisaged for consequence analysis.

- The evaporating vapor cloud may come in contact with an ignition source between its flammability limits resulting in flash fire and unconfined vapor cloud explosion.

This scenario envisages that the dispersing vapor cloud comes in contact with an ignition source resulting in Unconfined Vapor Cloud Expansion (UVCE). The hazard distances to over pressures of 0.3 bar, 0.1 bar, 0.03 bar are presented in Table-4.4 for wind speed 2B, 3D & 5D (day condition) and 2F, 3D & 5D (night condition).

Table - 4.4: Hazard distances to overpressure due to UVCE

Sl. No.	Wind Speed m/sec. (D/N)	Stability Class (D/N)	Max. distances (m) to overpressure of						LFL (m)	
			0.3 bar		0.1 bar		0.03 bar			
			D	N	D	N	D	N	D	N
01.	2/2	B/F	285	298	351	367	526	550	253	268
02.	3/3	D/D	351	322	412	385	575	552	279	268
03.	5/5	D/D	461	410	503	460	614	593	280	262

*references

A- Extremely Unstable	*D*	*Day*
B- Moderately Unstable	*N*	*Night*
C- Slightly Unstable		
D- Neutral		
E- Stable		
F- Highly Stable		

It is evident from Table-4.4, that the maximum distance to heavy damage i.e. for over pressure of 0.3 bar extends upto a maximum distance of 461 m for full bore failure of Pump discharge line. This may extend beyond the battery limits of the premises, however full bore rupture for the pump discharge line is non-credible in nature. The distance to LFL extends upto 280 m.

Due to presence of LPG leak detectors at several places (which detect LPG at 20% LFL concentration) pumps can be stopped immediately on hearing the sound of alarm.

- **Road Tanker Failure**

LPG shall be dispatched by Road Tankers. LPG is loaded to the tankers by LPG loading pump. Provisions are there to load 16 nos. of Tankers at a time in two separate TLF sheds. Pressure inside the Tankers shall be about 5-8 Kg/Cm^2 corresponding to ambient temperature.

For consequence analysis purpose, Road Tanker of 16 MT capacity has been considered. As the Tank Lorries come under pressurized vessels category its failure frequency is very low i.e. $1.0x10^{-6}$ per year. Risk assessment covers the consequences of the Road Tankers only while they are inside the battery limit of the terminal. Individual risk of the Tanker may not be different in quality than the mounded bullets while inside the terminal. A secondary consequence of BLEVE has been considered for Road Tankers which might be possible in the improbable case of a tanker engulfed in primary fire in the terminal. In the event of heat received by the tankers e.g. by flame impingement or from fire in the vicinity, the liquid inside the tanker shall start boiling and the pressure inside the tank shall start building up. If the safety valve provided in the tanker does not work properly or if it has not been designed properly, the phenomenon of BLEVE may occur. The vessel shall rupture and the immediate ignition of the expanding fuel/air mixture leads to intense combustion resulting in fire balls. The BLEVE analysis of road tankers of 16 MT capacity has also been done.

The fire ball details, hazard distances to thermal radiation and distances to over pressures are given in the Tables- 4.5 to 4.6.

Table - 4.5: Fire ball details due to BLEVE in road tankers

S. No.	Items	Capacity of Road Tanker
01.	LPG contained in the tanker Kg	16000
02.	Fire ball radius (m)	73
03.	Duration of fire ball, sec.	11

Table - 4.6: Thermal radiation due to BLEVE in road tankers

S. No.	Thermal Radiation KW/m^2	Distances (m) to Thermal Load (Day/Night)
01.	37.5	128/127
02.	12.5	227/233
03.	4.5	366/376

**references*

A- Extremely Unstable	*D*	*Day*
B- Moderately Unstable	*N*	*Night*
C- Slightly Unstable		
D- Neutral		
E- Stable		
F- Highly Stable		

It can be deduced from Tables 4.5 to 4.6, that the distance to heavy damage (0.3bar) extends upto 127 m for BLEVE in 16 MT road tanker which goes outside the battery limit. It is also seen that the LFL distance may extend upto 117 meters for road tanker having capacity of 16 MT. Hence extreme care should be taken to avoid any type of fire in the vicinity of the loading bays and so, the loading bays are provided with sprinkler system.

- **LPG Pump Mechanical Seal Failure**

The frequency of failure of mechanical seal of centrifugal pumps, pumping liquid from the mounded bullet to the road tanker is quite high and poses risk due to formation of vapor cloud. Failure of mechanical seals releases considerable quantity of hydrocarbons into atmosphere and creates a hazardous zone. Present thinking is to adopt double mechanical seal especially for light hydrocarbon services like naphtha, LPG etc. This helps in reducing their frequency of hydrocarbon releases to atmosphere but still contribute to a great extent to the overall risk of the terminal. However, the type of seal, single or double, does not affect their release rate or the hazard distances. Hazard distances have been calculated for the LPG pump mechanical seal failure. A shaft diameter of 40 mm and a seal gap of 1 mm have been assumed for release rate calculation. 3 minute's LPG release has been considered. The spilled LPG will disperse and may result in:

a) Dispersion
b) UVCE

The hazard distances with respect to the dispersion and UVCE are given in Tables - 4.7 and 4.8.

Table- 4.7: Hazard distances to LFL concentration of LPG pump mechanical seal failure

S. No.	Wind Speed m/sec.	Stability Class (Day/Night)	Maximum Distance to LFL (m) (Day/Night)
01.	2	B/F	33/34
02.	3	D/D	32/32
03.	5	D/D	32/30

**references*

A- Extremely Unstable

B-	*Moderately Unstable*
C-	*Slightly Unstable*
D-	*Neutral*
E-	*Stable*
F-	*Highly Stable*

From the Table-4.7 it is seen that the LFL concentration distance shall extend upto 34 m in case of 2F condition which remains within the factory premises. It may create a hazardous situation if a source of ignition is found within this distance.

Table - 4.8: Hazard distances to overpressure due to UVCE for LPG pump mechanical seal failure

S. No.	Wind Speed m/sec.	Stability Class (Day/ Night)	Max. distances (m) to overpressure of					
			0.3 bar		0.1 bar		0.03 bar	
			D	N	D	N	D	N
01.	2	B/F	67	78	75	87	94	109
02.	3	D/D	76	76	83	83	99	99
03.	5	D/D	76	77	82	83	99	101

**references*

A-	*Extremely Unstable*	*D*	*Day*
B-	*Moderately Unstable*	*N*	*Night*
C-	*Slightly Unstable*		
D-	*Neutral*		
E-	*Stable*		
F-	*Highly Stable*		

It is seen from Table-4.8, that the hazard distance to an overpressure of 0.1 bar (repairable damage) may extend upto 87 m under condition of 2F but the effect will be limited within factory boundary limit. It is desirable to provide LPG leak detection system for Pump House to take immediate necessary action in case of failure of mechanical seal.

- **LPG Pump Outlet Line Gasket Failure**

Gasket failure of pump, pumping liquid from the mounded bullet to the road tanker is one of the foreseeable scenarios, which is considered here. Gasket failure of flange joint may be full gasket failure or partial failure. Experience shows that gasket failures are mostly partial and segment between two bolt holes mainly fails. This is true for spiral wound metallic gasket normally used in such services. Use of CAF gasket may be discouraged as full segment rupture may be possible. The released LPG may cause jet fire or UVCE in following scenario:

- Evaporation, vapor cloud formation and safe dispersion beyond its LFL.
- UVCE, if the vapor cloud finds a source of ignition between its flammability limits.
- Jet fire, if the released hydrocarbon forms a jet and finds a ignition source within its flammability limits.

Hazard distances for partial failure of 200 mm gaskets have been calculated and are presented in the Table - 4.9 to 4.11.

Table - 4.9: Hazard distances to thermal radiation due to Jet fire for gasket failure

S. No.	Thermal Load KW/m^2	Distance (m) from centre of the liquid pool (Day/Night)		
		2B/2F	**3D/3D**	**5D/5D**
01.	37.5	76/76	70/70	64/63
02.	12.5	89/88	82/82	75/74
03.	4.5	102/102	96/95	88/88

**references*

2B	*Wind speed: 2m/s*	*A-*	*Extremely Unstable*
	Stability class B	*B-*	*Moderately Unstable*
2F	*Wind speed: 2m/s*	*C-*	*Slightly Unstable*
	Stability class F	*D-*	*Neutral*
3D	*Wind speed: 3m/s*	*E-*	*Stable*
	Stability class D	*F-*	*Highly Stable*
5D	*Wind speed: 5m/s*		
	Stability class D		

The 1st degree burn i.e. Radiation level of 4.5 KW/m^2 for partial failure of 200 mm gasket may extend upto 102 m. The jet may impinge any pipeline or equipment, which may fall within its distances in the direction of the flame. The domino effect of such impingement may be very severe and may cause failure of other adjacent equipment/pipeline.

Table - 4.10: Hazard distance to LFL concentration of LPG for gasket failure

Wind Speed m/sec	Stability Class(Day/Night)	LFL Distance (m) (Day/Night)
2	B/F	65/71
3	D/D	68/57
5	D/D	64/56

Reference

A-	*Extremely Unstable*
B-	*Moderately Unstable*
C-	*Slightly Unstable*
D-	*Neutral*
E-	*Stable*
F-	*Highly Stable*

The hazard distance with respect to LFL concentration of LPG remains within 71 meter from the source of leakage and shall be confined to the factory premises only.

Table - 4.11: Hazard distances to overpressure due to UVCE for gasket failure

S. No.	Wind Speed m/sec.	Stability Class (Day/ Night)	Max. distances (m) to overpressure of					
			0.3 bar		0.1 bar		0.03 bar	
			D	N	D	N	D	N
01.	2	B/F	135	145	149	167	188	217
02.	3	D/D	145	143	160	155	200	190
03.	5	D/D	143	142	156	154	191	187

**references*

A-	*Extremely Unstable*	*D*	*Day*
B-	*Moderately Unstable*	*N*	*Night*
C-	*Slightly Unstable*		
D-	*Neutral*		
E-	*Stable*		
F-	*Highly Stable*		

It is seen from Table-4.11, that heavy damage is 0.3 bar for partial failure of 200 mm gasket in pump discharge line may extend upto 145 m.

Present available data of flange gasket failure rate is about $0.5x10^{-6}$ per running hour which is considered as high rate of frequency. The consequence due to gasket failure may be considered as foreseeable or credible. Automatic gas detector/heat detector and automatic water sprinkler system have been considered to mitigate the hazard. The LPG leak detector detects leakage at 20% of LFL concentration and provides alarm at control room & fire pump house. Pumps can be stopped immediately on hearing the sound of alarm. Since, LFL distances are well within the plant premises, chances of ignition and consequent effects can be ruled out.

- **Road Tanker Loading Arm Failure**

LPG shall be loaded to road tankers through loading arm. Excess Flow check valves are provided on road tankers side. The road tankers are generally of capacity 6 MT to 18 MT. Loading arm failure is a non credible phenomena and its failure frequency is 3×10^{-8}/hr of operation which is very low. When pressurized, LPG is released and a fraction of the liquid flashes off. The flashed off vapors shall carry along with it tiny droplets of liquid which will be vaporized when it comes in contact with the warm surrounding air. The remaining liquid shall fall on the ground and evaporate due to heat from the substrate. However, the road tankers outlet line is provided with excess flow valve and in case of snapping of the loading arm this excess flow valve shall operate and stop the spillage of LPG. If this check valve also fails, then isolation valves on road tanker side as well as in the liquid outlet line side are to be closed. Consequence of 3 minutes spill has been considered in case of failure of road tanker loading arm.

Hazard distances with respect to the following have been calculated.

- Lower Flammability Limit of LPG in case of safe dispersion and
- Overpressures in case of UVCE.

The results are given in the Table- 4.12.

Table - 4.12: Hazard distance to overpressure & LFL distances due to UVCE for failure of road tanker loading arm failure

S. No.	Wind Speed m/sec.	Stability Class (Day/ Night)	Max. distances (m) to overpressure of						LFL (m) (Day/Night)
			0.3 bar		0.1 bar		0.03 bar		
			D	N	D	N	D	N	
01.	2	B/F	135	150	151	170	192	224	68/74
02.	3	D/D	146	143	162	156	204	191	72/61
03.	5	D/D	144	144	158	158	196	196	68/69

references

A- Extremely Unstable	*D*	*Day*
B- Moderately Unstable	*N*	*Night*
C- Slightly Unstable		
D- Neutral		
E- Stable		
F- Highly Stable		

The hazard distance under the stable weather condition of 2F for 0.1 bar overpressure (repairable damage) shall extend up to a distance of 170 meters which goes outside the factory premises.

➢ **MOUNDED BULLET SAFETY VALVE RELEASE**

Each Mounded Bullet is provided with two nos. of safety valves and set to release pressure 19.25 kg/cm^{2}g. In case of release of LPG through safety valve it will be discharged at a height of 8 m in the case of Bullets and will be dispersed in the direction of wind.

LFL distances due to dispersion at 100% opening of the safety valve under wind velocity & stability class of 2B, 3D & 5D (Day) and 2F, 3D & 5D (Night) conditions have been calculated and presented in Table-4.13.

Table - 4.13:100% opening of safety valve (mounded bullet)

LFL Distance (m) (Day/ Night)		
2B/2F	3D/3D	5D/5D
4/5	5/5	6/6

references

2B	*Wind speed: 2m/s*	*A- Extremely Unstable*
	Stability class B	*B- Moderately Unstable*
2F	*Wind speed: 2m/s*	*C- Slightly Unstable*
	Stability class F	*D- Neutral*
3D	*Wind speed: 3m/s*	*E- Stable*
	Stability class D	*F- Highly Stable*

5D	*Wind speed: 5m/s*
	Stability class D

It is evident from Table-4.13, that LFL concentration of LPG due to release from safety valves may extend upto 6 m in case of safety valve failure of Mounded Bullets, which is confined within the factory premises.

- **Full Bore/20% CSA Failure of the LPG Transfer Line**

A 20" dia. LPG transfer pipeline shall be provided for transfer of LPG from proposed jetty to LPG Terminal. The jetty will be constructed by M/s Cochin Port Trust. The length of transfer line will be approximately 2.8 km. In case, full bore / 20% CSA failure of the proposed line, LPG shall flow out from the line and shall spill on the ground and may cause UVCE. However, the failure frequency of full bore and 20% CSA failure of the 300 mm diameter pipeline are 0.03 x 10^{-6}/m/year and 1.0 x 10^{-7}/m/year respectively which indicate that chances of such failures are very remote. The consequence of 3 minutes spill of LPG due to guillotine / 20% CSA failure may be the following:

- The spilled liquid shall evaporate forming vapor cloud which may disperse safely beyond its lower flammability limit (LFL) in the direction of the wind, if not found any ignition source between its upper and lower flammability limits.
- The dispersing vapor cloud may come in contact with an ignition source between its flammability limits. In that event flash fire shall occur and unconfined vapor cloud explosion shall result. Any thing coming within the fire zone shall be severely affected.
-

The hazard distances for the above mentioned cases are given in Table-4.14. The evaporating cloud may disperse safely to LFL value of LPG if it does not come in contact with any ignition source. The hazard distance to LFL value of LPG has been calculated for various wind speed and stability class of 2B, 3D, 5D

(Day) and 2F, 3D, 5D (Night) conditions. The results are summarized in Table-4.15.

Table - 4.14: Maximum hazard distance to LFL of LPG for Failure of LPG transfer line

S. No.	Wind Speed (m/sec)	Stability Class (Day/Night)	Distances (meters) (Day/Night)
CASE-I: Full bore failure			
01.	2	B/F	267/285
02.	3	D/D	289/286
03.	5	D/D	288/285
CASE-II: 20% CSA failure			
01.	2	B/F	127/130
02.	3	D/D	140/119
03.	5	D/D	140/125

Reference

A-	*Extremely Unstable*
B-	*Moderately Unstable*
C-	*Slightly Unstable*
D-	*Neutral*
E-	*Stable*
F-	*Highly Stable*

It is evident from the Table-4.14 that the LFL distances go upto a maximum distance of 289 m & 140 m in Case-I & Case-II respectively. However, such cases are incredible in nature.

If the evaporating vapor cloud comes in contact with an ignition source between its flammability ranges, the unconfined vapor cloud explosion shall result. The hazard distances for over pressures of 0.3 bar, 0.1 bar and 0.03 bar are given in Table-4.15.

Table - 4.15: Hazard distances to overpressure due to UVCE for LPG transfer line F.B.

S. No.	Wind Speed m/sec.	Stability Class (Day/Night)	Max. Distances (m) to overpressure of					
			0.3 Bar		0.1 Bar		0.03 Bar	
			D	N	D	N	D	N
CASE-I: Full bore failure								
01.	2	B/F	494	416	568	512	766	770
02.	3	D/D	549	548	619	617	806	801

S. No.	Wind Speed m/sec.	Stability Class (Day/Night)	Max. Distances (m) to overpressure of					
			0.3 Bar		0.1 Bar		0.03 Bar	
			D	N	D	N	D	N
03.	5	D/D	550	549	609	607	770	765
CASE-II: 20% CSA failure								
01.	2	B/F	225	252	260	294	354	406
02.	3	D/D	256	246	292	271	389	340
03.	5	D/D	251	245	281	269	364	335

**references*

A- Extremely Unstable	*D*	*Day*
B- Moderately Unstable	*N*	*Night*
C- Slightly Unstable		
D- Neutral		
E- Stable		
F- Highly Stable		

It can be observed from Table-4.15, that the maximum distances to 0.3 bar overpressure (heavy damage) may extend upto 550 m and 256 m in the case of full bore/ 20% CSA failure of Transfer line respectively. However, the scenario is incredible in nature.

- **Holes in LPG Pipeline at a distance of 1km from the Jetty**

Three cases have been taken viz. creation of 5mm, 10mm & 15mm dia. hole. The failure frequency for 5mm and 10mm dia. hole is 3.8 X 10^{-7} per meter/yr and same for 15mm dia. hole is 1.0 X 10^{-7} per meter/yr. 10 minutes of release rate have been considered for evaluation of effect/damage distance. The details are given in Tables-4.16 to 4.18.

Table - 4.16: Hazard distances to thermal radiation due to jet fire

S. No.	Thermal Load KW/m^2	Distance (m)		
		2B	3D	5D
CASE-I: 5mm dia. hole 1km from the Jetty; Release Rate = 0.4Kg/sec.				
01.	37.5	NR	NR	NR
02.	12.5	25	23	21
03.	4.5	29	27	25

CASE-II: 10mm dia. hole 1km from the Jetty; Release Rate = 1.61Kg/sec.				
01.	37.5	NR	NR	NR
02.	12.5	46	43	39
03.	4.5	53	50	46
CASE-III: 15mm dia. hole 1km from the Jetty; Release Rate = 3.63Kg/sec.				
01.	37.5	NR	NR	NR
02.	12.5	66	61	55
03.	4.5	76	71	65

*references

2B	Wind speed: 2m/s	A-	Extremely Unstable
	Stability class B	B-	Moderately Unstable
2F	Wind speed: 2m/s	C-	Slightly Unstable
	Stability class F	D-	Neutral
3D	Wind speed: 3m/s	E-	Stable
	Stability class D	F-	Highly Stable
5D	Wind speed: 5m/s		
	Stability class D		

It is evident from Table-4.16, that the hazard distances for 12.5 KW/m^2 in Case-I, Case-II and Case-III may extend maximum upto a distance of 25 m, 46 m and 66 m respectively.

Table - 4.17: Maximum hazard distance to LFL of LPG

S. No.	Wind Speed (m/sec)	Stability Class (Day/Night)	Distances (meters)
CASE-I: 5mm dia. hole 1km from the Jetty; Release Rate = 0.4Kg/sec.			
01.	2	B	15
02.	3	D	15
03.	5	D	15
CASE-II: 10mm dia. hole 1km from the Jetty; Release Rate = 1.61Kg/sec.			
01.	2	B	28
02.	3	D	34
03.	5	D	31
CASE-III: 15mm dia. hole 1km from the Jetty; Release Rate = 3.63Kg/sec.			
01.	2	B	54
02.	3	D	56
03.	5	D	53

Reference

A-	*Extremely Unstable*
B-	*Moderately Unstable*
C-	*Slightly Unstable*
D-	*Neutral*
E-	*Stable*
F-	*Highly Stable*

It is evident from Table-4.17 that the LFL distances go upto a maximum distance of 15 m, 34 m and 56 m in Case-I, Case-II & Case-III respectively.

Table - 4.18: Hazard distances to overpressure due to UVCE

S. No.	Wind Speed m/sec.	Stability Class (Day/Night)	Max. Distances (m) to overpressure of		
			0.3 Bar	0.1 Bar	0.03 Bar
CASE-I: 5mm dia. hole 1km from the Jetty; Release Rate = 0.40Kg/sec.					
01.	2	B	12	14	19
02.	3	D	32	34	40
03.	5	D	12	14	20
CASE-II: 10mm dia. hole 1km from the Jetty; Release Rate = 1.61Kg/sec.					
01.	2	B	55	59	71
02.	3	D	67	75	94
03.	5	D	66	72	89
CASE-III: 15mm dia. hole 1km from the Jetty; Release Rate = 3.63Kg/sec.					
01.	2	B	94	108	145
02.	3	D	103	116	150
03.	5	D	100	111	138

Reference

A-	*Extremely Unstable*
B-	*Moderately Unstable*
C-	*Slightly Unstable*
D-	*Neutral*
E-	*Stable*
F-	*Highly Stable*

It is also evident from the Table-4.18, that the maximum distances to 0.3 bar overpressure (heavy damage) for Case-I, Case-II and Case-III may extends upto 32 m, 67 m and 103 m respectively.

- **Holes in LPG Pipeline at a distance of 2km from the Jetty**

Three cases have been taken viz. creation of 5mm, 10mm & 15mm dia. hole. The failure frequency for 5mm & 10mm dia. hole is 3.8 X 10-7 per meter/yr and same for 15mm dia. hole is 1.0 X 10-7 per meter/yr.10 minutes of release rate have been considered for evaluation of effect/damage distance. The details are given in Tables-4.19 to 4.21.

Table - 4.19: Hazard distances to thermal radiation due to jet fire

S. No.	Thermal Load KW/m^2	Distance (m)		
		2B	3D	5D
CASE-I: 5mm dia hole 2km from the Jetty; Release Rate = 0.38Kg/sec.				
01.	37.5	NR	NR	NR
02.	12.5	24	22	20
03.	4.5	28	26	24
CASE-II: 10mm dia hole 2km from the Jetty; Release Rate = 1.49Kg/sec.				
01.	37.5	NR	NR	NR
02.	12.5	45	41	37
03.	4.5	51	48	44
CASE-III: 15mm dia hole 2km from the Jetty; Release Rate = 3.34Kg/sec.				
01.	37.5	NR	NR	NR
02.	12.5	64	59	53
03.	4.5	74	68	63

**references*

2B	*Wind speed: 2m/s*	*A- Extremely Unstable*
	Stability class B	*B- Moderately Unstable*
2F	*Wind speed: 2m/s*	*C- Slightly Unstable*
	Stability class F	*D- Neutral*
3D	*Wind speed: 3m/s*	*E- Stable*
	Stability class D	*F- Highly Stable*
5D	*Wind speed: 5m/s*	
	Stability class D	

It is evident from the Table-4.19 that the hazard distances for 12.5 KW/m^2 in Case-I, Case-II & Case-III may extend maximum upto a distance of 24 m, 45 m and 64 m respectively.

Table - 4.20: Maximum hazard distance to LFL of LPG

S. No.	Wind Speed (m/sec)	Stability Class (Day/Night)	Distances (meters)
CASE-I: 5mm dia hole 2km from the Jetty; Release Rate = 0.38Kg/sec.			
01.	2	B	15
02.	3	D	15

S. No.	Wind Speed (m/sec)	Stability Class (Day/Night)	Distances (meters)
03.	5	D	14
CASE-II: 10mm dia hole 2km from the Jetty; Release Rate = 1.49Kg/sec.			
01.	2	B	27
02.	3	D	32
03.	5	D	30
CASE-III: 15mm dia hole 2km from the Jetty; Release Rate = 3.34Kg/sec.			
01.	2	B	52
02.	3	D	54
03.	5	D	51

Reference

A- Extremely Unstable
B- Moderately Unstable
C- Slightly Unstable
D- Neutral
E- Stable
F- Highly Stable

It is evident from Table-4.20 that the LFL distances go upto a maximum distance of 15 m, 32 m and 54 m in Case-I, Case-II and Case-III respectively.

Table - 4.21: Hazard distances to overpressure due to UVCE

S. No.	Wind Speed m/sec.	Stability Class (Day/ Night)	Max. Distances (m) to overpressure		
			0.3 Bar	0.1 Bar	0.03 Bar
CASE-I: 5mm dia hole 2km from the Jetty; Release Rate = 0.38Kg/sec.					
01.	2	B	11	13	18
02.	3	D	32	34	40
03.	5	D	12	14	19
CASE-II: 10mm dia hole 2km from the Jetty; Release Rate = 1.49Kg/sec.					
01.	2	B	56	62	79
02.	3	D	67	74	92
03.	5	D	66	72	87
CASE-III: 15mm dia hole 2km from the Jetty; Release Rate = 3.34Kg/sec.					
01.	2	B	93	107	141
02.	3	D	103	116	151
03.	5	D	95	100	132

Reference

A- Extremely Unstable

B-	*Moderately Unstable*
C-	*Slightly Unstable*
D-	*Neutral*
E-	*Stable*
F-	*Highly Stable*

It is also evident from Table-4.21 that the maximum distances to 0.3 bar overpressure (heavy damage) for Case-I, Case-II & Case-III may extend upto 32 m, 67 m and 103 m in the respectively.

- **Holes in LPG Pipeline at a distance of 2.5km from the Jetty**

Three cases have been taken viz. creation of 5mm, 10mm & 15mm dia hole. The failure frequency for 5mm & 10mm dia hole is 3.8 X 10^{-7} per meter/yr and same for 15mm dia hole is 1.0 X 10^{-7} per meter/yr.10 minutes of release rate have been considered for evaluation of effect/damage distance. The details are given in Tables-4.22 to 4.24.

Table - 4.22: Hazard distances to thermal radiation due to jet fire

S. No.	Thermal Load KW/m²	Distance (m) from centre of the liquid pool		
		2B	3D	5D
CASE-I: 5mm dia hole 2.5km from the Jetty; Release Rate = 0.36Kg/sec.				
01.	37.5	NR	NR	NR
02.	12.5	24	22	20
03.	4.5	28	26	24
CASE-II: 10mm dia hole 2.5km from the Jetty; Release Rate = 1.40Kg/sec.				
01.	37.5	NR	NR	NR
02.	12.5	44	40	36
03.	4.5	50	47	43
CASE-III: 15mm dia hole 2.5km from the Jetty; Release Rate = 3.19Kg/sec.				
01.	37.5	NR	NR	NR
02.	12.5	63	58	52
03.	4.5	72	67	62

**references*

2B	*Wind speed: 2m/s*	*A-*	*Extremely Unstable*
	Stability class B	*B-*	*Moderately Unstable*
2F	*Wind speed: 2m/s*	*C-*	*Slightly Unstable*
	Stability class F	*D-*	*Neutral*
3D	*Wind speed: 3m/s*	*E-*	*Stable*
	Stability class D	*F-*	*Highly Stable*

5D	Wind speed: 5m/s
	Stability class D

It is evident from Table-4.22 that the hazard distances for 12.5 KW/m^2 in Case-I, Case-II and Case-III may extend maximum upto a distance of 24 m, 44 m and 63 m respectively.

Table - 4.23: Maximum hazard distance to LFL of LPG

S. No.	Wind Speed (m/sec)	Stability Class (Day/Night)	Distances (meters)
CASE-I: 5mm dia hole 2.5km from the Jetty; Release Rate = 0.36Kg/sec.			
01.	2	B	14
02.	3	D	14
03.	5	D	14
CASE-II: 10mm dia hole 2.5km from the Jetty; Release Rate = 1.40Kg/sec.			
01.	2	B	25
02.	3	D	31
03.	5	D	28
CASE-III: 15mm dia hole 2.5km from the Jetty; Release Rate = 3.19Kg/sec.			
01.	2	B	51
02.	3	D	53
03.	5	D	49

Reference

A-	*Extremely Unstable*
B-	*Moderately Unstable*
C-	*Slightly Unstable*
D-	*Neutral*
E-	*Stable*
F-	*Highly Stable*

It is evident from Table-4.23 that the LFL distances go upto a maximum distance of 14 m, 31 m and 53 m in Case-I, Case-II and Case-III respectively.

Table - 4.24: Hazard distances to overpressure due to UVCE

S. No.	Wind Speed m/sec.	Stability Class (Day/Night)	Max. Distances (m) to overpressure of		
			0.3 Bar	0.1 Bar	0.03 Bar
CASE-I: 5mm dia hole 2.5km from the Jetty; Release Rate = 0.36Kg/sec.					
01.	2	B	21	22	25
02.	3	D	21	22	25
03.	5	D	12	14	19

S. No.	Wind Speed m/sec.	Stability Class (Day/Night)	Max. Distances (m) to overpressure of		
			0.3 Bar	0.1 Bar	0.03 Bar
CASE-II: 10mm dia hole 2.5km from the Jetty; Release Rate = 1.40Kg/sec.					
01.	2	B	93	106	140
02.	3	D	103	116	152
03.	5	D	90	100	127
CASE-III: 15mm dia hole 2.5km from the Jetty; Release Rate = 3.19Kg/sec.					
01.	2	B	58	65	86
02.	3	D	66	73	90
03.	5	D	56	61	76

Reference

A-	*Extremely Unstable*
B-	*Moderately Unstable*
C-	*Slightly Unstable*
D-	*Neutral*
E-	*Stable*
F-	*Highly Stable*

It is also evident from Table-4.24 that the maximum distances to 0.3 bar overpressure (heavy damage) for Case-I, Case-II and Case-III may extend upto 21 m, 103 m and 66 m respectively.

CHAPTER – 5

CHAPTER – 5

RISK ANALYSIS FOR LNG REGASIFICATION PLANT NEAR VYPEEN ISLAND

5.1 GENERAL

The terminal will be designed for an initial send out capacity of 3 MMTPA. Subsequently, the facility will be upgraded to achieve the final capacity of 5 MMTPA. Boil-off gas (BOG) handling system, recondenser and all utilities system will be designed for 5 MMTPA at the initial stage itself while facilities such as in-tank pumps, HP send-out pumps, vaporization system, metering system, pipeline, and gas turbine are envisaged to be augmented in the future (Phase II) in order to achieve the increased capacity of 5 MMTPA.

LNG will be delivered to the terminal by LNG carriers with capacity ranging from 120,000m^3 to 165,000m^3. LNG will be then stored, regasified, and sent out via pipeline to consumers.

5.2 PROCESS DESCRIPTION

LNG is received by LNG carriers and unloaded to two storage tanks (with a third tank to be installed for phase II of 155,000 m^3 net capacity each. The storage tanks will be full containment type cryogenic LNG storage tanks constructed with an inner tank of 9% Ni and for the outer tank of pre-stressed concrete.

Boil-off gas (BOG) from the storage tanks is compressed in the BOG compressors and routed to the recondenser where the compressed gas is condensed in sub-cooled LNG.

Three in-tank pumps for each storage tank send LNG to the HP Send-out Pumps where the pressure is increased to 95 bar. This LNG then passes through the shell-and-tube vaporizers (STV) where glycol is used to vaporize the LNG. Submerged combustion vaporizers (SCV) are also provided as backup.
After vaporization, natural gas (NG) will be sent to the ultrasonic metering station before being sent to the gas pipeline. Natural Gas will be delivered at a pressure ranging from 50 (min) to 90 kg/cm^{2}g (max).

LNG from the LP transfer header is also used to recondense BOG in the recondenser, maintain the unloading line in cold condition and supply the truck loading bay.

5.3 HAZARDS FROM LNG

LNG is a non-toxic, non-corrosive and flammable substance. If LNG is accidentally released from a temperature-controlled container, it will likely contact warm surfaces and air that transfer heat into the liquid. The heat input begins to vaporise some of the liquid, returning the liquid to the gaseous phase. The relative proportions of liquid and gaseous phases immediately following a release depend on the release conditions. The liquid phase will form an LNG pool on the ground which will begin to "boil", due to heat input from the surrounding environment.

Immediately following vaporization, the gas is colder and heavier than the surrounding air and forms a dense vapour cloud. As the gas disperses, it mixes with the surrounding air and warms up, eventually becoming buoyant and lifting off. The vapour cloud will only ignite if it encounters an ignition source while concentration is within its flammability range.

5.4 HAZARD EFFECTS

In the event of an accidental release of LNG from piping or equipment, following hazards may occur just like the case with LPG.

- Pool Fire
- Jet Fire
- Flash Fire
- Vapour Cloud Explosion
- BLEVE
- Rapid Phase Transition (RPT)

When LNG is spilled onto water, such as the sea surface, the heat in the water can cause the LNG to vaporize rapidly. This rapid phase transition (RPT) can cause a physical explosion with overpressure that can cause damage to equipment and property, or injure persons in the vicinity.

However, studies indicate that when LNG is spilled onto water, the maximum mechanical explosion energy amounts to 37.75 kJ/kg. This produces 1,325 times less overpressure energy per unit mass than the combustion process. Given that ignition of unconfined methane does not produce significant overpressure, it may be concluded that overpressures from rapid phase transition (RPT) of LNG will not be significant either. This is further supported by incident records which have recorded at most broken windows in adjacent buildings. There have been no reported incidents of injury or fatality due to rapid phase transition (RPT) of LNG.

To explore this a little further, the maximum overpressure from a rapid phase transition (RPT) was estimated using the BST model. If it is assumed that the amount of LNG as a result of a 2 minutes spill from the unloading arm is 76.5 tons, the RPT overpressure is expected to be similar to the combustion of 76,500 /1325 = 577 kg of LNG. Based on BST model, the peak overpressure at the centre of explosion resulting from this mass has been estimated as 0.0077 barg or 7.7mbarg, assuming 3D flame expansion and low congestion and confinement.

For comparison, windows begin to break at about 2mbar, while 35mbar will shatter windows. An overpressure of 7.7mbar is therefore expected to cause only minor damage with some broken windows. Damage to equipment or heavy machinery in the jetty area is not foreseen. Fatality of jetty operators (who are mostly located outdoor) is also not expected with this low overpressure. rapid phase transition (RPT), is therefore not a significant hazard for QRA and is not considered further.

5.5. CONSEQUENCE ANALYSIS

Source term modelling was carried out using PHAST model to determine the maximum (i.e. initial) discharge rates and physical conditions of the released materials that may be expected should a loss of containment occur.

For LNG storage tanks, the analysis considered complete failure or catastrophic rupture of tank resulting in instantaneous release of entire contents.

5.5.1 Release Rate Calculation

For liquid filled systems such as HP send out pump discharge, once the pump is stopped or the ESDV closed, the pressure will fall immediately and any further release will be governed by gravity and system inventory. Gravity draining will result in a significantly lower release rate compared to that before isolation. Hence, for the purpose of calculating hazard distances, the worst case corresponds to conditions before isolation and hence this was used for the analysis.

For full bore failure of liquid piping systems, where the calculated discharge rate is higher than the normal flow rate (i.e. pumping rate), the release rate was capped at 1.3 times the pumping rate to account for the pump running at end-of-curve condition. It was further assumed that such a release would have minimal momentum, air entrainment and vaporisation and hence would form a liquid pool on the ground.

For gas releases, the system pressure will fall gradually upon isolation leading to time varying discharge rate. As a conservative assumption, the 'initial' release rate is used as a steady state release for the duration of release.

5.5.2 Release Duration

For releases from piping, two release durations were considered:

- 2 minute release (automatic shutdown on detection)
- 10 minute release (human intervention)

Due to the provision of detectors and an emergency shutdown system for the terminal, it is assumed that releases can be detected and the shutdown/ isolation can be initiated within about 2 minutes. Detection and shutdown may however, fail or may be delayed due to some reason. To account for this case, a 10 minute release scenario has also been considered in the analysis. This value corresponds to typical minimum time for human intervention. The inventory available for release is calculated from the section volume, plus the quantity supplied (or in other terms make-up) from the adjacent section during this 2 min or 10 min duration before isolation is realized. Although it is possible that operator intervention may take longer than 10 minutes or even fail in the worst case, release durations beyond 10 minutes were not considered in this study as this longer release time does not actually increase the maximum consequence distance which is being used in the risk analysis. The dispersion modelling indicated that most of the gas clouds quickly reach its maximum distance or steady state within 2 to 3 minutes from release. Apart from this, credit of isolation was not taken for scenarios which the source inventory is emptied before actuation of isolation.

For unloading arm failure, a shorter release time is assumed given the fact that the jetty area will be continuously manned during unloading operations. Operators can initiate emergency shutdown (in addition to activation by the fire and gas detection system) on noticing the leak and also detectors for excessive movement of the arms are provided which will initiate an automatic shutdown/isolation. Two release durations were thus considered:

• 30 seconds release
• 2 minutes release

Also, simultaneous failure of more than one unloading arm is not considered in the analysis. This is based on the fact that even for the case of common cause failures such as excessive movement or carrier drifting away, the probability of failure of emergency release coupling of more than one unloading arm is considered to be insignificant. The 2-minute release duration therefore represents the case of failure in isolating one unloading arm. Duration longer than 2 minutes is not considered realistic given that besides isolation of unloading arm, stopping the transfer pumps on the carrier can itself stop any further release.

The results of source term modeling are given in Table-5.1.

Table- 5.1: Results of source Term Modelling

Ref.	**Section**	**Leak size (mm)**	**Release rate (kg/s)**
LOI	LNG Unloading Arms	50	21.1
		100	84.4
		FB	828.7
L02	LNG Transfer Pipeline from jetty to Storage Tanks	50	21.1
		100	84.4
		FB	2,486
V03	Ship Vapour Return Arm	50	035
		100	1.40
		FB	9.63
V04	Vapour Return Header	50	0.35
		100	1.40
		FB	48.0

Ref.	Section	Leak size (mm)	Release rate (kg/s)
L05	Tanks T-0101/02/03 (for Ph II)	FB	\/A
L06	LP send out to Recondenser	50	32.3
		100	123
		FB	123
V07	BOG Compressor C-0101A/B suction including KOD and Drain Por	50	0.33
		100	1.31
		FB	33.0
V08	BOG Compressor C-0101A/B discharge to Recondenser including compressor	50	2.69
		100	4.63
		FB	4.63
L09	Recondenser V-0104 to HP pumps	50	25.7
		100	102
		FB	124
L10	HP Pumps P-0104A/B/C	50	106
		100	124
		FB	124
L11	STVs	50	61.8
		100	61.8
		FB	61.8
L12	SCV	50	61.8
		100	61.8
		FB	61.8
V13	Pipeline from vaporizers to meters	50	33.0
		100	124
		FB	124
V14 & V15	NG-meter to send out pipeline, pig launcher and generator	50	33.0
		100	124
		FB	124
L16	LNG Truck Loading line-6”	50	32.6
		100	123
		FB	123
L17	LNG Truck Loading Arm 3”	50	5.70
		100	5.70
		FB	5.67
V18	LNG Vapour Return Line (Truck loading)	50	0.35
		FB	0.80
L19	LNG recirculation Header-4”	50	11.3
		FB	61.8

Ref.	Section	Leak size (mm)	Release rate (kg/s)
L20	Tanker-28 m^3	50	11.3
		FB	Inst
V21	Air fuel gas heaters-NG meters to heater inlets	50	4.69
		FB	4.69
L22	Deleted	-	-
L23	Diesel oil tank T-0401	50	11.6
		FB	N/A
V24	LNG Vapour Return Arm (Truck loading)-3”	50	0.02
		FB	0.02

Note : FB - Full Bore Rupture
N/A – Not Applicable

CHAPTER – 6

CHAPTER – 6

RISK ANALYSIS STUDY CONDUCTED FOR INTERNATIONAL CONTAINER TRANSSHIPPMENT TERMINAL (ICTT)

6.1 INTRODUCTION

The International Container Transshippment Terminal **(**ICTT) is developed in the Greenfield site of 115 hectares at Vallarpadam. The ICTT is the first Port-based SEZ in India and is stated to become the largest container terminal operated by a single entity in India. The ICTT will put Cochin firmly on the international maritime map, thereby reducing India's dependence on foreign ports to handle its own hinterland cargo.

Geostrategically located on the main east-west global shipping trade lanes and offering a draft of 14.5 m, Cochin is designed to handle the largest container vessels afloat today. Thus, Cochin is destined to develop as the premier gateway for the Indian Peninsula. The ICTT Vallarpadam will be completed in 3 phases. The first phase with a capacity of one million TEUs had been commissioned in February, 2011. The ICTT is connected to the National Highway network by an 18 km new two lane road (four laning in progress) from Vallarpadam to Kalamassery and an 8 km electrified rail link from Edappally to Vallarpadam.

6.2 RISK ANLAYSIS

The cargo being handled are not hazardous in nature. Hence, risks, e.g., fire, explosion, toxic effects, etc. are not anticipated during various operations of International Container Transshipment Terminal (ICTT).

As a part of risk analysis, following operations were assessed:

- Container handling Jetty and Rail Head:
- Container Storage Yard

- Utilities – D.G. Sets, Transformers, Water Treatment Plant, Cooling Tower, Incinerator (proposed) and Sewage Treatment Plants (STPs)
- Maintenance Workshop and diesel storage
- Administration Building, Canteen, scrap storage area, other general / miscellaneous operations, First-aid centre, etc.

6.3 CONSEQUENCE ANLAYSIS

The consequence of above activities listed in section -6.2 are given in Table-6.1 to 6.5.

Table- 6.1: Risks due to Container handling Jetty and Rail Head

Risk	Activity	Aspect	Environmental Impact
Air Emissions	Use of trucks, Empty Container Handling (ECH) and Reach stackers for loading / unloading of containers	Generation of fuel combustion products	Air pollution due to release of fuel combustion products
Liquid Effluents	Domestic activities of personnel at jetty and rail head	Generation of domestic waste water	Water pollution
Solid Wastes	Use of lubricating oil on moving parts and hydraulic oil on spreader of the Quay Cranes (QC) and Rail Mounted Gantry Cranes (RMGCs) used for loading / unloading of containers	Cleaning of leaked oil using cotton cloth resulting in waste generation	Potential soil contamination
	Unloading / loading of containers	Generation of damaged container interlocks	Resource conservation if the locks are recycled appropriately
Hazardous wastes	Use of QCs and RMGCs for container handling	Generation of spent lubricating and hydraulic oil	
Noise or	Container unloading /	Generation of	Noise Pollution

Risk	Activity	Aspect	Environmental Impact
Vibration	loading operations	noise due to operation of QCs, RMGCs and trucks	
Energy and / or Resource Usage	Container unloading / loading operations	Use of electrical energy and fuel oil	Energy consumption
Emergency	Container unloading / loading	Dislodging of containers while handling	• Damage to human life • Resource wastage • Potential water pollution (depending on the material leaked from the container) • Potential air pollution (depending on the material leaked from the container)

Table- 6.2: Risks due to Container Storage Yard

Risk	Activity	Aspect	Environmental Impact
Air Emissions	Use of Rubber Tyred Gantry Cranes (RTGCs) for container handling at the storage yard	Generation of fuel combustion products from the DG sets of RTGCs	Air pollution due to release of fuel combustion products
	Use of trucks for	Generation of	Air pollution due to

Risk	Activity	Aspect	Environmental Impact
	storage of containers at the storage yard and transfer to jetty or out of the terminal	fuel combustion products from the trucks	release of fuel combustion products
	Handling of reefers	Accidental damage of reefers resulting in leakage of freon (refrigerant media)	Air pollution
Liquid Effluents	Handling of containers	Accidental damage of containers resulting in leakage of liquid chemicals in the containers	• Water pollution • Resource wastage • Potential air pollution if the leaked product evaporates
	Domestic activities of personnel at storage yard	Generation of domestic waste water	Water pollution
	Operations at the storage yard during monsoon season	Storm water management	Potential water pollution if the storm water is contaminated
Solid Wastes	Use of lubricating oil on moving parts and hydraulic oil on spreader of the RTGCs used for loading / unloading of	Cleaning of leaked oil using cotton cloth resulting in waste generation	Potential soil contamination

Risk	Activity	Aspect	Environmental Impact
	containers		
	Use of RTGCs for container handling	Generation of worn-out rubber tyres	• Resource conservation if the scrap dealer recycles the metal scrap
	Use of RTGCs for container handling	Generation of damaged components of the RTGCs	• Resource consumption • Potential water pollution if spent oil from the waste oil tank leaks out
Hazardous wastes	Use of RTGCs for container handling	Generation of spent lubricating and hydraulic oil	• Resource consumption • Potential water pollution if spent oil from the waste oil tank leaks out
Noise or Vibration	Container unloading / loading operations	Generation of noise due to operation of RTGCs and trucks at the storage yard	• Noise pollution
Emergency	Container unloading / loading	Dislodging of containers while handling	• Damage to human life • Resource wastage • Potential

Risk	Activity	Aspect	Environmental Impact
			water pollution (depending on the material leaked from the container) • Potential air pollution (depending on the material leaked from the container)

Table- 6.3: Risks due to Utilities – D.G. Sets, Transformers, Water Treatment Plant, Cooling Tower, Incinerator (proposed) and Sewage Treatment Plants (STPs)

Risk	Activity	Aspect	Environmental Impact
Air Emissions	Operation of D.G. sets	Use of fuel oil for combustion	• Air pollution due to generation of combustion products
	Operation of Incinerator	Use of fuel oil for combustion	• Air pollution due to generation of combustion products
Liquid Effluents	Operation of Pressure Sand Filter	Generation of backwash water	• Water Pollution
	Domestic activities of personnel at the facility	Generation of domestic waste water	• Water pollution
	Operation of proposed	Generation of cooling tower	• Water Pollution

Risk	Activity	Aspect	Environmental Impact
	Cooling Tower	blow down	
	Storage of cooling tower treatment chemicals such as corrosion and scale inhibitors, biocides, near the cooling tower	Spillage of cooling tower treatment chemicals	• Water Pollution • Potential soil pollution • Resource consumption
Solid Wastes	Operation of Pressure Sand Filter	Topping off fresh sand	Beneficial impact on soil quality if disposed off appropriately
	Use of lubricating oil in the system	Use of cotton cloth for cleaning up lube oil spillage	Potential land contamination
	Use of cooling tower treatment chemicals	Generation of empty drums / carboys of cooling tower chemicals	Resource conservation if the scrap dealers reuse the drums
	Operation of Incinerator	Generation of Incinerator ash	Potential land pollution
	Operation of STPs	Generation of sewage sludge	Land contamination / water pollution depending on disposal mode
Hazardous wastes	Operation of transformers	Generation of spent transformer oil	Potential land pollution

Risk	Activity	Aspect	Environmental Impact
		containing Poly Chlorinated Biphenyls (PCBs)	
	Use of lubricating oil in the system	Generation of spent lube oil	Potential resource conservation if third party recycles or reuses the spent oil
	Storage of cooling tower treatment chemicals	Washings from empty containers of cooling tower treatment chemicals	Water pollution Potential land contamination
Land contamination	Use of lubricating oil in the system	Generation of spent lube oil	Potential land contamination Potential resource conservation if third party recycles or reuses the spent oil
Noise or Vibration	Operation of D.G. sets, cooling tower and incinerator	Use of motors and pumps	• Noise pollution
Fugitive dust or odour	Operation of STPs	Prolonged hold-up of sewage in the system due to plant failure	• Odour
Emergency	Operation of D.G. sets	Major spillage of fuel oil from D.G. set day tank resulting in fire	• Water pollution from fire fighting operations • Potential air pollution due to fuel oil combustion

Risk	Activity	Aspect	Environmental Impact
			products
	Operation of cooling tower	Major spillage of cooling tower treatment chemicals	• Water pollution • Potential land contamination • Resource consumption
	Operation of STPs	Release of untreated septic sewage due to plant / equipment failure	• Water pollution
	Fire in transformers	Possible discharge of transformer oil on ground	• Soil and water contamination • Resource loss

Table- 6.4: Risks Due to Maintenance Workshop And Diesel Storage

Risk	Activity	Aspect	Environmental Impact
Liquid Effluents	Washing of vehicles in the apron	Generation of oil containing wash water	• Water pollution • Resource recovery
	Operation of Hydropress and Diesel Oil Filter	Generation of waste oil	• Water pollution • Resource recovery
Solid Wastes	Maintenance activities at the workshop	Generation of metal scrap from damaged equipment parts	• Resource conservation if the third party recycles the

Risk	Activity	Aspect	Environmental Impact
			metal scrap
	Use of lubricating oil in the system	Use of cotton cloth for cleaning up leaked oil	• Potential land contamination
	Maintenance and repair activities at the workshop	Generation of worn-out rubber tyres	• Resource conservation if the third party reuses the tyres • Potential air pollution if the tyres are burnt
Hazardous wastes	Maintenance activities at the workshop	Removal of spent oil from the RTGCs, RMGCs, QCs, trucks, etc.	• Resource conservation if the third party reuse the spent oil
	Operation of drill machine and lathe machine in the workshop	Generation of oil contaminated metal cuttings	• Potential land contamination
	Use of coolant	Generation of spent coolant	• Potential water pollution • Potential for resource conservation if spent coolant is recycled / reused in the system
Land	Washing of	Seepage of wash	• Potential land

Risk	Activity	Aspect	Environmental Impact
contamination	vehicles in the apron	water through cracks in the apron area ground surface	contamination due to oil in the wash water
	Storage of oil (in drums) outside the maintenance workshop	Spillage of fuel oil from the drums	• Resource wastage • Potential water pollution if the spilled oil gets into the storm water drain
Noise or Vibration	Maintenance activities at the workshop	Maintenance activities at the workshop	• Noise in the work environment
Fugitive dust or odour	Storage and handling of Diesel Oil	Leakage of Diesel Oil	• Odour
Emergency	Storage and handling of Diesel Oil	Major accidental leakage of diesel oil from the storage tank	• Water pollution due to release of oil into storm water drains Resource wastage

Table- 6.5: Risks Due To Administration Building, Canteen, Scrap Storage Area, Other General / Miscellaneous Operations, First-Aid Centre, Etc.

Risk	Activity	Aspect	Environmental Impact
Air Emissions	Material handling	Use of forklifts	Air emission of diesel combustion products
	Civil construction	Usage of diesel driven concrete	Air emission of diesel combustion products

Risk	Activity	Aspect	Environmental Impact
		mixers and other diesel driven equipment	
	Usage of motor vehicles in plant	Usage of petrol or diesel for the engines	Air emission of diesel and petrol combustion products
	Use of air conditioners in the building	Release of AC coolant media	Air pollution
Liquid Effluents	Surface run off	Discharges from open areas within the facility	Water pollution
	Domestic activities of personnel at the facility	Generation of domestic waste water	Water pollution
Solid Wastes	Mechanical, civil, electrical and other maintenance	Metal, wooden, plastic and other scrap generation	Potential resource conservation if reused appropriately
	Canteen waste	Municipal refuse consisting of bio-degradable wastes	Beneficial impact on soil quality if disposed off appropriately Air pollution
	First aid centre	Sharps and bandages	• Small quantity of bio-medical waste (although not controlled by law) have

Risk	Activity	Aspect	Environmental Impact
			potential to create adverse health effects
Hazardous Wastes	Construction activities	Empty drums of paints, thinners, etc.	• Potential for water pollution if the drums are not disposed off appropriately
Land Contamination	Gardening	Usage of pesticides	• Potential soil and water contamination if used in excessive quantity
Noise or Vibration	Civil construction and related activities	Material handling and other related construction activities	• Noise within the premises
	Usage of motor vehicles in the facility	Engine operation	• Noise in ambient environment
Visual Impact	Scrap yard	Haphazard storage of various different kind of materials	• Adverse visual impact
Energy and / or Resource Usage	Usage of energy, food materials, construction materials, water, etc.	Usage of resources and energy	• Resources and energy consumption
Emergency	Fire	Fire in facility	• Potential loss of life and

Risk	Activity	Aspect	Environmental Impact
			property • Water pollution

CHAPTER – 7

CHAPTER – 7

RISK ANALYSIS STUDY FOR MULTI-USER LIQUID TERMINAL (MULT) AT PUTHUVYPEEN

7.1 INTRODUCTION

There are two major components of the proposed composite LPG unloading facility at MULT which attract siting applicability:

- LPG unloading platform and marine structure(s) in proximity of a LNG Jetty/storage
- LPG conveyance pipeline

7.2 METHODOLOGY ADOPTED

The risk assessment has been carried out in the following phases:

Hazard Identification

- Collection of relevant information on terminal, marine unloading arms and other facilities of port.
- Study of vulnerable operations in simultaneous handling and transport of LPG from different tankers/vessels at the existing Cochin Port and proposed MULT project.
- Past accident data analysis.
- Expected outcome: identification of hazard prone operations/units.

Hazard assessment and Evaluation

- Critical examination of hazard prone operations with an emphasis on quantification of hazard and its evaluation
- Consequence analysis of identified failure scenarios

Disaster Management Plan

Disaster Management Plan (DMP) has been prepared to minimize damage to existing facilities of Cochin Port Trust and surroundings.

7.3 HAZARD IDENTIFICATION

The hazardous Cargo being handled at the proposed port include POL and LPG. These liquid products are flammable, therefore, fire is one type of hazards due to handling of these at jetty. The liquid gas to be handled under pressurized and/or cryogenic conditions is LPG. Therefore any amount leaked will immediately form vapour cloud because their boiling point is much lower than ambient temperature. This vapour cloud may cause fire and explosion and hence can cause fire and explosion hazards.

Failure of unloading arm and consequent spillage may result into fire hazards but leakage of chemicals such as benzene, toluene, oxthoxylene and paraxylene will not only result in fire hazards but also in toxic hazards. The checklist of hazards as a result of handling of hazardous cargo at the proposed terminal is given in Table-7.1.

Table- 7.1 : Checklist Of Hazards Involved Due To Handling Of Various Cargo

Hazard Material	Possible Hazards			
	Fire	Explosion	Toxicity to Marine Environment	Toxicity To Human
LPG	Yes	Yes	No	No
POL	Yes	No	Yes	No

7.4 PAST ACCIDENT DATA ANALYSIS

The study of past accident data helps in identification of likely hazards for the installation under study. In the present case past failure data analysis for the following types of incidents is of relevance.

- Ship collision
- Ship grounding
- Leakage through pipeline
- Leakage through valves (emergency shut down valves)
- Berthing contact
- Leakage and spillage through excess flow check valves and flanges
- Leakage during loading/discharging

The above mentioned all failure cases will result into spillage of LPG/ pressurized liquefied gas and POL into sea or ground. The data collected for number of spills world wide from various sources in terms of quantities has been presented in Table-7.2. The data is based on various spillages occurred world wide during the period 1974-85. It is clear from this data that majority of spills were in less than 7 tonnes quantity and maximum occurrence was during loading/discharging operations.

Table- 7.2 : World Oil Spills In Numbers From Tankers (1974-1985) Resulting From Routine Operations And Major Accidents

Operation	**Quantity of Spillage Tonnes**			
	<7.0	**7- 700**	**>700**	**Total**
Loading/Discharge	2236	227	II	2474
Bunkering	442	22	-	464
Collision	39	134	54	7/ -- I
Grounding	69	134	70	273
Total	2786	517	135	3438

Source: International Tanker Owners Pollution Federation
- indicates data not available

The details of breakdown of the operations which was in progress when the oil spill occurred are given in Table-7.3. It is clear from Table-7.3 that majority of spills have occurred during discharging operations. The reasons given for these spills are summarized in Table 7.4.

Table-7.3: Percentage Wise Spill During Various Operations

Operation	Spillage %
Loading	24.4
Discharging	36.7
Bunkering	14.4
Ballasting/Deballasting	15.6
Others	8.9

Source: International Tanker Owners Pollution Federation

Table- 7.4 : Reasons For Oil Spillages

Operation	Spillage %
Equipment Failure	34.4
Human Error	46.0
Hull Failure or Defect	8.8
Errors not acceptable	3.6
Shore Fault	1.4
Other and not known	5.8

Source: International Tanker Owners Pollution Federation

The equipment failure and human error are the major reasons for spill hence these aspects need to accorded the top most priority while formulation and implementation of safety practices and Emergency Preparedness Plan. The equipment failures can also be divided into the major causes such as defective pipeline, hose pipe failure, leaking valve etc. The equipment failure data is given in Table-7.5.

Table- 7.5: Details of Equipment Failures

Reason	%
Defective Pipeline	10
Hose Failure	9
Loading Arm Failure	9

Reason	%
Open Valve	5
Leaking Valve	64
Manifold Failure	3

Source: International Tanker Owners Pollution Federation

This data shows valves are more vulnerable than any other equipment. This data reveals that adoption of proper procedures and increased level of responsibility of supervisors can easily help in controlling the number/quantum of oil spills.

7.5 ESTIMATION OF FAILURE FREQUENCY

The failure of unloading arm has been considered as credible accident situation. The failure rate for this primary event has been taken from similar failure frequency for unloading arm and assumed value is 4×10^{-4} $year^{-1}$. The detailed analysis of failure frequency for liquified gases (LPG) is given below:

1) Probability of Liquified gas release from unloading arm = 0.50

Probability of immediate ignition (within 30 seconds, which may be sufficient for flammable moisture to be formed) = 0.70

Frequency of pool fire = $4 \times 10^{-4} \times 0.50 \times 0.70$ per year

= 1.4×10^{-4} $year^{-1}$

$$\text{FAR (Fatality Accident Rate)} = \frac{1}{1 \times 1.4 \times 10^{-4} \times 1} = 7142 \text{ years}$$

Possibility of fire/leak is once in 7142 years.

2) Delayed Ignition

Probability of delayed ignition = 0.2

Wind directional probability = 0.0625 (Assuming equal likely

		chances of wind in all directions at time of spillage/leakage)
Vapour cloud explosion probability	=	0.50
Frequency of vapour cloud explosion	=	$4 \times 10^{-4} \times 0.2 \times 0.0625$
	=	7.5×10^{-6} year^{-1}
Flash fire probability	=	0.50
Frequency of jet fire occurrence	=	$4 \times 10^{-4} \times 0.3 \times 0.0625$
	=	7.5×10^{-6} (in all direction)

3) <u>Safe Dispersion</u>

Probability of no ignition	=	0.10
Wind direction probability	=	0.0625
Safe dispersion	=	$4 \times 10^{-4} \times 0.1 \times 0.0625 = 2.5 \times 10^{-6}$

7.6 VESSEL ACCIDENT

From the literature, probability of various events such as ship collision, ship grounding and ship berthing has been collected. The data collected here is from Port of London Authority. This data has been referred in many international studies for spillage/leakage. Following are the failure frequencies for ship collision, ship grounding, ship berthing and spillage during collision, grounding and berthing contact.

- Ship collision probability per transit = 0.5×10^{-4}
- Ship grounding probability per transit = 0.3×10^{-4}
- Ship berthing contact probability per transit = 1.5×10^{-4}
- Probability of spillage during collision = 2.0×10^{-2}
- Probability of spillage during grounding = 2.0×10^{-2}
- Probability of spillage during berthing contact = 1.0 x 10-4
- Total probability of spillage due to ship collision = 1×10^{-6}
- Total probability of spillage due to ship grounding = 0.6×10^{-6}

- Total probability of spillage due to berthing contact = 1.5×10^{-6}

The failure frequency for leakage/spillage at port is given in Table-7.6.

Table-7.6: Failure Frequency For Leakage/Spillage At Port

S. No.	Incident	Frequency (per Year)
A.	**UNLOADING ARM**	
1.	Unloading arm failure; (immediate	
	ignition of LPG vapour cloud)	1.4×10^{-4}
2.	Unloading arm failure; (Delayed	
	ignition LPG vapour cloud explosion)	7.5×10^{-6}
3.	Unloading arm failure; (LPG vapour	
	cloud flash fire)	7.5×10^{-6}
4.	Unloading arm failure; (safe dispersion	
	of LPG vapour cloud)	2.5×10^{-6}
B.	**VESSEL ACCIDENTS**	
1.	Total probability of spillage due to ship collision	1.0×10^{-6}
2.	Total probability of spillage due to ship grounding	0.6×10^{-6}
3.	Total probability of spillage due to berthing contact	1.5×10^{-6}

Note: Calculation based on failure data of Port of London Authority

7.7 PROPERTIES OF LPG

LPG is a mixture of commercial propane and commercial butane, which may also contain small quantity of unsaturated hydrocarbons. LPG marketed in India is governed by IS 4576 and test methods by IS-1448.

LPG being highly inflammable may cause fire and explosion. It, therefore, calls for special attention during its handling.

Physical properties

a) Density

LPG at atmospheric pressure and temperature is a gas, which is 1.5 to 2.0 times heavier than air. It is easily liquefied under moderate pressure. The density of liquid is approximately half that of water and ranges from 0.525 to 0.58 kg/l.

Since LPG vapour is heavier than air, it normally settles down at ground level/low lying areas. This accumulation of LPG vapour gives rise to potential fire and explosion.

b) Vapour Pressure

The pressure inside a LPG storage vessel is corresponding to the temperature in the storage vessel. This vapour pressure is dependent on temperature as well as the percentage composition of the mixture of hydrocarbons present in LPG. Beyond liquid full condition in cylinders / storage vessels any further expansion of the liquid will increase the cylinder / storage vessel pressure by 7-8 kg/Cm^2 for each degree centigrade rise in temperature. This clearly indicates the hazardous situation, which may arise due to overfilling of cylinders or any storage vessel.

c) Flammability

LPG has an explosive limit range of 1.8% to 9.5% by volume of the gas in air. This is considerably narrower than other common gaseous fuel.

d) Auto-ignition temperature

The auto-ignition temperature of LPG is around $410^{O}C$-$548^{O}C$ and will not ignite on its own at normal temperature.

e) **Combustion**

Combustion of LPG increases the volume of products in addition to generation of heat. LPG requires about 24 to 30 times its own volume of air for complete combustion and yields 3-4 times of its own volume of CO_2. The heat of combustion is about 10,900 Kcal/kg.

f) **Colour**

LPG is colourless both in liquid and vapour phase. During leakage, vapourisation of LPG cools the atmosphere and condenses the water vapour contained in it forming a white fog. This makes possible to see an escape of LPG.

g) **Viscosity**

LPG has a low viscosity (around 0.3 CS at 45^{O}C) and can leak when other petroleum products cannot. This property demands a high degree of integrity in the pressurized systems handling LPG to avoid leakage.

h) **Odour**

LPG has a very faint smell and as such for detecting leakage of LPG (in domestic gas cylinders), ethyl mercaptan is generally added in the ratio approx. 1 Kg of mercaptan per 100 ft3 of liquid LPG (20 ppm).

i) **Toxicity**

LPG is slightly toxic. Although it is not poisonous in vapour phase, it suffocates when present in large concentrations due to displacement of oxygen. IDLH value of LPG is generally taken as 19000 ppm.

The saturation vapour pressure, flammability range, toxicity data of Propane-Butane mixtures as well as pure compounds are listed in Table-7.7.

Table- 7.7: Various Properties Of LPG

Propane %	Butane %	S.V.Press at 55^{O}C, Kg/Cm^{2}	Flammability range %	Toxicity IDLH (ppm)	Odour Threshold (ppm)
100	-	21.12	2.1 - 9.5	20,000	5,000
20	80	7.31	1.8 - 9.5	N/A	N/A
30	70	8.25	1.8 - 9.5	N/A	N/A
-	100	5.84	1.9 - 8.4	N/A	N/A

The physical properties of LPG taken into consideration in preparation of this report in the Risk Analysis are given as below:

<u>Physical properties of LPG</u>

Formula	C_3-C_4 mixture
Molecular weight	51.10 Kg/Kmol
Boiling temperature at 1 bar	(-) 21.2^{o}C
Critical temperature	124.5^{o}C
Critical pressure	40.00 Bar
o Density (liquid) at 30^{o}C	528.1 KG/M^{3}
Density at boiling temperature	588.9 KG/M^{3}
o Density (gas) at 1 bar and 30^{o}C	2.03 KG/M^{3}
At boiling temperature	2.44 KG/M^{3}
o Heat capacity (liquid) at 30^{o}C	2654 J/Kg/K
At boiling temperature	2286 J/Kg/K
o Heat capacity (gas) at 30^{o}C	1686 J/Kg/K
o Heat of vaporization at 30^{o}C	33.93 x 10^{4} J/Kg
At boiling Temperature	40.00 x 10^{4} J/Kg

- o Vapour pressure at 30^{O}C — 6.76 bar
- o Ratio of spec. heats (cp/cv) — 1.11
- o Dyn. viscosity (gas) at 30^{O}C — 8.36 x 10^{-6} PA.S
  - At boiling temperature — 7.08 x 10^{-6} PA.S
- o Dyn. viscosity (liquid) at 30^{O}C — 8.62 x 10^{-5} PA.S
  - At boiling temperature — 1.56 x 10^{-4} PA.S
- o Surface tension at 30^{O}C — 6.41 x 10^{-3} N/M
  - At boiling temperature — 1.8 x 10^{-2} N/M
- o Thermal conductivity (gas) at 30^{O}C — 1.86 x 10^{-2} W/M/K
  - At boiling temperature — 0.00 W/M/K
- o Thermal conductivity (liq) at 30^{O}C — 9.20 x 10^{-2} W/M/K
  - At boiling temperature — 12.17 x 10^{-2} W/M/K
- o Heat of combustion — 45.94 x 10^{6} J/Kg
- o Stochiometric ratio — 0.036 M^3/M^3
- o Explosion limit — Lower — 0.020 M^3/M^3
  - Upper — 0.090 M^3/M^3
- o Reactivity — Medium explosive

7.8 CONSEQUENCE ANALYSIS

Consequence analysis considers individual failure cases and damages caused by them. It is done to predict the potentially possible consequences on man and material in and around installation battery limit. It is carried out on a variety of preconceived accidental scenarios.

The results of consequence analysis provide sufficient information about hazard effects from an accident scenario and also on how to deal with catastrophic events. It gives installation personnel and public living around an understanding of risk they are living in.

Approach to the Consequence Analysis

The consequence analysis will generate information to consider major change in jetty layout to control any accident effectively. LPG and POL are flammable in nature and pose fire and explosion hazards. On finalization of credible scenarios, the likely spillage quantities for the credible accidental scenario and the worst case accidental scenario were subjected to consequence analysis.

Methodology for Consequences Analysis

The methodology adopted in study for thermal radiation, vapour cloud dispersion, fire ball burning and overpressure calculation is summarized in the following paragraphs:

Thermal Radiation

The thermal radiation calculation is based on Thomas correlation as modified by Moorhouse. In computing fire radiation intensity at different distances effect of smoke cover has not been taken into account to estimate thermal radiation intensity at source.

Vapour Cloud Dispersion

The vapour cloud dispersion or dispersion of vapours of various materials to be handled at port site has been computed using the equations proposed by TNO. It may be mentioned that for vapour cloud dispersion the concept of virtual source has been used.

Overpressure Calculations

The distances of occurrence of tolerable overpressure of various objects have been computed using TNT deflagration equivalent model.

Fireball Burning

If a flammable vapour cloud ignites but fails to explode, it forms a fire ball. This is of short duration and only harms people and ignites emergency vents or pools of flammable liquids. The correlations proposed by TNO for fireball durations, fire ball diameter and for thermal radiation intensity at different distances have been used.

Effects of Release

The hazardous materials on escape to atmosphere lead to formation of a vapour cloud in the air. Direct cloud formation occurs when a gaseous or flashing liquid escapes to atmosphere. Indirect cloud formation occurs through evaporating pools of liquids which have come to rest on ground.

In the event of release of hydrocarbon products to be handled at port to atmosphere, the following effects will usually be observed:

a. Spreading of hydrocarbon vapour with wind till it finds a source of ignition or safely disperses.
b. Pool fire of a spillage mainly causing different levels of incident thermal radiation.
c. Unconfined Vapour Cloud Explosion (UVCE) which generates damaging blast wave.
d. Fireball or BLEVE (Boiling Liquid Expanding Vapour Explosion) due to burning of vapour cloud.

Damage Criteria

The damage effects are different for different scenarios mentioned above. In order to appreciate the damage effects produced by various scenarios, it will be appropriate to discuss the physiological/physical effects of hydrocarbon vapours, blast wave, thermal radiation or BLEVE and toxic release.

a) Hydrocarbon vapour released accidentally will normally spread out in the direction of wind. If, it finds an ignition source before being dispersed below Lower Flammability Limit (LFL), a flash fire is likely to occur and the flame may travel back to source of leak. Any person caught in the flash fire is likely to suffer fatal burn injury. Therefore, in consequence analysis, the distance of LFL value is usually taken to indicate the area which may be affected by flash fire. Any other combustible materials within flash fire are also likely to catch fire and secondary fire may ensue. In the area close to source of leak there is a possibility of oxygen depletion. For human lives, a minimum of 16% oxygen in air is considered essential.

b) Thermal radiation due to pool fire, jet flame or fireball may cause various degrees of burn on human bodies. Moreover, their effects on inanimate objects like equipment, piping or vegetation also need to be evaluated to assess the impact. The damage effect due to thermal radiation intensity is summarized in Table-7.8. In case of jet flames, effect of direct impingement is severe as it may cut through equipment, pipeline or structure.

c) When a pressurized liquified gas is subjected to external fire, the metal temperature rises so much that it may fail at the operating pressure itself. With metal failure, the entire content of the vessel is released to atmosphere. The liquid starts boiling and expands violently. Huge vapour cloud is formed almost instantaneously. Because of high degree of turbulence, a lot of air is drawn in and the vapour cloud that is formed is quickly diluted within flammable range. Immediately, following rupture of the vessel the body of this expanding boiling liquid is likely to be ignited by the fire that initiated the failure; since the core of the body is still too rich, the fire remains limited to the periphery, the rate of burning is usually controlled by the rate at which the air is drawn.

d) For transient fires like fire ball, the steady state heat flux cannot be used to estimate the damage for such incident. In this case the dosage of thermal radiation (i.e. total incident energy) is used to estimate threshold damage levels. Thermal radiation dose is a combination of incident radiation intensity and time of exposure. The dose and damage effect due to various thermal dose levels is given in Table-7.9. The tolerable thermal radiation for various time exposures to human body has been given in Table-7.10. For a continuous thermal radiation intensity (specially resulting from pool fires) the tolerable thermal radiation intensities have been given in Table-7.11. The LFL and UFL concentration of all materials handled at site are given in Table-7.12.

Table- 7.8 : Damage Due To Incident Radiation Intensity

Incident Radiation Intensity (kw/m^2)	**Type of Damage**
62.0	Spontaneous ignition of wood
37.5	Damage to process equipment. 100% lethality in 1min. 1% lethality in 10sec
25	Minimum energy to ignite wood at indefinitely long exposure without a flame. 100 % lethality in 1 min. Significant injury in 10sec.
12.5	Minimum energy to ignite wood with a flame; melts plastic tubing. 1% lethality in 1min. 1st degree burns in 10 sec.
4.5	Sufficient to cause pain to personnel who is not able to reach cover within 20 seconds; however blistering of skin (1st degree burns) is likely.
1.6	Causes no discomfort for long exposure

Source : Guidelines for Chemical Process Quantitative Risk Analysis, Centre for Chemical Process Safety, American Institute of Chemical Engineers, New York

Table-7.9: Physiological effect of threshold thermal Doses

Dose Threshold	Unit	Effect
375	KJ/m^2	3rd degree burns
250	KJ /m^2	2nd degree burns
100	KJ /m^2	1st degree burns
2nd Degree Burn	Involve whole of epidermis over the area of the burn plus some portion of dermis area of the burn.	
3rd Degree Burn	Involve whole of epidermis and dermis. Subcutaneous tissues may also be damaged	

Source: Guidelines for Chemical Process Quantitative Risk Analysis, Centre for Chemical Process Safety, American Institute of Chemical Engineers, New York

Table-7.10: Tolerance Thermal Radiation For Various Time Exposures To Human Body

Radiation Intensity	Tolerance time(seconds)
BTUlhr/ft^2	
440 (2.39 kW/m^2)	60
550 (1.6 kW/m^2)	40
740 (2.333 kw/m^2)	30
920 (2.9 kW/m^2)	19
1500 (4.7 kW/m^2)	9
2200 (6.93 kW/m^2)	6
3000 (9.5 kW/m^2)	5
3700 (11.66 kW/m^2)	4
6300 (19.9 kw/m^2)	2

Source : Guidelines for Chemical Process Quantitative "Risk Analysis, Centre for Chemical Process Safety, American Institute of Chemical Engineers, New York

Table-7.11: Tolerable Intensities Of Various Objects

Object	Tolerable Intensity (kW/m^2)
Drenched Tank	38
Special Buildings (No Windows, Fire Proof 000\ s)	25
Normal Buildings	14

Object	Tolerable Intensity (kW/m^2)
Vegetation	10-12
Escape Route	6 (upto 30 seconds)
Personnel in Emergencies	3 (upto 30 seconds)
Plastic Cables	2 .
Stationery Personnel	1.5

Source : Mecklenburgh, J.G., "Process Plant Layout", George Godwin, London

Table- 7.12: Threshold Limit, LFL And UFL Concentration Of LPG

Unit	Concentration(ppm)
LFL	18000
UFL	95000

e) In the event of an explosion taking place within tank farm due to hydrocarbon and air mixing and catching fire, the resultant blast wave have damaging effects. The tanks, buildings structures etc. can only tolerate low level of over-pressure. Human body, by comparison, can withstand higher overpressure. But injury of fatality can be inflicted by collapse of buildings or structures. The blast peak overpressure is a transient one and the equivalent static pressure will vary depending on material of construction and other factors. The damaging effects of blast overpressures are listed in Table-7.13.

Table- 7.13: Tolerable Overpressure Intensities Of Various Objects

Object	Tolerable Overpressure (Bar)
High concentration of people e.g. School Hospitals	0.02
Domestic Housings	0.04
Public roads	0.05
Ordinary plant buildings	0.07
Buildings with shatter resistant windows, fired roof tanks containing highly flammable or toxic Materials	0.10
Floating roof tanks, other fixed roof tanks, cooling towns, utility areas, site roads	0.20
Plant with large atmospheric pressure vessels or units having large superficial area	0.30
Other Hazardous Plants	0.40
Non Hazardous (if occupied) plants, control rooms designed for blast resistance	0.70

Source : Mecklenburgh, J.G., "Process Plant Layout", Godwin London.

7.9 SCENARIOS IDENTIFIED FOR COSEQUENCE ANALYSIS FOR LPG

Following scenarios of escape or loss of containment of LPG have been identified on the range of activities involved in the handling, transfer on the jetty, pipeline transfer over a pipe rack/sleeper pipeline inside a service trench, and storage in mounded bullets. The various scenarios considered for consequence Analysis is given in Table-7.14.

Table -7.14: Consequence Analysis Scenarios

S. No.	Material	Activity/Event	Worst Case Loss Scenario	Maximum Credible Loss Scenario
1.	LPG	Loss of containment during ship to unloading arm on the jetty	**WC01:** Full bore rupture of 4" pipeline unloading LPG, instantaneous	**MS01:** 1.5 cm dia rupture or equivalent area gasket failure on the unloading

S. No.	Material	Activity/Event	Worst Case Loss Scenario	Maximum Credible Loss Scenario
			loss of containment, immediately meeting with a source of ignition	arm, gradual loss of containment, immediately meeting with a source of ignition
		Loss of containment during pipeline transfer of LPG	**WC02:** Full bore rupture of 4”, 1.5 km pipeline carrying LPG to the LPG bullet in the tankfarm, instantaneous loss of containment, immediately meeting with a source of ignition	**MS02:** 1 cm dia rupture or equivalent area gasket failure on the pipeline gradual loss of containment, immediately meeting with a source of ignition
		Loss of containment in the 350 kl LPG partially mounded bullet	**- -**	**MS03:** 5 cm dia rupture on the bottom bullet, rapid loss of containment, immediately meeting with a source of ignition

Consequence Threat Distances

- **WC01 – Flash Fire**

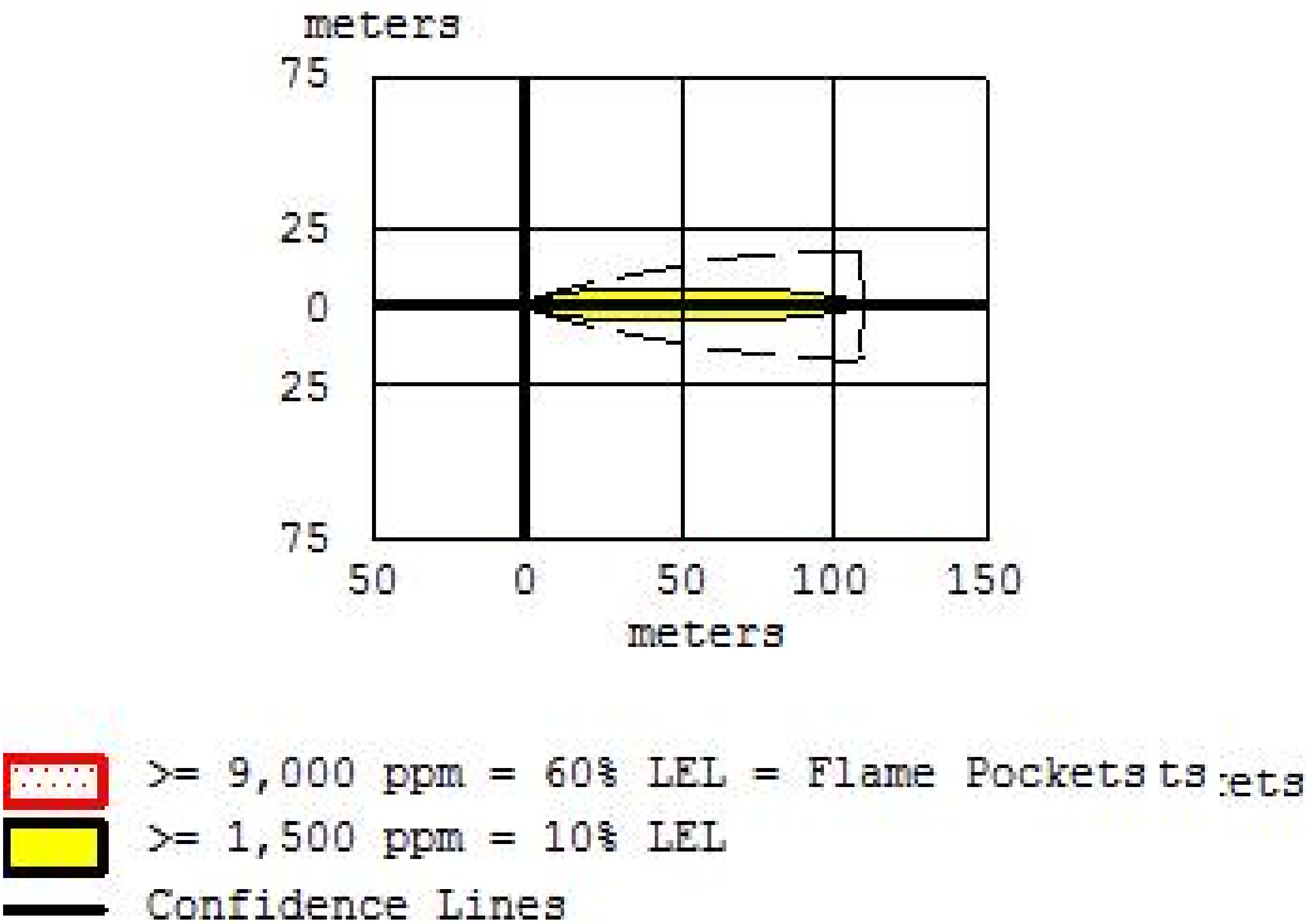
Threat Modeled: Flammable Area of Vapor Cloud

Model Run: Heavy Gas

Red : 35 meters --- (9,000 ppm = 60% LEL = Flame Pockets)

Note: Threat zone was not drawn because effects of near-field patchiness make dispersion predictions less reliable for short distances

Yellow: 110 meters --- (1,500 ppm = 10% LEL)



Note: *"Confidence line" in a consequence analysis footprint drawing means the threat zone within which the threat exists with 95% probability, taking into account uncertainties in terms of wind speed and direction*

- **MS01 – Flash Fire**

Same as WC01 as the quantity of material lost is too small to account for graduation of release.

- **WC02 – Explosion**

Threat Modeled: Overpressure (blast force) from vapor cloud explosion

Time of Ignition: 10 seconds after release begins

Type of Ignition: ignited by spark or flame

Level of Congestion: congested

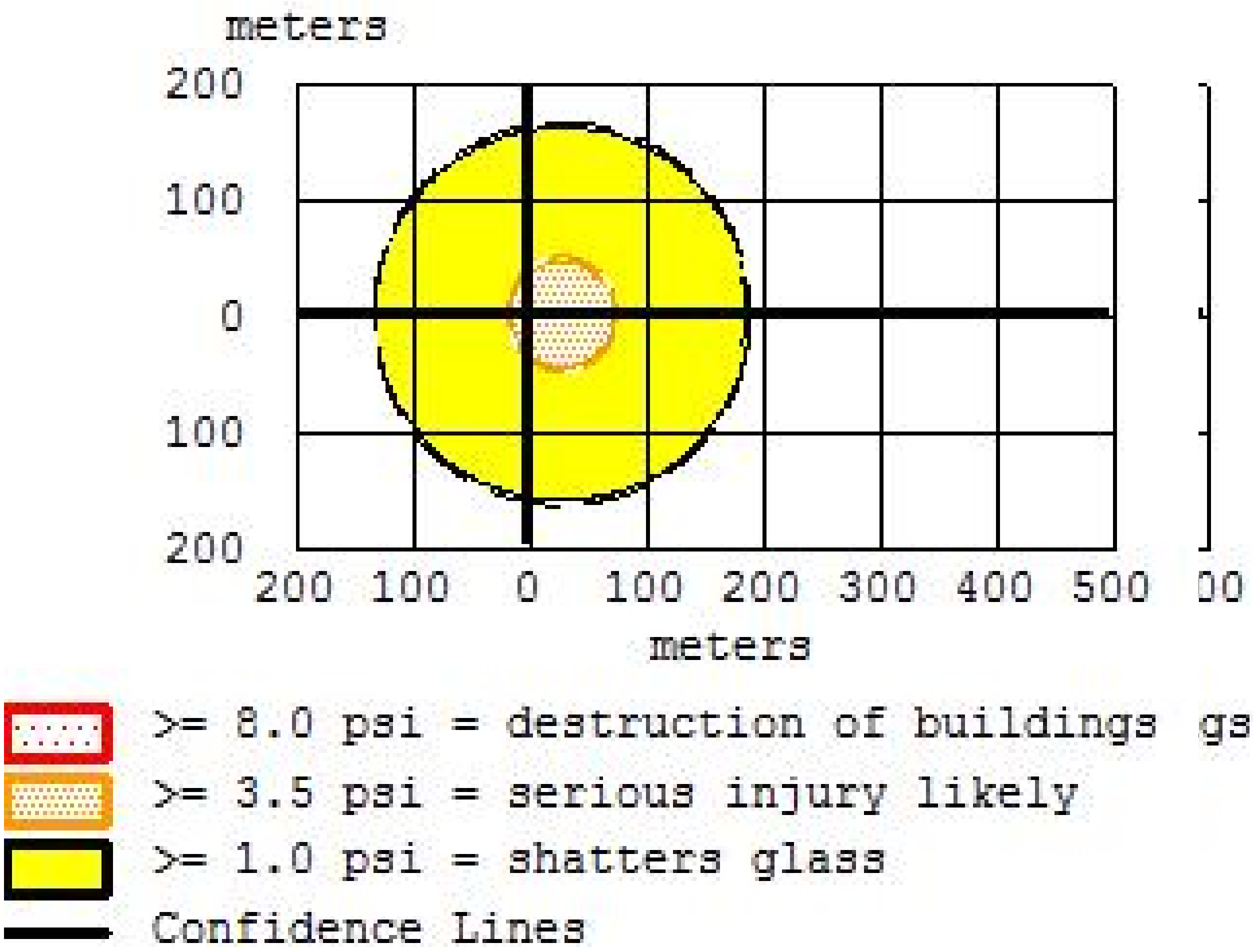
Model Run: Heavy Gas

Explosive mass at time of ignition: 1,323 kilograms

Red : LOC was never exceeded --- (8.0 psi = destruction of buildings)

Orange: 75 meters --- (3.5 psi = serious injury likely)

Yellow: 191 meters --- (1.0 psi = shatters glass)



WC03 – Jet Fire

Leak from hole in horizontal cylindrical tank

Flammable chemical is burning as it escapes from tank

Tank Diameter: 4 meters Tank Length: 45 meters

Tank Volume: 565 cubic meters

Tank contains liquid Internal Temperature: 35° C

Chemical Mass in Tank: 300 tons Tank is 86% full

Circular Opening Diameter: 5 centimeters

Opening is 0 meters from tank bottom

Max Flame Length: 29 meters

Burn Duration: ALOHA limited the duration to 1 hour

Max Burn Rate: 1,190 kilograms/min

Total Amount Burned: 70,822 kilograms

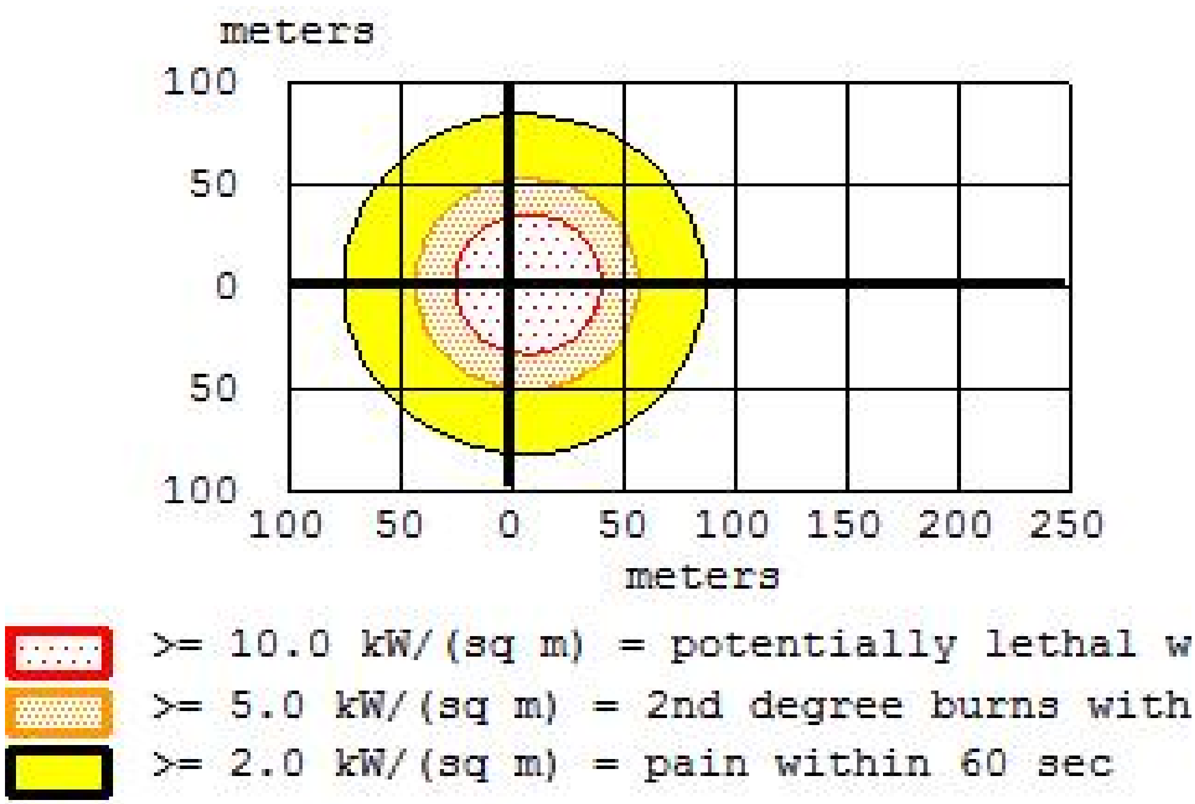
Note: The chemical escaped from the tank and burned as a jet fire.

Threat Modeled: Thermal radiation from jet fire

Red : 41 meters --- (10.0 kW/(sq m) = potentially lethal within 60 sec)

Orange: 58 meters --- (5.0 kW/(sq m) = 2nd degree burns within 60 sec)

Yellow: 88 meters --- (2.0 kW/(sq m) = pain within 60 sec)



7.10 POL PRODUCTS LEAKAGE POOL FIRE

The POL product to be handled at the proposed MULT at Cochin Port. The average pumping rate to be maintained will be 800 TPH. The released quantity for one minute intervention period will be 13.33 tonnes (say 14 tonnes). This quantity is assumed to be spilled on ground. The distances of occurrence of various thermal radiation intensities due to pool fire are given in Table-7.15. The radiation intensity causing first degree burns occur at a distance of 100 m.

Table-7.15: Distances Of Occurrence Of Various Thermal Radiation Intensities For POL Products

Radiation Intensity (Kw/m^2)	Distance (m) of Occurrence from Edge of Pool
38	41
25	48
14	62
12	66
6	88
4.5	100
3	119
2	143
1.5	162

7.11 SPILLAGE OF LPG AND POL PRODUCTS

The main causes of spillage identified in previous sections is unloading arm failure, grounding, collision and ship berthing contact. The frequencies estimate indicate that there are very rare chances of occurrence of spillage on account of any of above mentioned reasons. The past failure data studied indicates that in the past due to normal operations maximum number of spillages (81 %) have resulted into less than 7 tonnes. This minor release of flammable chemicals/POL products will be of no consequence to marine ecology. The LPG in liquefied form whatsoever spilled will evaporate immediately due to enormous heat available to it from sea water and it will not have any impact on marine ecology. Further, the unloading operations will be manned from ship and control room.

CHAPTER – 8

CHAPTER – 8

RISK ASSESSMENT

8.1 RISK AND FAILURE PROBABILITY

The term Risk involves the quantitative evaluation of likelihood of any undesirable event as well as likelihood of harm of damage being caused to life, property and environment due to sudden/ accidental release of any hazardous material from the containment. This sudden/accidental release of hazardous material can occur due to failure of component systems. Even if failure occurs, the probability of fire/explosion and the extent of damage will depend on many factors like:

- Quantity and physical properties of material released.
- Source of ignition.
- Wind velocity and direction
- Presence of population, properties etc. nearby.

Failure frequency of different components like pipes, valves, instruments, pressure vessels and other equipment manufactured in India are not available nor has any statutory authority tried to collect the information and form an acceptable data bank to be used under Indian conditions.

Failure frequency data for some components accepted in USA and European Countries are given in Table – 8.1.

Table – 8.1: Failure Frequency Draft

S. No.	Item	Failure Frequency / 10^6 Years
1]	Shell Failure (a) Process/pressure vessel (b) Pressurized Storage Vessel	 3 1
2]	Full Bore Vessel Connection Failure (Diameter mm) < 25 .... 40 .... 50 .... 80 .... 100	 30 10 7.5 5 4

S. No.	Item	Failure Frequency / 10^6 Years
	>150 …….	3
3]	Full Bore Process Pipeline Failure d <50 mm .... 50 <d <150 mm .... d >150 mm	 0.3 * 0.09 * 0.03 *
4]	Articulated Loading / unloading arm failure	$3x10^{-8}$**

* Failure frequency expressed in (/m/10^6 years)
** Failure frequency expressed in (/hr of operation)

Failure frequency data for some components accepted in USA and European Countries are given in Table – 8.2.

Table- 8.2: Failure Frequency Data

Sl. No.	Item	Failure Frequency / 10^6 Years
1]	Shell Failure (a) Process/pressure vessel (b) Pressurized Storage Vessel	 3 1
2]	Full Bore Vessel Connection Failure (Diameter mm) < 25 .... 40 .... 50 .... 80 .... 100 .... >150 …….	 30 10 7.5 5 4 3
3]	Full Bore Process Pipeline Failure d <50 mm .... 50 <d <150 mm .... d >150 mm	 0.3 * 0.09 * 0.03 *
4]	Articulated Loading / unloading arm failure	$3x10^{-8}$**

* Failure frequency expressed in (/m/10^6 years)
** Failure frequency expressed in (/hr of operation

8.2 RISK ASSESSMENT

For the assessment of 'Individual Risk' due to the various activities at the port, following has been taken into consideration:

- The individual risk for the plant has been calculated as cumulative effect of all the scenarios mentioned for selected failure cases as listed in Table No. 4.4 for 2B, 3D, 5D (Day) and 2F, 3D, 5D (Night) weather condition where wind speed of 2 m/sec. unstable stability class & wind speed of 3 m/sec. & neutral stability class, and in night wind speed of 2 m/sec. & stable stability class, etc atmospheric conditions respectively.
- Probability of wind directions has been taken from IMD data.
- Mitigation factors such as shelters, escape etc. are considered which will result in conservative risk estimation.
- During risk assessment population data and source of ignition has been considered.

Acceptability of Risk

Risk evaluation is done in order to assess the impact on the people being exposed both inside and outside the factory premises. The values are generally presented in terms of chances of death per million per year.. Risk values of some of the familiar activities are given in Table – 8.3.

Table – 8.3: Individual Risk Of Some Human Activities

Activities	Chance of Death per Million Per Year
Voluntary Risk:	
Rock Climbing (UK)	40
Smoking (20 cigarettes/day)	5000
Accident at work (UK)	33
Playing Football (UK)	40
Involuntary Risk:	
Railway Accident (India)	15
Road Accident (India)- risk in urban is much more	50
Motor Vehicle Accident (UK)	106
Lighting (in UK)	0.1
Meteorite strikes	0.00006
Aircraft Crash (In UK)	0.02

Data source: Loss prevention in Process Industries - F.P. Lees

The acceptability level of risk for people employed within the organization is generally higher. This is because of the fact that those employed are well aware of the risk involved and have accepted voluntarily some amount of risk while accepting the job. This voluntary risk can be compared to the risk associated with other voluntary activities like rock climbing, motor vehicles accidents smoking etc.

Risk of death 1 per million per year or $1x10^{-6}$ per year inside the factory premises are generally accepted without concern and this risk in often seen to be lower than voluntary and involuntary risk of death from human activities and other cases an individual is exposed to.