Bharat Petroleum Corporation Limited,

Ennore Installation,
Survey No: 1556 B Vallur village and 354/1 Athipattu village, Chennai 600081

RECEIPT, STORAGE & DISTRIBUTION OF MOTOR SPIRIT (MS), HIGH SPEED DIESEL (HSD) & ETHANOL

RISK ANALYSIS STUDY REPORT

December 2014

RiskChem Engineering
Chennai

Project Details

1.	**Report No.**	1408
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4.	**Reporting organization name & address** **Mob:** **Ph:** **email:**	RISKCHEM ENGINEERING #4 FIRST STREET, VGP GOLDEN BEACH SOUTH PART III CHENNAI 600 119 098401 44908 044 2453 0699 consultancy@riskchem.com
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- Risk analysis studies were carried out for BPCL's proposed POL installation at Ennore, Tamil Nadu.
- The exercise has been undertaken in compliance with The Manufacture, Storage and Import of Hazardous Chemicals Rules, 1989 (Amended 2000) that govern installations involving hazardous chemicals
- The methodology and guidelines given in INDIAN STANDARD HAZARD IDENTIFCATION AND RISK ANALYSIS - CODE OF PRACTICE (IS 15656:2006) were adopted for the analysis.
- Risk analysis tools used in the assessment include PHA, consequence and frequency analyses.
- The assessment was based on site and operation related information provided by the client.
- The findings are the result of the application of the best available techniques and practices applicable to the project. The conclusions drawn are the educated and unbiased opinion of the consultant.

Signatory:

DR. A. KOSHY (*Chem. Engg*.)
(PROJECT CONSULTANT)

DECEMBER 2014

Executive Summary of Risk Analysis Study

A risk analysis study was undertaken to assess the risk levels of BPCL's proposed POL Installation at Ennore.

The main findings are summarized below.

1. The hazardous outcomes from eighteen potential hazardous scenarios were envisaged for the POL installation.
2. The consequences for each of these hazardous scenarios were estimated and the effects on life & property quantified. This included effects of thermal radiation from tank fires, pool fires, and flash fires & overpressures effects from vapour cloud explosions.
3. The estimated effects in terms of damage distances were projected on the installation layout to demarcate vulnerable areas with respect to plant personnel, property and the public.
4. The effects from tank & pool fires and flash fires were found to be localized and fall within the proximity of dykes
5. However the critical effects from vapour cloud explosions were seen to impact areas outside the dykes but well within the installation.
6. The damage zones are largely confined within the installation with no significant impacts falling outside.
7. The risk was assessed considering the full implementation of the M.B. Lal Committee recommendations.
8. Risk was noted at two manned locations viz., pump house and TLFG. No risk is expected to personnel stationed at the other locations such control room, admin, MCC/LT panel room, metering/VCB room, security gates, etc., within the site.
9. The risk was assessed and found to range between 10^{-10}/ yr to 10^{-11}/ yr. This level has been compared with criteria for new hazardous industries given in IS 15656: 2006, and was found to be above the negligible range.
10. As the risk number is relative, mitigation measures have been given for further reduction in the risk levels.

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LIST OF ABBREVIATIONS

A/G	Above Ground
ALARP	As Low As Reasonably Practicable
BPCL	Bharat Petroleum Corporation Limited
CAS	Credible accident scenarios
CCA	Cause-Consequence Analysis
CCOE	Chief Controller of Explosives
CO2	Carbon dioxide
CW	Cross Wind
DCMP	Disaster Control Management Plan
DCP	Dry Chemical Powder
DW	Down Wind
F&EI	Fire & Explosion Index
FLR	Floating Roof
FR	Fixed Roof
FW	Fire Water
GPH	General Process Factor
HPCL	Hindustan Petroleum Corporation Limited
HSD	High Speed Diesel
IS	Indian Standard
KL	kiloliter
MBLCR	M B Lal Committee Recommendations
MF	Material Factor
MS	Motor Spirit
MSDS	Material Safety Data Sheet
OGP	International Association of OIL & GAS PRODUCERS
OISD	Oil Industry Safety Directorate
OWS	Oil Water Separator
PESO	Petroleum and Explosives Safety Organisation
PHA	Preliminary Hazard Assessment
PL	Pipeline
PM	Preventive Maintenance
POL	Petroleum, Oils, Lubes
RADD	Risk Assessment Data Directory
RO	Retail Outlets
ROSOV	Remote Operated Shut Off Valve
SMS	Safety Management System
SOP	Standard Operating Procedures
SPH	Special Process Factor
STD	Standard
TF	Tank Farm
TLFG	Tank Lorry Filling Gantry
TT	Tank Truck
U/G	Underground

CHAPTER One Project Description

1.1 Introduction

Bharat Petroleum Corporation Limited (BPCL) proposes to commission a new POL Installation at Ennore in Tamil Nadu. The need for new POL has arisen as expansion of the company's existing Installation at Tondiarpet is not viable due to population growth around this site.

The new facility at Ennore will receive, store and supply POL products, namely, motor spirit (MS) and high speed diesel (HSD) to meet the rapidly growing market demand in Chennai city, districts of Chennai Urban and Chennai Rural and some adjacent districts of Tamil Nadu. The Ennore Installation is expected to feed approximately 182 retail outlets, 84 industrial customers and 1 aviation filling station.

The petroleum products will be received through ocean tankers from Mumbai and Kochi Refineries. These products will be dispatched to the end consumers in the Chennai urban and rural, other districts of Tamilnadu and some northern some parts of Andhra Pradesh by road through contracted tank lorries. The new installation being proposed at Ennore will also contribute to the socio economic development of the region.

The onsite storage units will consist of underground and aboveground tanks. The total petroleum storage tankage capacity will be 1,17,035 KL.

As the activities involve flammable materials and are classified as hazardous[1], risk analysis studies were conducted to assess the degree of risk. The report contains the results of this study carried out for the receipt, onsite storage, filling and associated operation and activities.

The management of the plant has entrusted the risk analysis studies to be carried out by consultants from RiskChem Engineering (RCE), Chennai

1.2 Description of the site

The proposed installation will be located near the Ennore port of Tamilnadu, adjacent to the HPCL Petroleum product storage site.

The plot is free from any unauthorized encumbrance and overhead LT/ HT lines etc. The site is well connected by road and has access to all the infra-structural facilities available at Ennore and Chennai, including well-equipped hospitals and health care facilities.

The layout of the installation, including proposed tanks and other facilities, is designed so as to maintain the highest safety standards, compliant with the latest standards of OISD, CCOE/ PESO guidelines and MB Lal recommendations. The design of the facilities in the Installation is in line with the OISD and API standards, so as to ensure highest degree of safety during construction and operation

The location is in the zone of moderate seismic activity.

Fig 1.1 shows the proposed location of the installation.

[1] As per the various rules and schedules given under The Manufacture, Storage and Import of Hazardous Chemicals Rules, 1989 (Amended 2000) of the Environment (Protection) Act, 1986.

Fig 1.1 Location of proposed site for POL Installation

A detailed description of the installation is given in Appendix 1

1.3 Objective and Scope of Risk Analysis studies

The risk analysis studies cover the POL receipt, storage and distribution operations and associated facilities located within BPCL's proposed Installation at Ennore. The items covered in the studies are

1. Receipt of hydrocarbons (MS & HSD) at the Tap-Off Point (TOP) from ocean tankers at the jetty and via underground dedicated pipelines of HPCL
2. Storage of hydrocarbons in dedicated overground and underground tanks of various capacities
3. Distribution of hydrocarbons via tank lorry loading facilities at the gantry

The risk arising from these activities and operations was evaluated at areas within the installation where personnel may be located such as the MCC room, DG room, Admin building, laboratory, control room, main gate, etc.

The main elements of the risk analysis studies include

- Preliminary identification of hazards and hazardous scenarios
- Assessment of consequences of leak or spill of petroleum products within the installation in terms of radiation, blast waves or dispersion including
  - Effects on areas where personnel maybe located within the installation
  - Effects on areas external to the installation
- Estimation of frequency of occurrence of the hazards
- Probabilistic risk analysis based on risk contour mapping
- Recommendations based on the results of the above studies

The methodology and approach for the studies are based on Indian Standards **IS 15656: 2006** HAZARD IDENTIFICATION & RISK ANALYSIS – CODE OF PRACTICE. The study was carried out using internationally employed tools and techniques. The techniques use safety-related data, practical experience and human factors even while considering scientific based quantitative techniques. The results provide an independent and objective assessment of various types of hazards.

The risk assessment study has culminated in the identification of hazards, evaluation of risk and the development of risk control strategies to minimize the identified risks. The results of the studies are described in the subsequent chapters.

Appendix 1 Brief description of Operations/ Activities

The installation has facilities for receipt, storage and dispatch of petroleum products namely motor spirit (MS) and high speed diesel (HSD). The installation is an intermediate stock point for feeding BPCL's retail outlets (RO) in the vicinity to ensure there is no disruption in the stock.

The main activities carried out at BPCL's Ennore Installation are described briefly under the following headings

i. Receipt of petroleum products
ii. Storage
iii. Dispatch

The facility comprises of pipeline receipt, above ground and underground storage for MS, HSD & ethanol, PLT decanting facilities as well as loading facilities for tank trucks. The proposed layout is given in Fig 1.2

i Receipt

The products are mainly received from ocean tankers at the jetty via HPCL pipeline, pumped into the storage tanks and distributed by road tankers to the retail outlets in the region.

a) Receipt by PLT

Petroleum products are received through interconnection of pipeline of 16" dia for MS and 20" dia for HSD from adjacent HPCL installation to proposed BPCL installation

Table 1A1 Material flow rate on Incoming pipeline to Installation

Sl no	Product Material	Size	Flow rate
1	MS	16"	600KL/hr
2	HSD	20"	1200KL/hr

The lines are taken to another exchange pit where the main feed is sub divided into multiple lines for distribution to BPCL storage.

b) Description of Tank Lorry unloading at Unloading platform (occasional)

Ethanol is to be received at the installation from tank lorries at the unloading platform which is also used for receipt of other petroleum products in the event of deficit in supply of product by pipeline. The plant will receive 10 lorries of 20 KL each

ii Storage

The facility includes bulk storage of large quantities of flammable material in aboveground storage tanks, with smaller quantities in underground tanks. The total product wise capacity at the facility is shown in Table1A2

Table 1A2 Product wise Storage Capacity at Facility

S. No	Product	Quantity
1	MS (Motor Spirit)	56620 KL
2	HSD (High Speed Diesel)	60115 KL
3	Ethanol	200 KL
3	SLOP (MIXED PRODUCTS)	100 KL
	TOTAL	117035 KL

The details of the storage units currently available at the installation are given in the table 1A3 below.

Table 1A3 Proposed storage units at the site

Tank No.	Tank Dia (m)	Tank Ht (m)	Nature of Tank	Product	Total Capacity (KL)	Safe Capacity (KL)	Classification	Location
T1	40	16.80	A/G Fixed Roof	BS 4 HSD	20000	19400	Class - B	TF 1
T2	40	16.80	A/G Fixed Roof	BS 3 HSD	20000	19400	Class - B	
T3	40	16.80	A/G Fixed Roof	BS 3 HSD	20000	19400	Class - B	
T4	40	15.00	A/G Floating Roof	BS 4 MS	18840	16950	Class - A	TF2
T5	40	15.00	A/G Floating Roof	BS 4 MS	18840	16950	Class - A	
T6	40	15.00	A/G Floating Roof	BS 3 MS	18840	16950	Class - A	
T7	3.20	14.10	U/G Horizontal	MS	100	100	Class – A	-
T8	3.20	14.10	U/G Horizontal	HSD	100	100	Class – B	-
T9	3.20	14.10	U/G Horizontal	SLOP	100	100	Class - A	-
T10	2.00	5.00	U/G Horizontal	HSD	15	15	Class – B	-
T11	3.20	14.10	A/G Horizontal	Ethanol	100	100	Class – A	-
T12	3.20	14.10	A/G Horizontal	Ethanol	100	100	Class - A	-
				Total	**117035**	**109565**		

Storage tanks are provided with radar type and mechanical level gauges for monitoring the tank levels. The dykes provided are of 110% capacity.

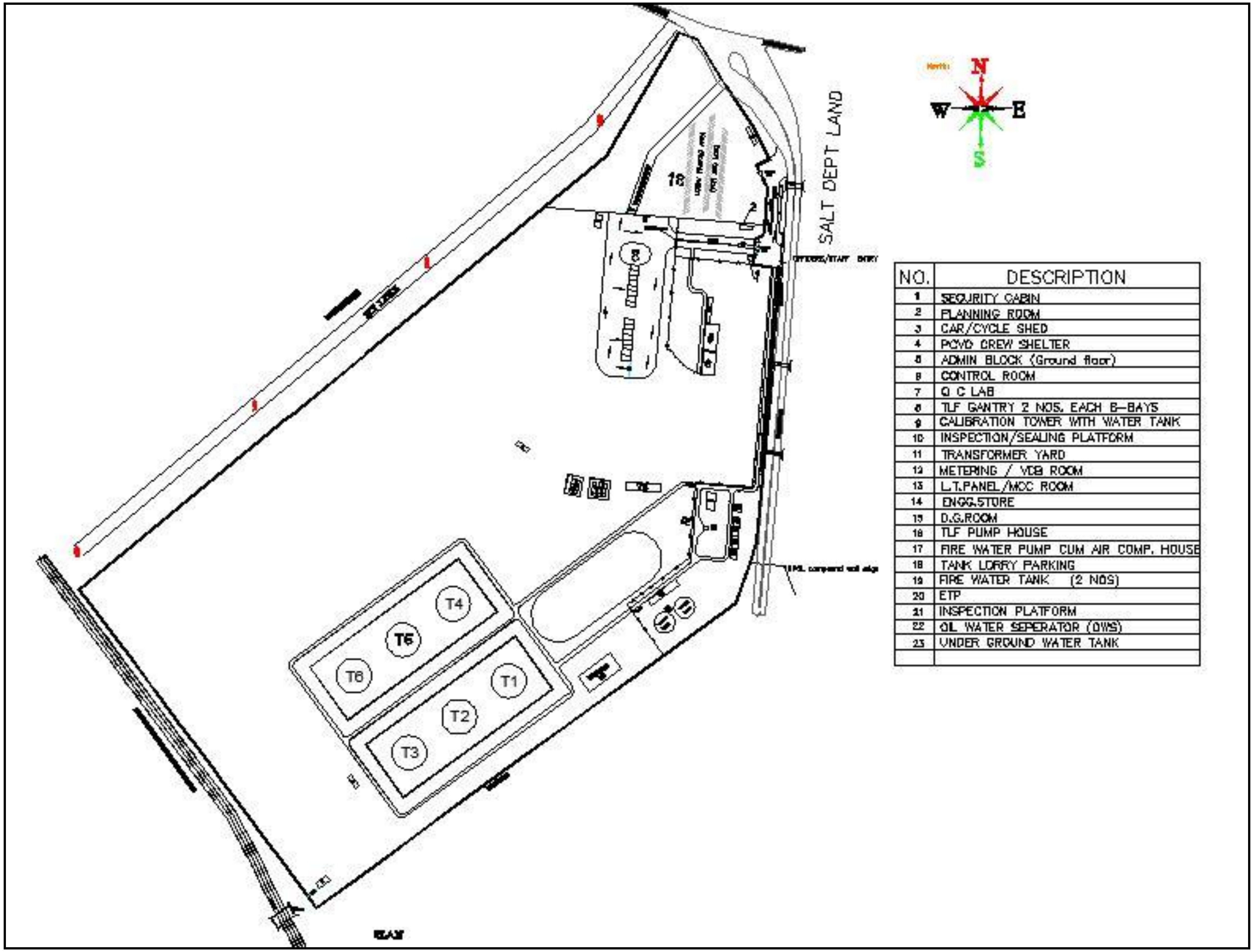
iii Dispatch

The hydrocarbons in the storage tanks are transferred through trucks to the retail outlets within the distribution circle for public usage. The TLFG is designed to fill tank lorries in two shifts of 8 working hrs and the T/L crew carries out the entire operation themselves. Approximately 430 (Around 250 per shift) lorries are filled every day.

There are two gantries on site of 8 bays each. The bays at TLF gantry are provided with loading points for various products and filling metering assembly consisting of strainers, PD meters, set stop valves and batch control units (BCU) for tank lorry filling.

Transfer occurs through the TLF pump to the gantry at a pump discharge rate of 150-200kl/hr. Loading takes place through loading arms (2 at each bay) which are fuelled by a common header. Tank Lorries are filled to 85% under supervision.

Fig 1.2 Proposed Layout of BPCL Ennore POL Installation



NO.	DESCRIPTION
1	SECURITY CABIN
2	PLANNING ROOM
3	CAR/CYCLE SHED
4	PCVD CREW SHELTER
5	ADMIN BLOCK (Ground floor)
6	CONTROL ROOM
7	Q C LAB
8	TLF GANTRY 2 NOS. EACH 8-BAYS
9	CALIBRATION TOWER WITH WATER TANK
10	INSPECTION/SEALING PLATFORM
11	TRANSFORMER YARD
12	METERING / VDB ROOM
13	L.T.PANEL/MCC ROOM
14	ENGG.STORE
15	D.G.ROOM
16	TLF PUMP HOUSE
17	FIRE WATER PUMP CUM AIR COMP. HOUSE
18	TANK LORRY PARKING
19	FIRE WATER TANK (2 NOS)
20	ETP
21	INSPECTION PLATFORM
22	OIL WATER SEPERATOR (OWS)
23	UNDER GROUND WATER TANK

CHAPTER Two **Hazard Identification**

2.1 Hazard Identification Methods used and the basis

Hazards are present in any system, installation or unit that handles or stores flammable materials. The mere existence of hazards, however, does not automatically imply the existence of risk. Screening & ranking methodologies based on Preliminary Hazard Analysis (PHA) techniques have been undertaken for evaluation of the risk.

The hazard assessment was based on the following methodologies

A) Inventory guidelines based on The Manufacture, Storage & Import of Hazardous Chemicals (Amendment) Rules, 2000 of the Environment (Protection) Act, 1986;

B) Past accident analysis;

C) Fire & Explosion Indexing based on Dow's Hazard Classification Guide (7^{th} edition)

2.2 Source characteristics - Hazard Classification based on Inherent Hazards

There are a number of properties that identify the hazard potential of a petroleum product. Table 2.1 summarizes the hazardous properties of products in storage.

Table 2.1 Hazardous Properties of Chemicals

Property		MS	HSD	ETHANOL
Boiling point (°C)		30 - 215	110 - 375	78
Flash point (°C)		< - 10	> 35	16.6
Auto ignition (°C)		250 - 280	230 - 250	363
Lower Flammable Limits (%)		1.4	0.5	3.3
Upper Flammable Limits (%)		7.6	5	19
National Fire Protection Agency (NFPA) rating *	NH	0	0	2
	NF	3	2	3
	NR	0	0	0

* NFPA classification for Health NH, Flammability NF & Reactivity NR of a chemical on a scale of 0 – 4 least to worst

The properties show that while MS and ethanol are easily ignitable and will burn rapidly, HSD would require much higher external temperature to produce vapour. However all petroleum products require interaction with air or oxygen and an ignition source for the hazard to be realised.

Based on the properties and the definitions given in the MSIHC Schedule 1, Part 1(b), the hydrocarbons can be classified as follows.

- Motor Spirit as 'Extremely Flammable Liquid'
- Ethanol as 'Very Highly Flammable Liquid'
- HSD as 'Flammable Liquid'

Detailed Material Safety Data Sheets for MS, HSD and Ethanol are given in *Annexure I.*

2.3 Credible accident sources/worst case scenarios - Past Accident Analysis.

The possibility of fire and/or explosion in hydrocarbon tank farms has been largely confirmed from accounts of past incidents. *Annexure II* gives a list of recent accidents in hydrocarbon tank farms.

The lessons learnt from the major events will help in improving the standards of tank farm safety.

2.3.1 Analysis of Tank fires

An analysis of past accidents involving tank fires was carried out based on information collected from published reports.

- The predominant causes of tank fire are lightning, nearby external fire, and poor maintenance.
- The damage potential of fires/ explosions is considerably different depending on the types of tanks used for storage.
- Over half (52%) of the incidents involving floating roof tanks were seal fires, most of which were extinguished by portable foam or water hose streams before serious damage occurred
- Total collapse is less common in the case of floating roof tanks than fixed roof tanks.
- While 46% of the fixed roof tank was completely destroyed with an additional 50% suffering major damage to the roof supports, ring or shell, only 12% of the floating roof tanks were totally destroyed and 36% suffered roof, ring or shell damage.

2.3.2 Analysis of VCEs from Tank Overflows

While tank fires have occurred and damages were localized, vapour cloud explosion are more devastating and can cause injury/fatality to personnel.

An analysis of some incidents involving MS are listed in Table 2.2 below

Table 2.2 Occurrence of VCE in past accidents involving MS

Location	Qty leaked before explosion (t)	Cause for explosion	Time of leakage (before the explosion)	Probable Source of Ignition
Indian Oil Corporation's Jaipur Oil Terminal, Sanganer, India	1000	Leak at Hammer Blind Valve	One hour and 15 or 20 minutes	Pump house, vehicles
Buncefield Oil Terminal near Heathrow Airport, U.K.	300 (pumping rate of 550 m^3/hr increased to 890 m^3/hr just 10 min before explosion)	Tank Overflow (malfunction of tank level control and associated safety interlocks)	45 minutes	Pump house located within 10 to 15 m from source of release from dyke

Location	Qty leaked before explosion (t)	Cause for explosion	Time of leakage (before the explosion)	Probable Source of Ignition
Petroleum oil terminal in the Caribbean Refinery at Puerto Rico	800	MS spill due to overflow of MS tank during ship unloading	20 minutes after discovery	-

From the past accident analysis, it was noted that the sources of ignition were available close to the spill areas (within 20 m). Considerable time was also available between the start of the leak and the occurrence of the explosion, allowing the material to vaporize and build up within the affected areas.

2.4 Methodology for Hazard Identification - Fire & Explosion Index (F&EI)

As flammable material like MS, HSD and ATF are being received, transferred and stored onsite in large quantities, the F&EI for the various units were calculated to show the relative degree of hazard posed.

2.4.1 Conduct of F&EI

This stage of hazard identification involves the estimation of F&EI for a sampling of the units in the facility to give the relative severity of the units from the fire angle.

These are evaluated from the knowledge of the material hazard factor, General (GPH) and Special Process Hazard (SPH) factors. Material Factor (MF) is the measure of the energy potential of a particular chemical or its mixture with other chemicals. GPH and SPH are evaluated by taking into account the exotherm or endotherm of a reaction, material handling and transfer hazards, accessibility, severity of process conditions and possibilities, dust and other explosions, inventory level of flammable material, etc.

The F&EI value is then calculated as the product of MF, GPH and SPH and evaluated using the criteria given in Table 2.3.

Table 2.3 Criteria for Degree of Hazard for Fire and Explosion Index

Index range	Degree of Hazard
1-60	*Light*
61- 96	*Moderate*
97-127	*Intermediate*
128-158	*Heavy*
>159	*Severe*

The worksheet for the F&EI estimated for the units is given in *Appendix 2.* The results are summarized in the following section.

2.4.2 Analysis of F&EI Results

A summary of the results including the material factors for the largest tanks of each of the hydrocarbons stored on site is given in Table 2.4.

Table 2.4 F&EI Calculations -- Summary Table for Storage Units

Units	Max. Qty./ unit	Material Factor MF	Fire & Explosion Index F&EI	Degree of Hazard
HSD Storage Tank (T 1)	20000	10	48	*Light*
MS Storage Tank (T 6)	18840	16	82	*Moderate*
Ethanol (T 11)	100	16	61	*Moderate*

2.5 Summary

PHA approach was used to identify the nature of hazard of petroleum products stored and handled at the installation and determine the degree of hazard. Further, accidents have been reported in the past involving fixed/ floating-roof tanks storing petroleum products. The findings have established that there is a need for further investigation and quantification of potential damage and evaluation of the proposed safety systems.

Appendix 2 Fire & Explosion Index Worksheet

Name of Facility Unit: Material in Unit Location	Bharat Petroleum Corporation Ltd (BPCL) Storage at Installation Petroleum products Ennore, Chennai	Date	11/11/2014	
State of Operation	Normal operation			
Storage Unit		Above ground HSD tank (T 1)	Aboveground Motor spirit tank (T 6)	Aboveground Ethanol tank (T 11)
Quantity		20000	18840	100
Material Factor		10	16	16
General Process Hazards	*Penalty Factor Range*	*Penalty Factor Used*	*Penalty Factor Used*	*Penalty Factor Used*
Base Factor	1.00	1.00	1.00	1.00
A) Exothermic Chemical Reactions	0.30 – 1.25	0.00	0.00	0.00
B) Endothermic Processes	0.20 – 0.40	0.00	0.00	0.00
C) Material Handling and transfer	0.25 – 1.05	0.50	0.50	0.50
D) Enclosed or Indoor process units	0.25 – 0.90	0.00	0.00	0.00
E) Access	0.20 – 0.35	0.00	0.00	0.00
F) Drainage and spill control	0.25 – 0.50	0.00	0.00	0.00
General Process Hazards Factor (F_1)		1.50	1.50	1.50
Special Process Hazards	*Penalty Factor Range*	*Penalty Factor Used*	*Penalty Factor Used*	*Penalty Factor Used*
Base Factor	1.00	1.00	1.00	1.00
A) Toxic Material(s)	0.20 – 0.80	0.00	0.20	0.00
B) Sub-Atmospheric Pressure	0.50	0.00	0.00	0.00
C) Operation in or near Flammable Range				
1. Tank Farms Storage Flammable Goods	0.50	0.50	0.50	0.50
2. Process Upset or Purge Failure	0.30	0.00	0.00	0.00
3. Always in Flammable Range	0.80	0.00	0.00	0.00
D) Dust Explosion	0.25 – 2.00	0.00	0.00	0.00
E) Relief Pressure	0.00	0.00	0.00	0.00
F) Low Pressure	0.20 – 0.30	0.00	0.00	0.00
G) Quantity of Flammable/ Unstable Material				
1. Liquids or Gases in Process	0.10 – 10.00	0.00	0.00	0.00
2. Liquids or Gases in Storage	0.10 – 10.00	1.20	1.20	0.55
3. Combustible Solids in Storage, Dust in Process	0.10 – 10.00	0.00	0.00	0.00
H) Corrosion and Erosion	0.10 – 0.75	0.50	0.50	0.50
I) Leakage - Joints and Packing	0.10 – 1.50	0.00	0.00	0.00
J) Use of Fired Equipment	0.10 – 1.00	0.00	0.00	0.00
K) Hot Oil Heat Exchange System	0.15 – 1.15	0.00	0.00	0.00
L) Rotating Equipment		0.00	0.00	0.00
Special Process Hazards Factor (F_2)		3.20	3.40	2.55
Process Unit Hazards Factor ($F_1 \times F_2 = F_3$)		4.80	5.10	3.83
Fire and Explosion Index (F_3 x MF)		48	81.60	61.2
Degree of Hazard		Light	Moderate	Moderate

CHAPTER Three **Consequence Modelling**

3.1 Preamble

The units and activities connected with receipt, filling and storage of POL products have been assessed for potential to initiate and propagate an unintentional event or sequence of events that can lead to an accident and/or emergency. Credible accident scenarios were initially constructed followed by the quantification for these identified scenarios. The quantification was carried out using mathematical modelling and the results are given in this chapter.

3.2 System Boundaries

Data collection and review of the facilities included understanding of the operations carried out as well as reviewing the operating parameters for each activity.

The assessment was based on well-recognized and internationally accepted modelling methodologies. Each area where a fire/explosion or toxic hazard exists, and is separated from another area by distance or isolation valves, has been identified as a study area. Inventory data has been defined for each volume between isolation valves. This typically includes such physical characteristics as composition, pressure, and temperature.

For all the above ground facilities, the releases are considered to be in the horizontal direction as a worst case. The leaks from piping and valves are assumed to be continuous. The range of leak sizes i.e. 10% leak and full bore rupture were assessed as applicable depending on the maximum flow rate in each pipe section. The leak size is limited to the maximum flow rate. The available mitigation measures have been considered.

The damage potential associated with the various hazardous outcomes was assessed based on pre-defined impairment criteria for losses. For the purposes of this assessment, a fatality is conservatively assumed to result for any person receiving a dangerous thermal dose or worse (where “dangerous” is actually defined as a 1% risk of fatality). The risk estimates have been derived using data and assumptions which are considered to be conservative (i.e. to over-estimate rather than under-estimate the risk level where judgement was required).

The most pessimistic meteorological conditions (wind speed 2.2 m/s, stability class F) and wind direction were taken for dispersion simulations. A vapour cloud in event of leak is assumed to disperse in the most probable wind direction (west to east).

In case of leak and /or rupture the corrective systems are assumed to respond within 5 min for all scenarios within the installation.

3.3 Identification and Construction of Hazardous Scenarios

Several hazardous scenarios were identified using information from past accidents and engineering judgment. Escape of petroleum product can take place in an installation due to leak or rupture in a pipeline, overflow of a product from tank, or failure of a tank or from transfer piping and associated connections (gasket, flanges, etc.). These could occur during the conduct of the normal activities/ operations of the installation.

From the results of the preliminary hazard analysis, vulnerable locations were selected where leak of vapour or spill of liquid from the inlet/ outlet pipelines or catastrophic failure of vessels can occur. The list of representative potential events covers mainly the release of hydrocarbon which could lead to loss of life and/ or damage to property. The range of leak sizes representative for small and large leaks that have been considered for the assessment based on the pipe sizes.

Credible accident scenarios (CAS) were initially constructed followed by quantification using Cause-Consequence Analysis (CCA) for the identified scenarios.

Depending on the amount of inventory released, release scenarios would result in the formation of a pool of hydrocarbon, with the potential to extend to the full surface area of the bund. Ignition of the spill would subsequently result in a pool fire.

In addition to the potential for a fire as a result of a spill, there is also the potential for a tank fire scenario. A full tank surface fire may occur as a result of:

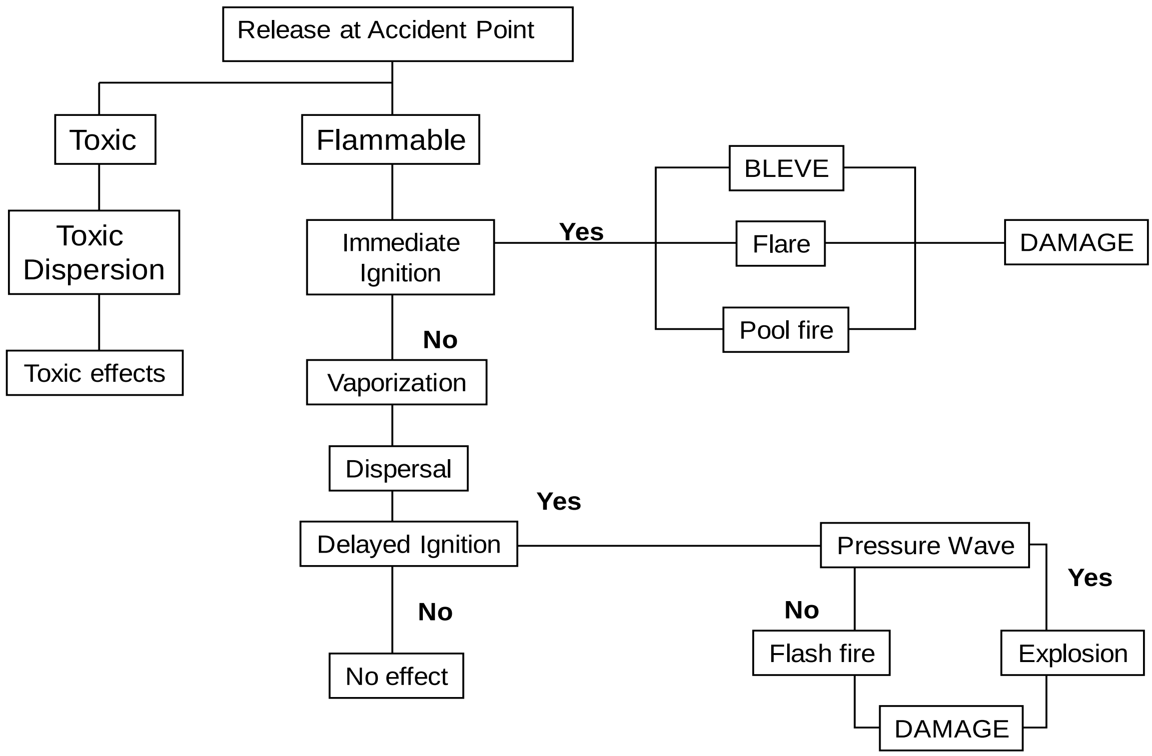
- The sinking of the floating roof tank (Motor Spirit) and subsequent product ignition
- The escalation of a rim seal fire
- Lightning strike

Depending on the type of the operating conditions and the composition of the material handled, one or more of the following potential hazards/consequences could be encountered due to loss of containment:

1. Jet Fire
2. Pool Fire
3. Flash Fire
4. Vapour Cloud Explosion

Fig 3.1 gives a graphic representation of the development of the various potential consequences, subsequent to release.

Fig 3. 1 Evolution of Effects following release of Hazardous Material



The potential for dispersion of flammable vapour from spills of Motor Spirit to atmosphere was also considered during the analysis. The distance to which flammable vapours would extend is dependent on the response time for all cases. Flash fires and Unconfined Vapour Cloud Explosion were therefore also analysed further in the risk assessment.

The list of credible hazardous scenarios at each location are given in table below

Table 3.1 Identified Scenarios and possible outcomes

Event no.	Location/ Activities	Product considered	Scenario	Probable consequence
1	Exchange pit (25m X 15 m)	HSD	Leak (10%) on pipeline (confined)	Pool fire
		MS	Leak (10%) on pipeline (confined)	Pool fire Flash fire/ VCE
2	Inlet line	HSD	Leak (10%) on pipeline (unconfined)	Pool fire
		MS	Leak (10%) on pipeline (unconfined)	Pool fire Flash fire/ VCE
3.1	At TF1 (T1, T2, T3)	HSD	Liquid spill from leak (10%) on inlet/ outlet pipe	Pool fire
3.2			Overfilling of tank T1	Pool fire
3.3			Tank fire on fixed roof HSD tank	Tank fire
4.1	At TF 2 (T4, T5, T6)	MS	Liquid spill from leak(10%) on inlet/ outlet pipe	Pool fire/ Flash fire/ VCE
4.2			Overfilling of tank T 4	Pool fire/ Flash fire/ VCE
4.3			Tank fire on floating roof MS tank	Tank fire
4.4			Two Tanks simultaneously on fire (e.g., due to lightning strike)	Tank fire
5	U/G Horizontal Tanks	MS	Overfilling of tank T7	Pool fire Seepage/ soil contamination
6	A/G Horizontal Tanks	Ethanol	Overfilling of tankT11	Pool fire
7	Tank lorry pump house	MS	Flange leak on pipeline (10%)	Pool fire Flash fire/ VCE
8.1	TLF Gantry (8 + 8 bay)	MS	Common header- Gasket leak (10%)	Pool fire Flash fire/ VCE
8.2			Loading arm failure (100%)/ Overfilling	Pool fire Flash fire/ VCE
9	Lorry Tanker (filled)	MS	Shell leak	Pool fire Flash fire/ VCE
10	Oil Water Separator (OWS)	MS	Excess inflow due to overflow at tank farm 2 & failure to drain OWS	Pool fire Flash fire/ VCE

Detailed consequence analysis was carried out for each of the identified scenarios. The results are given in Appendix 3

3.4 Consequence Modelling

The consequence modelling of fire, explosion and dispersion scenarios has been performed using guidelines and models provided Indian standards (IS 15656: 2006 HAZARD IDENTIFICATION & RISK ANALYSIS – CODE OF PRACTICE) and international guidelines.

The extent of the consequences of an accident in a hydrocarbon installation depends on the type and quantity of the product stored and handled, mode of containment, and external factors like location, density of population in the surrounding area, etc. In many cases realisation of hazard and its damage potential also depend on prevailing meteorological conditions and availability of ignition source.

Petroleum products such as motor spirit require interaction with air or oxygen and an ignition source for the hazard from loss of containment to be realised. Under certain circumstances, vapours of the product when mixed with air may be explosive, especially in confined spaces.

Essential details used in the analysis such as sources of ignition, location of personnel on site, etc., are given in Annexure III.

Dense dispersion model was used to calculate the extent of dispersion up to lower flammable limits (LFL). The amount in the flammable limits was considered for calculation of pressure effects.

Fire damage estimates are based upon correlation with recorded incident radiation flux and damage levels.

3.4.1 Damage Criteria for heat radiation effects

The damage criteria give the relation between extent of the physical effects (exposure) and the percentage of the people that are killed or injured due to those effects.

Thermal radiation effects are used as damage criteria for fires. Damage criteria are given and explained for heat radiation

The consequence caused by exposure to heat radiation is a function of:

- The radiation energy onto the human body [kW/m^2]
- The exposure duration [sec]
- The protection of the skin tissue (clothed or naked body)

100% lethality may be assumed for all people suffering from direct contact with flames. The effects due to relatively lesser incident radiation intensity are given below.

Table 3.2 Effects due to Incident Radiation Intensity

Incident Radiation (kW/m2)	Type of Damage
0.7	Equivalent to Solar Radiation
1.6	No discomfort for long exposure
4.0	Sufficient to cause pain within 20 secs. Blistering of skin (first degree burns are likely) Minimum distance for fire man to operate
9.5	Pain threshold reached after 8 sec, second degree burns after 20 sec.
12.5	Minimum energy required for piloted ignition of wood, melting of plastic tubing, etc

Incident Radiation (kW/m2)	Type of Damage
	1% fatality for exposure above 60 secs
37.5	Sufficient to cause damage to process equipment 99% fatality for exposure above 60 secs

3.4.2 Damage Criteria for overpressure effects

Explosion damage is estimated based on recorded peak overpressures and corresponding potential damage effects. A Vapour Cloud Explosion [VCE] is a deflagration accompanied by a blast effect that occurs in the open air as a consequence of the ignition of a cloud containing flammable vapour.

The estimate of the likely maximum value of overpressure that may be generated in a VCE is of considerable importance for the consequence analysis. If no immediate ignition of a released material occurs, it can disperse into the atmosphere. Following ignition, the vapour cloud will start to burn. It is assumed that fatality will be 100% in the projected area of the vapour cloud.

The factors that affect VCEs are:

a. Shape of the cloud

b. Composition of the cloud

c. Mass of the combustible vapour in the explosive range

d. Type of ignition

e. Flame acceleration

f. Surroundings

The shock wave model, used for a wide range of flammable vapour clouds, expresses explosion overpressure as a function of distance from the centre of the cloud. This correlation uses a measure of distance from the cloud centre, which is scaled to one-third the power of the available combustion energy. The damage criteria used to assess VCEs are given in Table 3.3 below

Table 3.3 Overpressures and corresponding types of damage

Over pressure (bar)	Type of damage
0.30	Heavy; 50% fatality
0.20 to 0.27	Rupture of Oil storage tanks
0.20	Steel frame constructions distorted and pulled away from foundations; Serious injuries are common, fatalities may occur
0.10	Repairable; People injured by flying glass and debris
0.03	Large & small windows usually shattered
0.02	10% window glass broken
0.01	Crack of windows

3.5 Damage Contour Plots

Hazardous situations identified in this section have been quantified using consequence models. Quantification provides an estimate of the damage potential for each individual scenario. The damage is expressed in terms of the area involved.

The damage contours for the most credible release scenarios at each location were plotted on the layout of the installation. These contours are shown in Figs. 3.2 to 3.10

LEGEND for Figures

Code for Pool Fire	Thermal Radiation in kW/m2
(red line)	37.5
(magenta line)	21.5
(blue line)	12.5
(green line)	4
Code for Overpressures	Overpressures in bar
(red line)	0.3
(purple line)	0.1
(light blue line)	0.03
(red filled box)	CODE For Flash Fire/ Spill area

Fig 3.2 Damage contours due to Pool fire from Unconfined gasket leak (10%) on MS inlet pipeline (Event no 2)

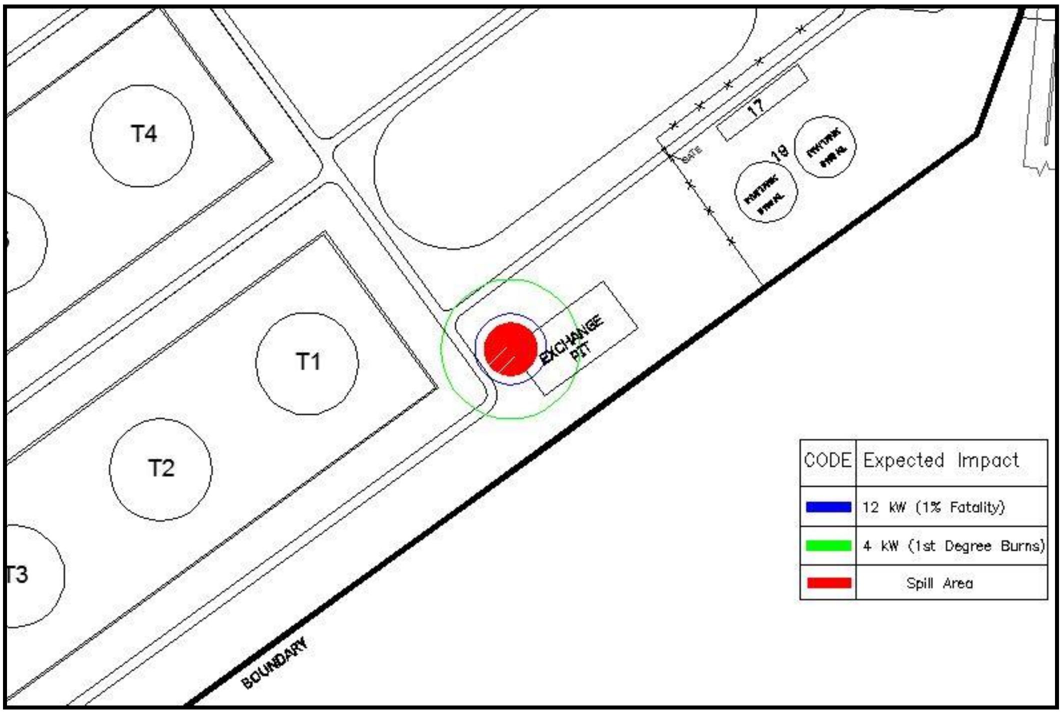


Fig 3.3 Damage contours due to pool fire at Tank Farm 1 (Event nos 3.1/ 3.2-HSD)

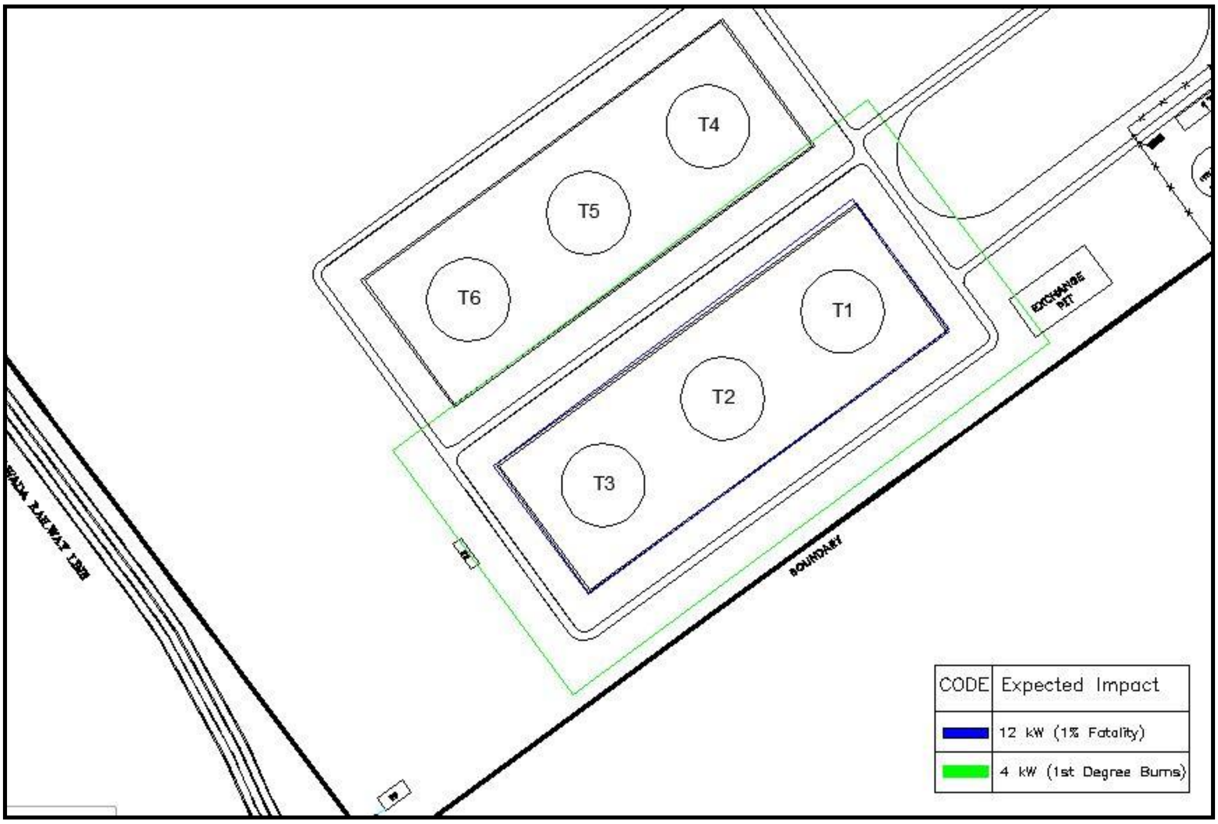


Fig 3.4 Damage contours due to tank fire at Tank 1 (Event no 3.3 -HSD)

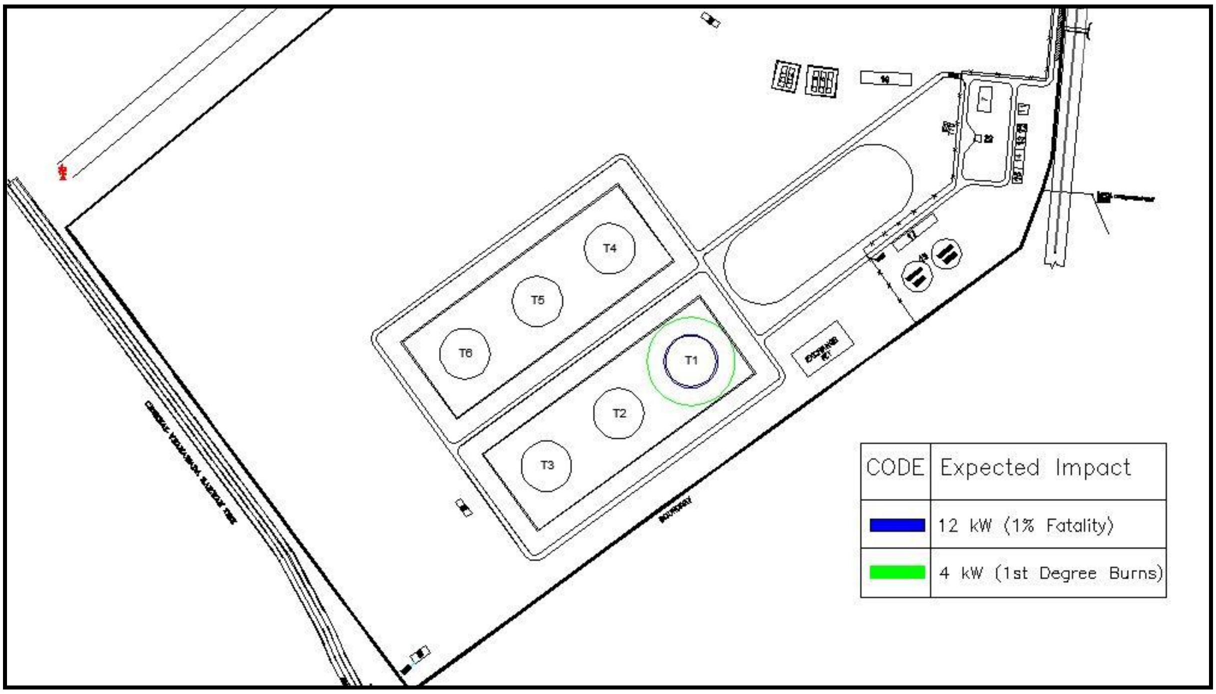


Fig 3.5 Damage contours due to pool fire at Tank Farm 2 (Event nos 4.1/ 4.2 -MS)

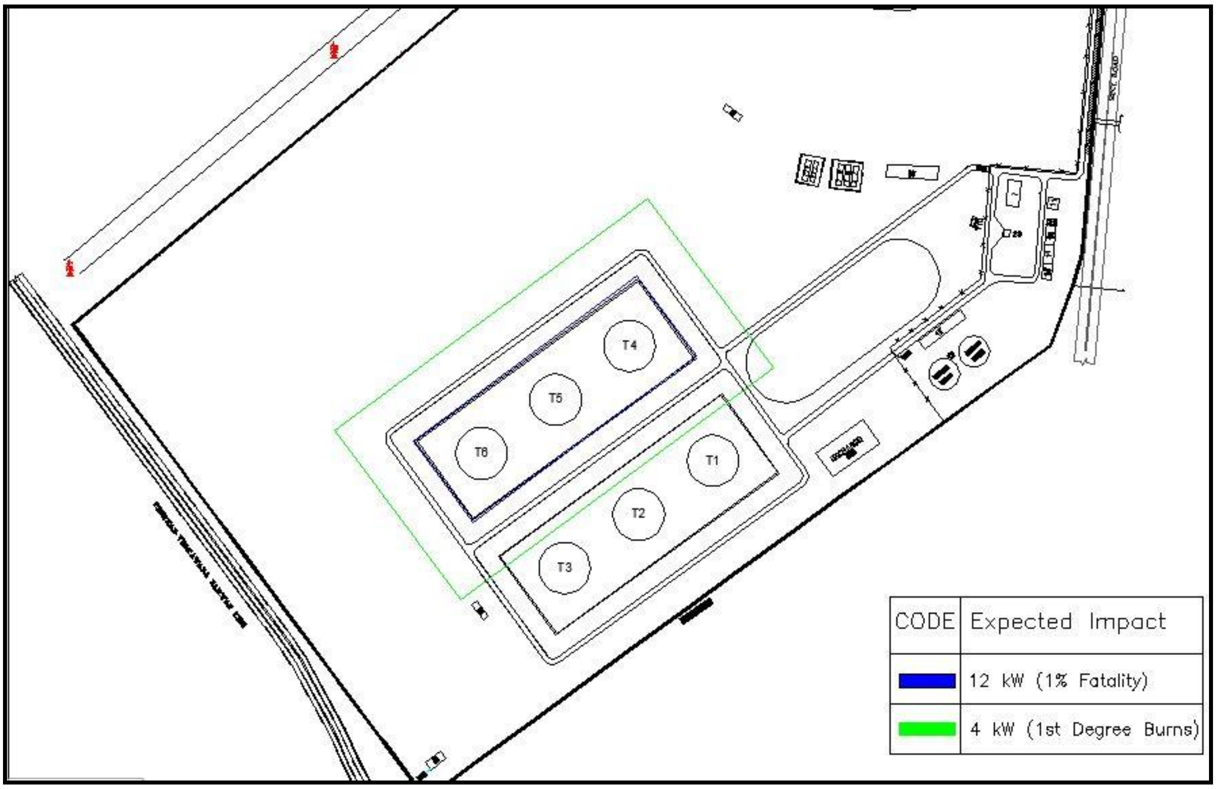


Figure 3.6 Damage contours due to Flash fire/ VCE at Tank Farm 2 (Event nos 4.1/ 4.2-MS)

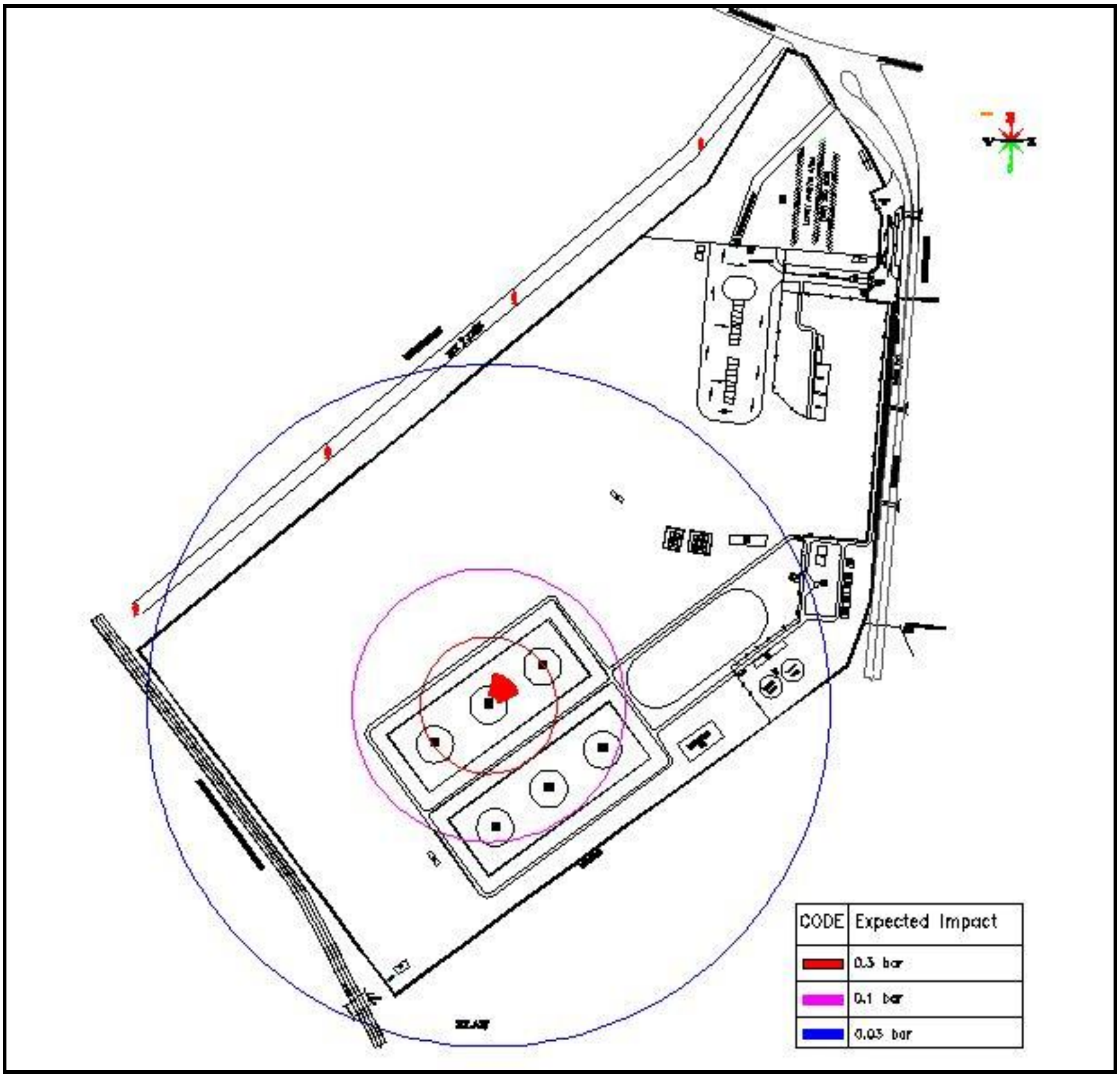


Fig 3.7 Damage contours due to tank fire at Tank 4 (Event no 4.3)

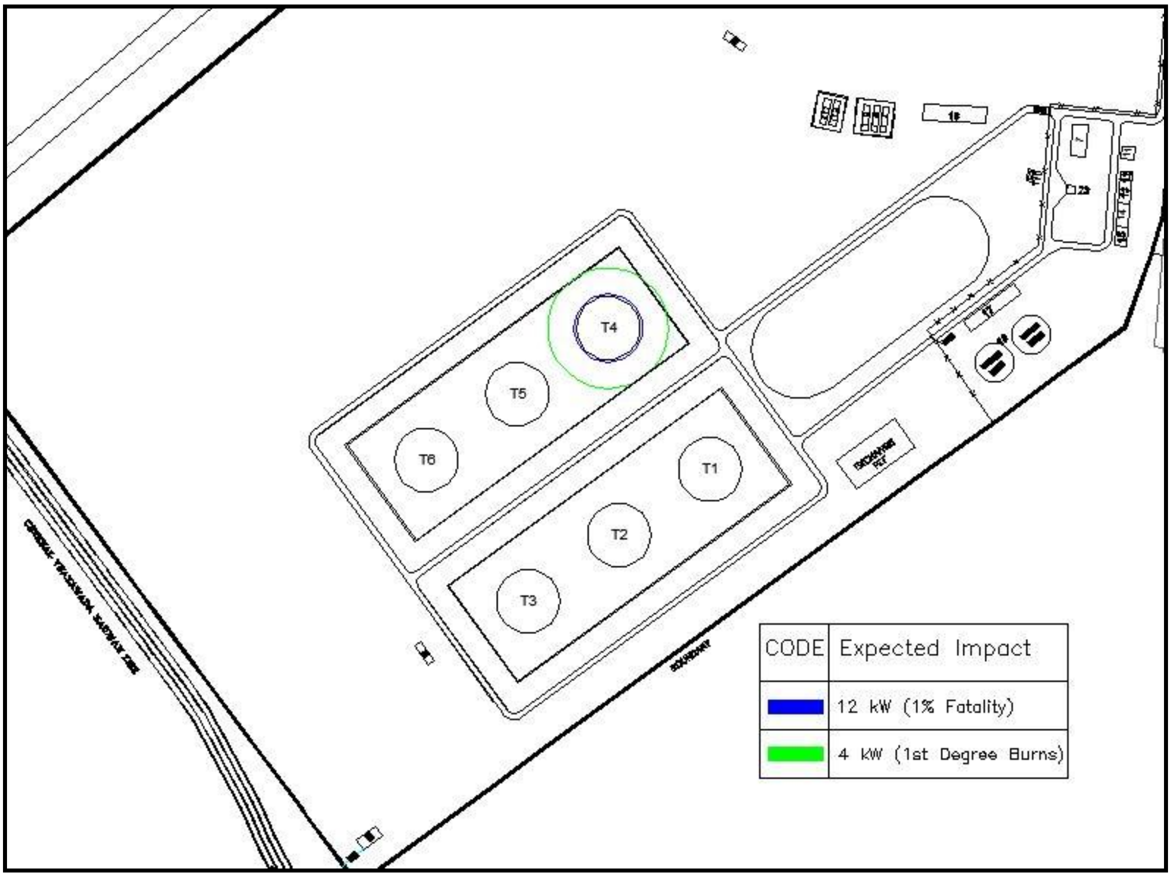


Fig 3.8 Damage contours due to two tanks (T4 & T5) simultaneously on fire (Event no 4.4)

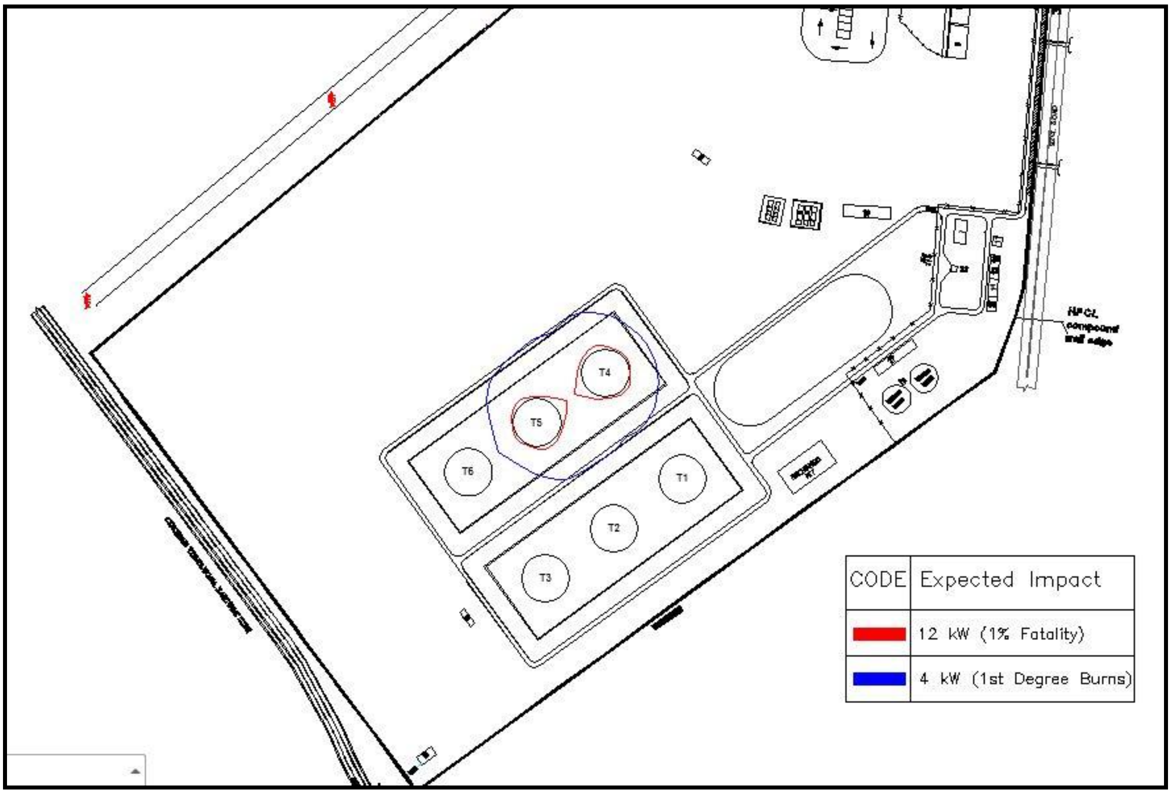


Fig 3.9 Damage contours due to pool fire at Tank lorry gantry pump house (Event no 7)

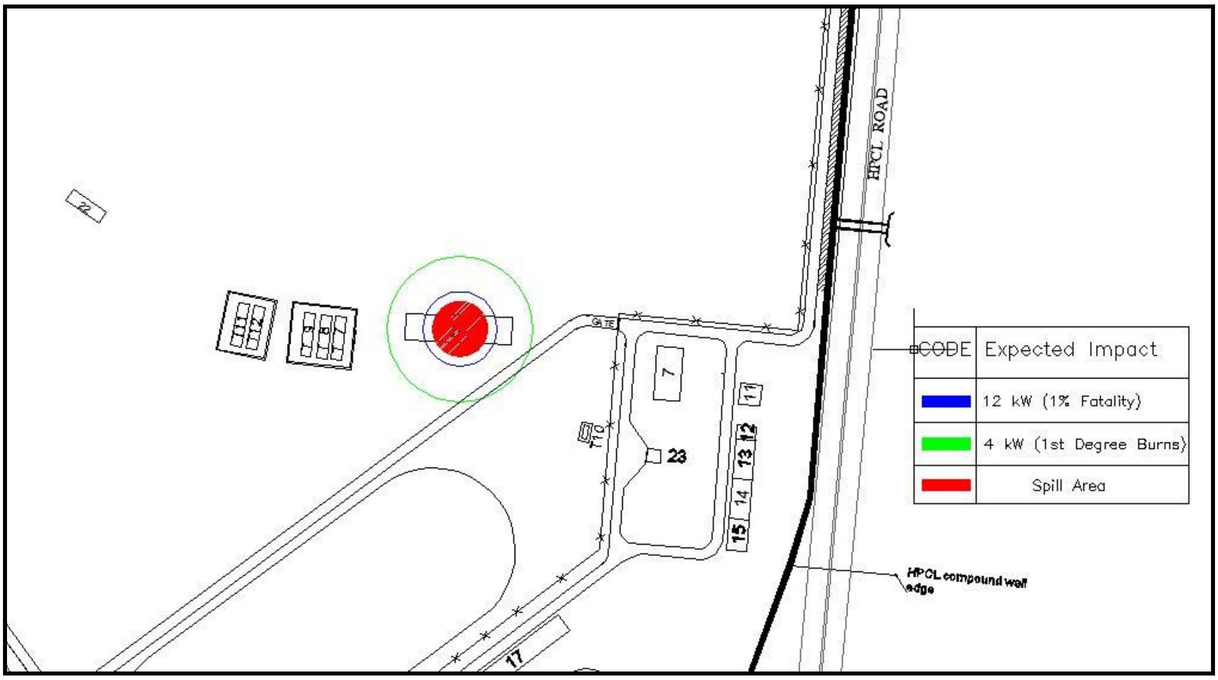
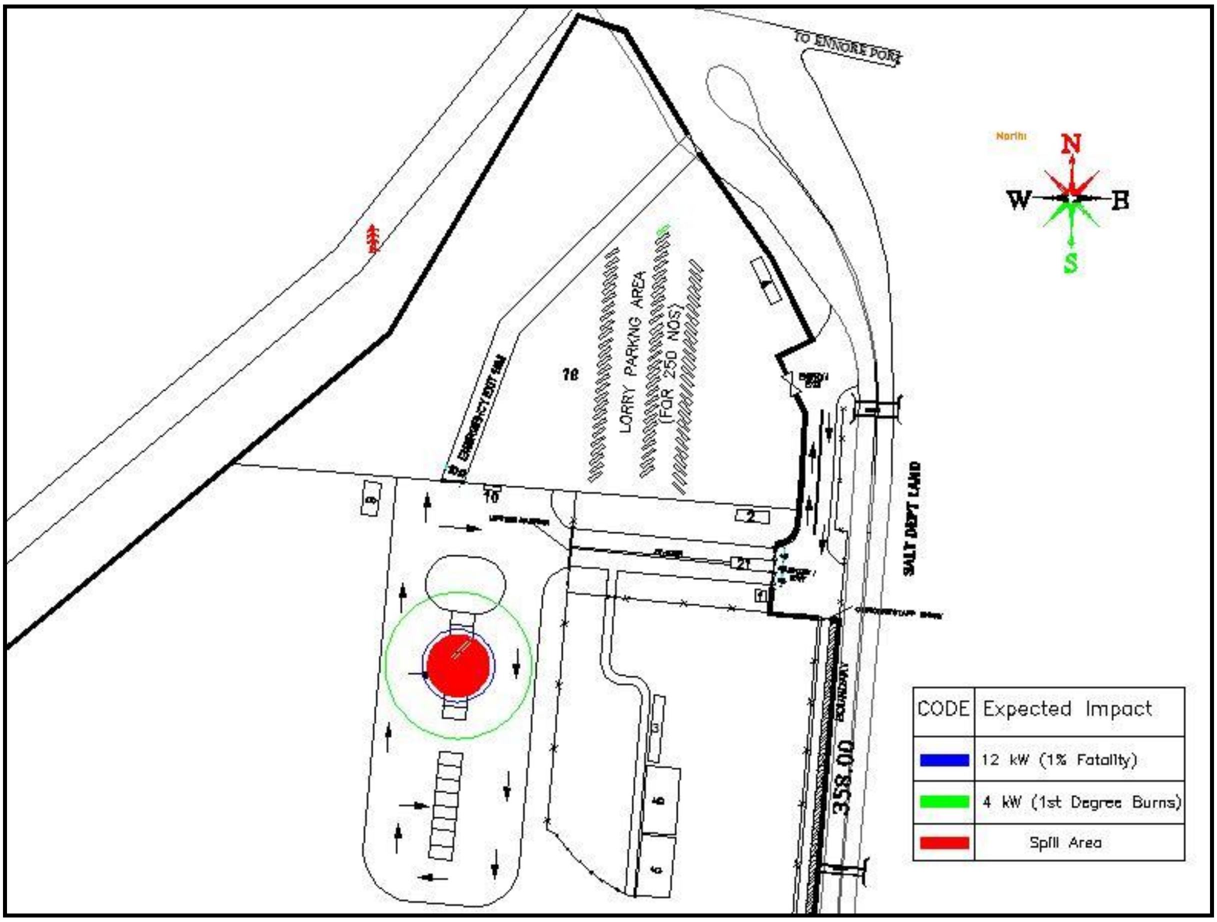


Fig 3.10 Damage contours due to pool fire at TLF gantry (Event no 8.2)



3.6 Summary

A total of eighteen scenarios with potential to result in fire or explosion were identified. Credible accident scenarios were initially constructed followed by consequence estimation using mathematical modelling. The effects from the various hazardous outcomes have been given in terms of thermal radiation and overpressure levels.

The estimated damage distances from the worst cases at each location were plotted on the site layout. Vulnerable zones for three levels of impact on personnel signifying fatality, injury and safe distance for firefighting/ mitigative actions have been demarcated for the significant scenarios.

Appendix 3 Outputs from Consequence Calculations

A) TANK FIRE RESULTS

Table 3A1 Estimation of effects of Tank fire at individual storage tanks

Event no.	Location	Product	Scenario	Pool Area	Radiation Intensity inside tank	Distance from the edge of the tank (m)			
				(m^2)	(kW/ m^2)	37.5 kW/m^2	21.5 kW/m^2	12.5 kW/m^2	4 kW/m^2
3.3	T 1	HSD	Tank fire on fixed roof HSD tank, T1	1256	20.9	Within pool	Within pool	1.3	15
	T 2	HSD	Tank fire on fixed roof HSD tank, T2	1256	20.9	Within pool	Within pool	1.3	15
	T 3	HSD	Tank fire on fixed roof HSD tank, T3	1256	20.9	Within pool	Within pool	1.3	15
4.3	T 4	MS	Tank fire on floating MS tank, T4	1256	20.9	Within pool	Within pool	1.8	18
	T 5	MS	Tank fire on floating MS tank, T5	1256	20.9	Within pool	Within pool	1.8	18
	T 6	MS	Tank fire on floating MS tank, T6	1256	20.9	Within pool	Within pool	1.8	18

Emergency Scenario: Lightning Strike on two MS tanks and both tanks on fire simultaneously

Estimations of damage effects for simultaneous fire scenario for two MS tanks are given in the table below

Table 3A2 Damage Effects due to simultaneous fire in Tanks T4 & T5

Scenario	Radiation Intensity within each tank (kW/ m^2)	Distance from the edge of the dyke (m)			
		37.5 kW/m^2	21.5 kW/m^2	12.5 kW/m^2	4.5 kW/m^2
4.4 Simultaneous fire in Tanks T4 & T5	20.9	Not attained		Within the dyke (North) Within the dyke (East) Within the dyke (South) Within the dyke (West)	19.4 (North) Within the dyke (East) 18.2 (South) Within the dyke (West)

B) POOL FIRE RESULTS

Table 3A3 Estimation of Impact of Pool fires within the plant

Event no.	Location/ Activities	Product	Scenario	Pool Area	Radiation Intensity inside tank	Distance from the edge of the pool (m)			
				(m^2)	(kW/ m^2)	37.5 kW/m^2	21.5 kW/m^2	12.5 kW/m^2	4 kW/m^2
1	Exchange pit	HSD	Confined gasket leak (10%) on pipeline	375	28.7	Not attained	Within pool.	2.7	14
		MS	Confined gasket leak (10%) on pipeline	375	28.7	Not attained	Within pool.	3.4	17
2	Inlet line	HSD	Unconfined gasket leak (10%) on pipeline	9326	20.0	Not attained	Not attained	1.5	30
		MS	Unconfined gasket leak (10%) on pipeline	1345.5	20.8	Not attained	Not attained	1.8	19
3.1	At TF1	HSD	Liquid spill from gasket leak on inlet/ outlet pipe	15831	20.0	Not attained	Not attained	1.6	36
3.2			Overfilling of tank T1	15831	20.0	Not attained	Not attained	1.6	36
4.1	At TF 2	MS	Liquid spill from gasket leak on inlet/ outlet pipe	15688	20.0	Not attained	Not attained	2	45
4.2			Overfilling of tank T4	15688	20.0	Not attained	Not attained	2	45
5	U/G Horizontal tanks	MS	Liquid spill from gasket leak on inlet/ outlet pipe	329.3	30.2	Not attained	Within pool.	3.7	17
6	A/G Horizontal tanks	Ethanol	Liquid spill from gasket leak on inlet/ outlet pipe	244.2	60.20	Within pool.	3.9	9.0	21.9
			Overfilling of tank T18	244.2	60.20	Within pool.	3.9	9.0	21.9

Event no.	Location/ Activities	Product	Scenario	Pool Area	Radiation Intensity inside tank	Distance from the edge of the pool (m)			
				(m^2)	(kW/ m^2)	37.5 kW/m^2	21.5 kW/m^2	12.5 kW/m^2	4 kW/m^2
7	Tank lorry pump house	MS	Flange leak on pipeline (10%)	329.3	30.2	Not attained	Within pool.	3.7	17
8.1	TLF Gantry (8+8 bay)	MS	Common header- Gasket leak at (10%)	237.7	34.8	Within pool	1.2	4.2	17
8.2			Loading arm failure (100%)/ Overfilling	598.0	24.3	Not attained	Within pool	2.5	19
9	Lorry Tanker (filled)	MS	Shell leak	688	23.44	Not attained	Within pool	2.5	17
10	Oil Water Separator (OWS)	MS	Excess inflow due to overflow at tank farm 2 & failure to drain OWS	75	57.13	Within pool	2.6	6	17

C) VCE RESULTS

Table 3A4 Estimation of Damage Effects of Flash fires and VCE within the plant

Event no.	Location/ Activities	Product	Scenario	Spill area	Evaporation/ Dispersion Rate	Distance up to LFL		Distance up to UFL		Amount in Explosive Limits	Damage Distance in meters for Different Overpressure			
				m^2	(kg/s)	DW[2]	CW[3]	DW	CW	(kg)	0.3 bar	0.1 bar	0.03 bar	0.01 bar
1	Exchange pit	MS	Confined gasket leak (10%) on pipeline (during day)	375	1.8	4	2.8	0	0.34	3.6	Quantity low. Explosion unlikely			

[2] DW- Down wind

[3] CW- Cross wind

Event no.	Location/ Activities	Product	Scenario	Spill area	Evaporation/ Dispersion Rate	Distance up to LFL		Distance up to UFL		Amount in Explosive Limits	Damage Distance in meters for Different Overpressure			
				m^2	(kg/s)	DW^2	CW^3	DW	CW	(kg)	0.3 bar	0.1 bar	0.03 bar	0.01 bar
2	Inlet line	MS	Unconfined gasket leak (10%) on pipeline (during night)	1345.5	6.05	10	7.6	2	2.7	30.25	Quantity low. Explosion unlikely			
4.1	At TF 2	MS	Liquid spill from gasket leak on inlet/ outlet pipe	15688	57.17	30	33.4	8	14.2	627	73.02	146.0	365.1	973.6
4.2			Overflow of tank T4	15688	57.17	30	33.4	8	14.2	627	73.02	146.0	365.1	973.6
7	Tank lorry pump house	MS	Flange leak on pipeline (10%)	329.3	1.6	2	1.7	0	0.3	1.6	Quantity low. Explosion unlikely			
8.1	TLF Gantry (12 bay)	MS	Common header- Gasket leak at (10%)	237.7	1.2	2	1.5	0	0.2	1.2	Quantity low. Explosion unlikely			
8.2			Loading arm failure (100%)/ Overfilling	598.0	3.1	8.8	5.1	2.2	2.1	9.3	Quantity low. Explosion unlikely			
9	20 KL Lorry Tanker (filled)	MS	Shell leak (5 KL emptied in 5 min)	688	3.51	8.8	5.3	2.2	2.2	10.5	Quantity low. Explosion unlikely			

CHAPTER Four Determination of Risk at the Installation - Probability Assessment

4.1 Accident Frequency Estimation

Several credible scenarios with potential to cause damage were considered and quantified in the previous chapters. However, the probability of occurrence of these events depends on the protection provided by safety systems inbuilt in the design and activated during the operation of the facility.

The POL installation will be provided safety and automation features for the pipelines, individual tanks, tank farms, tank lorry filling gantry, and other areas as per recommendations of MB Lal Committee. The probabilities of the occurrence of the credible scenarios were evaluated assuming the full implementation of these recommendations as applicable to the facility.

4.2 Summary of Safety & Automation features

In this section all the safety systems, both preventive and mitigative, have been collated and linked to the individual scenarios considered. These are summarized below:

Table 4.1 Summary of proposed Safety and Automation Features

Safety System	Details of System
1) HC detector	With sound alarm (to be located at Tank farm, pump house)
2) LI & Alarm (for all storage tanks)	Radar gauge - Will close ROSOV (inlet line) MOV
	Level switch (only alarm) - configured to close ROSOV & MOV
	Servo gauge Same as above function
3) ROSOV	On inlet and outlet line to the storage tanks
4) ESD	To trip a) TLF pump, b) MOV, c) ROSOV, d) Barrier gate - will open if ESD pressed as the lorries go out.
5) MCP	Will sound siren and locate the fire area
6) Tanks dyke capacity	110 % of the largest tank within each tank farm
7) Fire fighting system (for all tank farms)	Medium expansion foam generator (MEFG) to all tanks
	High Velocity Long Range (HVLR) system for MS tanks (trolley mounted for Class B)
8) For Floating roof tanks	Swivel joints on drainage system Articulated drainage system with PIVOT MASTER
	Automatic actuated rim seal fire detection and extinguishing system to be provided on all external floating roof tanks storing Class A petroleum.

These automation features address critical areas that directly rely on human intervention, where failure rates are high and response systems may be delayed. The frequency of occurrence of hazardous events at the facility was estimated assuming the implementation of the above features.

4.3 Failure Frequency Analysis

The starting point of the risk calculations is the potential leak frequency. Generic failure frequencies for each type and size of the component and safety features were used to determine the cumulative failure frequency of the event as envisaged. These are combined with the ignition probabilities to give ignited event frequencies.

This methodology was adopted for the estimation of frequency of occurrence and probability of an event.

4.3.1 Events in the accident chain and safety features

An incident will occur only under the following chain of events.

1. Initiating event
    - Leak, spill, etc.
2. Failure of protective/ warning devices
    - Instruments, human action
3. Presence of ignition sources (fixed & mobile)
4. Failure of mitigation measures
    - Dykes, firefighting equipment, training

The assumption of the assessment is that risk of an accidental outcome can be contained if any of the systems identified in the chain of events functions as designed.

The effectiveness of the safety systems in preventing and or mitigating the effects of leak has been assessed through event-tree. The technique gives due consideration to the element of time and sequence of activation as every leak of hydrocarbon, as it disperses, has the potential to either ignite immediately or at a later time.

4.3.2 Estimation of Probability

The probabilities of failure of the components that make the accident chain were combined to arrive at the probability of occurrence, i.e., whether it is poolfire, flash fire or vapour cloud explosion (VCE) or any combination of consequences within the site. The methodology for identifying layers of protection and arriving at the estimate of frequency of an event is described in Annexure IV.

It was assumed that the primary events are pipe leaks which have higher failure rates than vessel rupture. These primary events can lead to damage to vessels and escalation of fire situations.

The proposed system for detection, monitoring and safety systems on the units and the transfer systems were also taken into consideration when estimating the probability of occurrence of each scenario. For each case, the probability of ignition was considered.

Being a new installation credit has been given to preventive, isolation and quick response mitigation measures.

The probability of each event was estimated considering the number and type of units and sequence of operation of safety systems available at each location.

Generic failure data collated from published industrial databases such as Risk Assessment Data Directory of the International Association of Oil & Gas Producers[4], UK Health Safety Executive (UK HSE) database, etc. was used to generate the probabilities at each location. Ignition probabilities given in OGP Risk Assessment Data Directory – Ignition Probabilities [5]were used in the analysis

The results showing the probability of occurrence per year of an incident of fire or explosion arising at each location considering available safety features for the proposed facility are given in Table 4.2.

[4] OGP RADD – Storage Incident Frequencies Report No. 434 – 3, March 2010

[5] OGP RADD – Ignition Probabilities Report No.: 434-6.1 March 2010

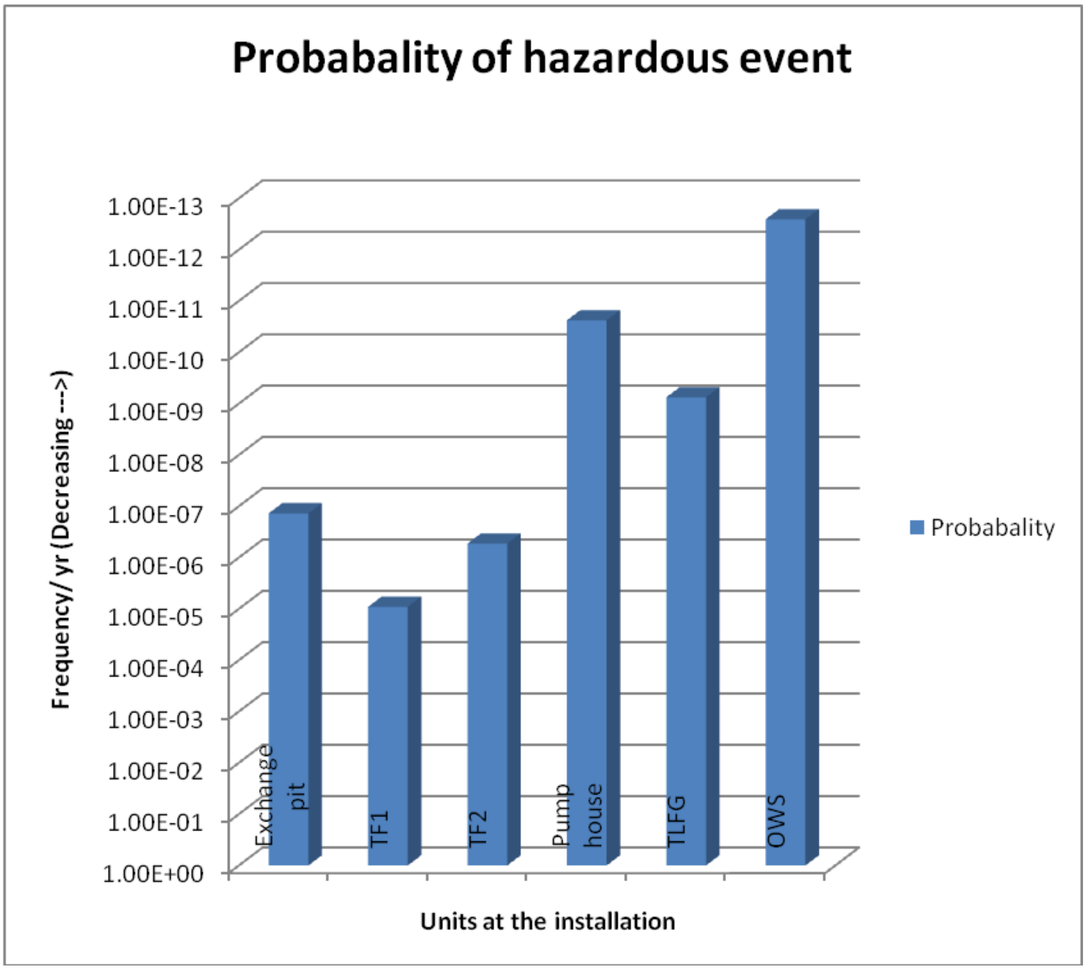
Table 4.2 Frequency estimation of single credible event at different locations within the installation

Event no.	Location/ Activities	Product	Scenario	PROBABILITY OF FIRE (Tank/ Pool)	PROBABILITY OF FLASHFIRE	PROBABILITY OF EXPLOSION
1	Exchange pit (25m X 15 m)	HSD	HSD Leak (10%) on pipeline (confined)	5.50E-08	-	-
		MS	MS Leak (10%) on pipeline (confined)	5.50E-08	2.75E-08	-
2	Inlet line	HSD	HSD Leak (10%) on pipeline (unconfined)	1.15E-07	-	-
		MS	MS Leak (10%) on pipeline (unconfined)	1.15E-07	5.76E-08	-
3.1	At TF1 (T1, T2, T3)	HSD	HSD spill from gasket leak on inlet/ outlet pipe	1.70E-11	-	-
3.2			Overfilling of tank T1	2.43E-12	-	-
3.3			Tank fire on fixed roof HSD tank	9.00E-06	-	-
4.1	At TF 2 (T4, T5, T6)	MS	MS spill from gasket leak on inlet/ outlet pipe	1.70E-11	8.52E-12	8.52E-12
4.2			Overfilling of tank T4	2.43E-12	1.22E-12	1.22E-12
4.3			Tank fire on floating roof MS tank	1.20E-07	-	-
4.4			Two Tanks simultaneously on fire	2.40E-07	-	-
5	U/G Horizontal Tanks	MS	Overfilling of T7	1.30E-07	6.50E-08	-
6	A/G Horizontal Tanks	Ethanol	Overflow of T11	1.30E-07	6.50E-08	-
7	Tank lorry pump house	MS	Flange leak on pipeline (10%)	9.50E-12	4.75E-12	-
8.1	TLF Gantry	MS	Common header- Gasket leak (10%)	9.50E-13	4.75E-13	-
8.2			Loading arm failure (100%)/ Overfilling	5.50E-15	2.75E-15	-
9	Lorry Tanker (filled)	MS	shell leak	5.00E-10	2.50E-10	-
10	Oil Water Separator (OWS)	MS	Excess inflow due to overflow at tank farm 2 & failure to drain	1.70E-13	8.52E-14	-

4.4 Probability of Hazardous Event within the installation

The probability of occurrence of all the hazardous events arising at the various locations within the installation are presented in the figure 4.1

Fig 4.1 Probability of occurrence of Hazardous event from locations at the installation



It can be noted from Fig 4.1 that the highest probability of occurrence of a hazardous event inside the installation is at the tankfarms 1 & 2, followed by the exchange pit, TLF gantry, and TL pumphouse

4.5 Observations

The frequency of the each of the events at different locations was estimated considering representative cases from Class A and Class B products.
The highest frequency of occurrence of an unwanted event with the proposed introduction of safety features is of the order of 10^{-7} per year, i.e., the chance of occurrence is once in ten million years.

CHAPTER Five Evaluation of Risk to Personnel within and outside the installation

5.1 Preamble

The risk to personnel located within and outside the installation was evaluated and presented in this chapter. Risk numbers are based on the probability of occurrence and the severity of the consequences of a particular outcome and provide a relative measure of the risk associated with the proposed operations.

5.2 Risk Evaluation

Risk was calculated as the product of the consequence and probability for each individual event. The approach includes superimposing the damage contours on the layout and studying the combined effects of the individual events.

The scenarios shortlisted are these that can cause potential fatalities/ serious injuries to personnel and/or substantial damage to property. This included worst damage from an occurrence of pool fire, flash fire/ VCE within the installation.

The following criteria equivalent to 1% fatality were employed for risk evaluation

Table 5.1 Risk Criteria considered for individual risk evaluation

Effects	Level of interest (equivalent to 1% fatality)
Thermal radiation	12.5 kW/m^2
Overpressures	0.1 bar

The impact on the individual was calculated at locations where personnel are stationed.

Table 5.2 Scenarios with potential for fatal effects on personnel

Event no.	Scenario	Potential Fatal Effects on personnel arising from	
		Thermal radiation of 12.5 kW/m^2	Overpressure of 0.1 bar
1	Leak (10%) on pipeline (confined)	Nil	Nil
2	Leak (10%) on pipeline (unconfined)	Nil	Nil
3.1	HSD spill from gasket leak on inlet/ outlet pipe (TF1)	Nil	Nil
3.2	Overfilling of tank T1	Nil	Nil
3.3	Tank fire on fixed roof HSD tank	Nil	Nil
4.1	MS spill from gasket leak on inlet/ outlet pipe (TF2)	Nil	Nil
4.2	Overfilling of tank T4	Nil	Nil
4.3	Tank fire on floating roof MS tank	Nil	Nil
4.4	Two Tanks simultaneously on fire	Nil	Nil
5	Overfilling of T7	Nil	Nil

Event no.	Scenario	Potential Fatal Effects on personnel arising from	
		Thermal radiation of 12.5 kW/m^2	Overpressure of 0.1 bar
6	Overflow of T11	Nil	Nil
7	Flange leak on pipeline (10%)	TLF pumphouse	Nil
8.1	Common header- Gasket leak (10%)	TLF pumphouse/ TLFG	Nil
8.2	Loading arm failure (100%)/ Overfilling	Tank lorry unloading platform, TLF gantry 5 bays	Nil
9	Shell leak	Tank lorry unloading platform, TLF gantry 5 bays	Nil
10	Excess inflow due to overflow at tank farm 2 & failure to drain	Nil	Nil

5.2.1 Risk criteria

As risk is the product of frequency and severity, the qualitative Risk matrix approach described below, was adopted. This serves to provide a relative ranking of the credible outcomes

The individual frequency values are classified in terms ranging from 'Extremely remote' to 'Frequent' based on industrial experience worldwide[6]. Severity values used in risk matrix are based on the effects within the site that are likely to occur when a hazardous event takes place.

The magnitude and category of risk at the plant was assigned based on the following Matrix.

Table 5.3 Qualitative Risk Matrix for Potential effects on human life

		Frequency of occurrence			
		Extremely Remote (< 10^{-9})	Remote (10^{-6} to 10^{-9})	Occasional (10^{-3} to 10^{-6})	Frequent (10^{-1} to 10^{-3})
Severity of occurrence		1	2	3	4
No significant effect	1	**Low**	**Low**	**Low**	**Low**
Injury or serious health effects/ Repairable Property damage	2	**Low**	**Low**	**Medium**	**Medium**
Fatality/ permanent disability/ Structural damage	3	**Low**	**Medium**	**Medium**	**High**

The following table gives the category of risk of each hazardous scenario identified at the plant.

[6] Values of failure frequencies given in OGP RADD & 'Layer of Protection Analysis – Simplified Process Risk Assessment' published by Center for Chemical Process Safety of the American Institute of Chemical Engineers, New, York, New York, 2001

Table 5.4 Risk levels from various credible scenarios at different locations inside the proposed installation

Sl no	Initiating event/ location	Scenario	Frequency rating	Severity rating	Risk Rating
1	Leak (10%) on pipeline (confined)	Pool Fire	2	1	Low
		Flashfire	2	1	Low
2	Leak (10%) on pipeline (unconfined)	Pool fire	2	1	Low
		Flashfire	2	1	Low
3.1	HSD spill from gasket leak on inlet/ outlet pipe (TF1)	Pool fire	1	1	Low
3.2	Overfilling of tank T1	Pool fire	1	1	Low
3.3	Tank fire on fixed roof HSD tank	Tank fire	3	1	Low
4.1	MS spill from gasket leak on inlet/ outlet pipe (TF2)	Pool fire	1	1	Low
		Flash fire	1	1	Low
		VCE	1	2	Low
4.2	Overfilling of tank T4	Pool fire	1	1	Low
		Flash fire	1	1	Low
		VCE	1	2	Low
4.3	Tank fire on floating roof MS tank	Pool fire	2	1	Low
4.4	Two Tanks simultaneously on fire	Pool fire	2	1	Low
5	Overfilling of T7	Pool fire	2	1	Low
		Flash fire	2	1	Low
6	Overflow of T11	Pool fire	2	1	Low
		Flash fire	2	1	Low
7	Flange leak on pipeline (10%)	Pool fire	1	3	Low
		Flash fire	1	2	Low
8.1	Common header- Gasket leak (10%)	Pool fire	1	2	Low
		Flash fire	1	2	Low
8.2	Loading arm failure (100%)/ Overfilling	Pool fire	1	3	Low
		Flash fire	1	2	Low
9	Shell leak	Pool fire	1	3	Low
		Flash fire	1	2	Low
10	Excess inflow due to	Pool fire	1	1	Low

Sl no	Initiating event/ location	Scenario	Frequency rating	Severity rating	Risk Rating
	overflow at tank farm 2 & failure to drain	Flash fire	1	1	Low

It may be noted that the severe damage effects corresponding to 1% fatality from hazardous scenarios are localized and the risk is restricted to within the plant boundaries.

5.3 Potential for Secondary/ Cascade Events

The potential for occurrence of secondary or cascade effects was also identified. Secondary events will be experienced at a few locations within the installation, leading to substantial equipment damage and secondary events. Table 5.5 below summarizes the expected secondary events.

Table 5.5 Summary of Risk of secondary events

EVENT NO.	SOURCE			EFFECTS	
	Location	Material	Scenario	Within the installation	Outside the installation
4.1/ 4.2	Tank farm 2 containing T4, T5 & T6	MS	VCE from spill in dyke	Damage to adjacent tanks causing tank fires	No major units identified in this area

5.4 Summary

The maximum individual risk arising from primary events for the proposed operation at areas inside and outside the installation has been estimated. The levels are noted to be low at these locations due to sufficient interspacing distances and the introduction of safety features and automation of the system.

CHAPTER Six Major Findings of the Risk Assessment Study

6.1 Preamble

The risk assessment for the BPCL Ennore installation was conducted through a series of steps, viz., hazard identification, consequence estimation, probability assessment and risk evaluation. The risk levels for the proposed installation were calculated assuming full implementation of safety systems as recommended by M B Lal Committee.

The main findings are discussed under the following headings; viz., potential impacts from consequence assessment and risk levels on persons inside and outside the installation.

6.2 Main Findings of Consequence Assessment

Consequence analyses were conducted at several locations (including the exchange pit, incoming pipeline corridor, storage tanks, pump houses and TLFG) where potential release of petroleum products within the installation can occur. About eighteen scenarios were identified covering transfer and storage operations at the installation and the assessment carried out.

The main findings from the assessment at these sections are summarized below.

1. **Assessment of hazardous scenarios resulting in fire:**

   The thermal radiation effects corresponding to 1% fatality were seen to be confined within the immediate proximity of the spill areas for all classes of petroleum products handled and stored.

   i. Fires at the gantry and pumphouse due to spill during pumping are seen to have localised effects. Personnel stationed in TLFG and pumphouse may be affected by any localized spill or fire.

2. **Areas of potential damage from VCE:** Among the petroleum products, storage and handling of MS was assessed for its potential to generate significant quantities of vapour that could result in flash fire or VCE. Eight scenarios were considered to have potential for occurrence of VCE. The potential effects of two scenarios seen to be significant are summarized below:

   i. The overpressures from VCE capable of causing ‘severe’ damage (.3 bar) from MS tank (T4 in Tank Farm 2) was found to affect an area corresponding to a radius of 73m, as shown in Table 3A3. This falls on adjacent tanks within the tank farm 2. This may be considered as representing the maximum damage within the installation.
   ii. The overpressure levels corresponding to ‘repairable’ damage effects (0.1 bar) from VCE of the an MS tank fall on HSD tanks within the tankfarm 1
   iii. Damage zones representing 1% fatality (0.1 bar) from explosions lie within the installation and extend up to 146 m from the source. No personnel are expected to be stationed in this region
   iv. Personnel stationed at the rest of installation such as at the Control Room, Admin, MCC room, electrical substation, and security areas will not be affected as these locations fall outside the fatality zone.

3. **Cascade or secondary events**: Primary events such as VCE from spills of MS may have potential to affect neighbouring units leading to secondary/ cascade events and resulting in escalation of the primary incident. These secondary events may result in multiple tank fires and impact areas external to the installation.

   i. Cascade potential of primary events causing secondary events occurs when overpressures from VCE are above 0.3 bar and/or when heat radiation from fire is above 37.5 kW/m2.
   ii. The primary event at the proposed installation that has potential to cause secondary events arise due to leak/ spill in MS tank at Tank farm 2 and subsequent ignition resulting in VCE
   iii. It expected that the other MS tanks in tank farm 2 may collapse and cause escalation of primary incident leading to a serious emergency situation
   iv. Hence emergency planning should particularly focus on MS tank farm 2 to prevent and contain the escalation of the primary events

6.3 Incident Frequencies of Hazardous Outcomes within the installation

For every hazardous outcome (such as tank fire, pool fire, flash fire and VCE) quantified in the consequence assessment, frequency of its occurrence were determined. The analysis took into consideration the sequence of development of the event and the preventive and mitigation measures available within the installation.

The probabilities of these hazardous outcomes were assessed for proposed safety systems within the installation, considering the failure rates of primary events and available measures for detection and control. The main findings are summarised below

a) The probability of a hazardous outcome for the operation was estimated to be in range from 10^{-7} to 10^{-15} per year.
b) These frequency values for the individual outcomes can be considered to be extremely low due to the provision of several safety features and redundancies provided.
c) It can also be inferred the frequency of occurrence of secondary events will be extremely low as they require primary events for initiation, which itself is low.

6.4 Summary of Risk levels arising at the Installation

Individual risk levels inside the installation were evaluated at locations where people are stationed. The maximum individual risk (IR) is the cumulative effect of several events that may have impact on specific locations. These areas have been identified based on the distribution of personnel with the installation given in Annexure III.2

The maximum individual risk inside the installation falls at the TLFG and is of the order of 10^{-10} per year.

Table 6.2 Risk at manned location

Manned location	Event	Risk to personnel (/yr)
Pumphouse	Pool fire/ Flashfire from spill of MS	1.43E-11
	Pool fire from spill of HSD	9.50E-12

Manned location	Event	Risk to personnel (/yr)
TLFG	Pool fire/ Flashfire from spill of MS	7.52E-10
	Pool fire from spill of HSD	5.01E-10

Other manned locations lie beyond the damage zones of the hazardous events identified.

6.5 Acceptance Criteria

To assess the risk posed by the installation, a comparison may be made with risk criteria for levels of risk that is considered tolerable for similar industries. A selection based on the type of industry was made among the criteria commonly adopted (Hazard Identification & Risk Analysis – Code of Practice IS 15656 : 2006; ANNEX E) and is given below.

Table 6.3 Risk Criteria adopted for the installation

Application	Maximum Tolerable Risk (per year)	Negligible Risk (per year)
New Hazardous Industry	1.0E-6	1.0E-8

It can be seen that against these criteria the maximum risk at the installation (1.0E-10) falls above the range of negligible risk.

6.6 Conclusion

The risk evaluation for the proposed installation was carried out taking into consideration the severity and likelihood of occurrence of the most credible hazardous scenarios with potential to impact life, property and the environment. Risk is contained within the site and no significant impacts are expected beyond the boundaries. The maximum risk arises from events at the TLFG; however, this was found to be in the negligible range. This can be attributed to the layout of the various units within the site with ample interspacing distances and the presence of several safety features.

CHAPTER Seven Recommendations for Risk Reduction

7.1 Preamble

While the risk evaluated for the proposed operations at BPCL's site in Ennore has been found to be low, risk presentation for the scenarios within the installation should be considered in relative terms as BPCL has not adopted risk criteria of its own. BPCL should therefore continue its risk reduction programs to bring down the risk levels further.

Measures at reduction of risk have been suggested for events with potential to cause significant damage to life and property.

7.2 Control of ignition sources (conventional and unconventional)

Vapour clouds from tanks containing MS can be ignited if a suitable ignition source is present within a radius of 30 m from the edge of the dyke areas. Leaks in the pump and filling area from errors in handling can be ignited due to sparks from unconventional ignition sources.

a. All activities within the area, however well protected, should be considered as potential ignition sources.
b. BPCL has included several types of protection within the licensed areas. However, over time, switches & fixtures, cables connection joints, etc., may deteriorate due to moisture or aging and cause sparks and become potential source of ignition.
c. BPCL may therefore consider identification of unconventional sources of ignition with potential for generation of static charges and provide the necessary controls. This is a requirement under the latest international Hazardous Area Classification codes & guidelines.

7.3 Compliance with MB Lal Committee Recommendations (MBLCR)

As this is a new installation, it is expected that the safety features, layout and design of dyke & layout features are fully compliant with the latest recommendations. This will ensure the control of spread of inadvertent leaks from the tank farms. The following points may be emphasized.

a. Dykes should be made to be leak proof
b. The drain connection from the dyke to OWS should be sloped to minimize vaporization.
c. Adequate fire hydrants & monitors should be provided to OWS.
d. The above areas should be declared ignition free.

7.4 Vapour cloud dispersal

VCEs from the spill at the storage of MS are major contributors to risk levels in the installation. The chance of an explosion may increase if large spills of MS are not diluted or dispersed immediately.

BPCL may consider effective vapour cloud dispersal of leaked hydrocarbons along the following lines.

a. Activation of the sprinkler systems directly by gas detectors to disperse and dilute the escaping hydrocarbons. Such activation may be provided at storage tanks, pump house, and gantry

b. Areas surrounding the tankfarms should be kept free from any congestion (buildings, structures, pipeline racks, etc.) to prevent accumulation and ensure effective natural dispersal of spilled hydrocarbon vapours.

7.5 Manual of Permitted Operations

Several simultaneous operations may be conducted during the operation as part of BPCL's activities. To avoid any incident that may arise due to miscommunication and prevent any ad-hoc decisions or changes to operational sequences, BPCL is advised to prepare a manual of permitted operations, covering all units and activities for the proposed operations.

7.6 Site specific emergency planning

The installation needs to prepare emergency management system covering the storage and activities within the installation. Several primary events (e.g., VCE, tank fires, fires at TLFG, etc.) if realized could result in escalation and secondary events as noted in the risk study. Though these are events of low probability, they need to be addressed in the development of the site specific emergency plans accordingly.

7.7 Conclusion

Risk analysis studies were carried out for the BPCL's proposed POL Installation at Ennore covering the storages and associated operations and activities at the upcoming site. The study has assessed the site for potential to initiate and propagate an unintentional event or sequence of events that can lead to an incident and/or an emergency situation within the installation.

The risk of fires and explosion from the proposed POL installation affecting the operating personnel were found to be relatively low. The risk zones will be mainly confined within the plant site and will not have any effect on the persons outside the plant.

The maximum individual risk at manned location in the installation was assessed and found to range between 10^{-10}/yr to 10^{-11}/yr.

These risk levels are below the negligible levels when compared with risk criteria for new hazardous industry noted in Indian Standard - Hazard Identification & Risk Analysis – Code of Practice IS 15656 : 2006; (ANNEX E).

The risk was assessed considering the full implementation of the MB Lal Committee recommendations. The safety measures and other suggestions made in this report will further decrease the risks and ensure the long-term safe operation of the plant. The risk evaluated in report may be reviewed before the commissioning of the proposed installation.

Annexure I   Material Safety Data Sheets

1. Motor Spirit

2. High Speed Diesel

3. Ethanol

MOTOR SPIRIT

1 - Chemical Identity	
Chemical Name :	Motor Spirit
Chemical Formula :	Complex mixture of hydrocarbons
Synonyms :	Gasoline, Petrol
General Use :	Motor Fuel
C A S No. :	Not Listed
U N No. :	1203
Regulated Identification:	Shipping Name: Gasoline Hazchem Code : 3YE

2 – Hazards Identification	
Primary Entry Routes :	Ingestion, inhalation, skin and eyes
Acute Effects :	Inhalation: can cause dizziness, headache and nausea, depresses central nervous system and has an anesthetic effect. Breathing of liquid droplets may lead to chemical pneumonia. Ingestion : can lead to nausea, diarrhea and affect central nervous system.
	Skin irritant : Prolonged contact can result in skin drying and dermatitis.
	Eye irritant: Contact with eye causes pain and slight transient corneal epithelial disturbances.
Carcinogenicity :	Benzene component is listed as carcinogenic
Chronic Effects :	No data available

3 – First Aid Measures	
Eyes :	Flush with water for 15 min. Get medical attention.
Skin :	Wash with warm water & soap.
Inhalation :	Remove to fresh air. Consult a physician if irritation persists.
Ingestion :	Do not induce vomiting. Do not give liquids. Get medical help at once.

4 – Fire Fighting Measures	
Flash Point :	< - 10 °C
Auto ignition Temperature :	250 °C to 280 °C (highly variable)
LEL :	1.4 %
UEL :	7.6 %
Flammability Classification :	Flammable
Extinguishing Media :	Foam, Dry Chemical Powder, CO_2

Unusual Fire or Explosion Hazards :	Heat produces vapours and can cause violent rupture of containers. Vapours may travel long distance and can flash back
Hazardous Combustion Products :	Carbon di oxide, carbon mono oxide, benzene
Fire-Fighting Instructions :	Small fires can be extinguished by hand held extinguishers. Major fires may require withdrawal and allowing the tank to burn. Fire fighters should wear self breathing apparatus while fighting fire

5 – Accidental Release Measures	
Small Spills :	Shut off leaks without risk. Absorb on sand or earth.
Containment :	Prevent spillage from entering drains or water sources
Cleanup :	After spills wash area with soap and water preventing runoff from entering drains.

6 – Handling and Storage	
Handling Precautions :	Do not use/store near heat/open flame. Avoid contact with liquid or vapours. Use gumboots, gloves while handling the product. Do not inhale. Stay upwind while handling the product. Product should never be used to remove oil or grease from skin. It should not be siphoned by mouth. Tanks and dispensing equipments should be grounded to reduce static charge fires. It should be stored in closed containers away from heat & source of ignition. Avoid contact with skin and eyes. Wash thoroughly after handling.
	Use flameproof electrical equipment only.
	Earth all equipment and pipelines properly.
	Store in an enclosed vessel in a cool, well ventilated area away from heat & flame.
	Gas free the tank before entering / cleaning.
	Change oil soaked clothings promptly.
Storage Requirements :	Do not use/store near heat/open flame/water/acids

7 – Exposure Controls / Personal Protection	
Engineering Controls :	Provide proper ventilation for environment to be below Time Waited Average (TWA)
Respiratory Protection :	Use respiratory protection if ventilation is improper
Protective Clothing /	Use face shield, PVC gloves, safety boots while handling.
Equipment :	Contaminated clothing to be immediately removed

8 – Protection Physical and Chemical Properties	
Physical State :	Liquid at 15^{o}C & 1 atm
Appearance and Odour :	Water white liquid, dyed orange or red for detection. Characteristic hydrocarbon like odour
Vapor Pressure :	5.0 to 8.7 psi at 38 °C (RVP)

Specific Gravity :	0.71 to 0.77 gm / cc
Water Solubility :	Insoluble
Boiling Point :	35 °C to 215 °C
Freezing Point :	-40°C (Approx.)
Vapour Density :	3 to 4 (Air = 1)

9 – Stability and Reactivity

Stability :	Chemically stable.
Chemical Incompatibilities :	Incompatible with oxidizing agents & chlorine. Reacts vigorously with oxidising materials.
Conditions to Avoid :	Can undergo auto-oxidation in air & generate heat which can build up in a confined space to cause spontaneous combustion

Hazardous Decomposition Products: Carbon di oxide, carbon mono oxide

10 – Toxicological Information

* AICIGH TLV TWA : Gasoline – 300 ppm , Benzene – 0.5 ppm, MTBE – 50 ppm Toxicity Data : LD50 (Oral-Rat) 18.75 ml / kg

Acute Inhalation Effects : Benzene component is carcinogenic.

11 – Ecological Information

Prevent spillage from entering drains or water sources. After spills wash area with soap and water preventing runoff from entering drains. Can burn with lot of heat producing CO2 and CO.

12 – Disposal Considerations

Disposal : Dispose off Sludge through Bio-remediation or incineration.

13 – Transport Information

Shipping Name : Motor Spirit, Gasoline

14– Regulatory Information

Non - Toxic/Flammable Substance

* American Institutional Conference for Industrial & Govt. Hygienists (AICIGH)

* Threshold Limit Value (TLV)

* Time Waited Average (TWA)

HIGH SPEED DIESEL

1 – Chemical Identity

Chemical Name :	High Speed Diesel
Chemical Formula :	Complex mixture of hydrocarbons
Synonyms :	Diesel, Gas oil, High Flash HSD (HF HSD)
General Use :	Motor Fuel and in Defense aircrafts
C A S No. :	Not listed
U N No. :	1202
Regulated Identification:	Shipping Name: High Speed Diesel, Hazchem Code : 3 Z High Flash Diesel

2 – Hazards Identification

Primary Entry Routes :	Ingestion, inhalation, skin and eyes
Acute Effects :	Inhalation: can cause dizziness, headache and nausea, depresses central nervous system and has an anesthetic effect. Breathing of liquid droplets may lead to chemical pneumonia. Ingestion: can lead to nausea, diarrhea and affect central nervous system. Skin irritant : Prolonged contact can result in skin drying and dermatitis. Eye irritant :
Carcinogenicity :	Not listed as carcinogenic
Chronic Effects :	No data available

3 – First Aid Measures

Eyes :	Flush with water for 15 min. Get medical attention.
Skin :	Wash with warm water & soap.

Inhalation : Remove to fresh air. Consult a physician if irritation persists.

Ingestion : Do not induce vomiting. Do not give liquids. Get medical help at once.

4 – Fire Fighting Measures

Flash Point : > 35 °C and > 66°C for HF HSD

Auto ignition Temperature : 230 °C to 250 °C (highly variable)

LEL : 0.5 %

UEL :	5.0 %
Flammability Classification :	Flammable
Extinguishing Media :	Foam, Dry Chemical Powder, CO2

Unusual Fire or Explosion Hazards: Heat produces vapours and can cause violent rupture of containers	
Hazardous Combustion Products Carbon di oxide, carbon mono oxide, benzene	
Fire-Fighting Instructions :	Small fires can be extinguished by hand held extinguishers. Major fires may require withdrawal and allowing the tank to burn. Fire fighters should wear self breathing apparatus while fighting fire

5 – Accidental Release Measures	
Small Spills :	Shut off leaks without risk. Absorb on sand or earth.
Containment :	Prevent spillage from entering drains or water sources
Cleanup :	After spills wash area with soap and water preventing runoff from entering drains.

6 – Handling and Storage	
Handling Precautions :	Do not use/store near heat/open flame. Use gumboots, gloves while handling the product. Do not inhale. Stay upwind while handling the product. Product should never be used to remove oil or grease from skin. It should not be siphoned by mouth. It should be stored in dry, cool, well ventilated area in closed containers away from heat & source of ignition. Avoid contact with skin and eyes. Wash thoroughly after handling. Keep away from oxidising agents.
Storage Requirements :	Do not use/store near heat/open flame/water/acids

7 – Exposure Controls / Personal Protection	
Engineering Controls : Provide proper ventilation for environment to be below Time Waited Average (TWA)	
Respiratory Protection :	Use respiratory protection if ventilation is improper
Protective Clothing / Use face shield, PVC gloves, safety boots while handling.	
Equipment :	Contaminated clothing to be immediately removed

8 – Protection Physical and Chemical Properties	
Physical State :	Liquid @ 15°C & 1 atm
Appearance and Odour :	Straw yellow or dark yellow liquid. Characteristic hydrocarbon like odour
Vapor Pressure :	0.5 mm of Hg at 38 °C (RVP)
Specific Gravity :	0.82 to 0.86 gm / cc
Water Solubility :	Insoluble
Boiling Point :	110 °C to 375 °C
Freezing Point :	0 - 18°C
Vapour Density :	3 to 5 (Air = 1)
Sulphur content:	150 ppm to 2500 ppm and < 0.2% for HF HSD

9– Stability and Reactivity	
Stability :	Chemically stable.
Chemical Incompatibilities :	Incompatible with oxidizing agents & chlorine. Reacts vigorously with oxidising materials.
Conditions to Avoid :	
Hazardous Decomposition Products :	Carbon di oxide, carbon mono oxide

10 – Toxicological Information	
*AICIGH TLV TWA :	Yet to be ascertained
Toxicity Data :	To be established
Acute Inhalation Effects :	To be established

11 – Ecological Information

Prevent spillage from entering drains or water sources. After spills wash area with soap and water preventing runoff from entering drains. Can burn with lot of heat producing CO_2 and CO.

12 – Disposal Considerations

Disposal : Dispose off Sludge through Bio-remediation or incineration.

13 – Transport Information

Shipping Name : High Speed Diesel, High Flash Diesel

14 – Regulatory Information

Non - Toxic/Flammable Substance

* American Institutional Conference for Industrial & Govt. Hygienists (AICIGH)

* Threshold Limit Value (TLV)   * Time Waited Average (TWA)

ETHANOL

1 – Chemical Product and Company Identification	
Chemical Name :	Ethanol,
Chemical Formula :	C_2H_5OH
Synonyms :	Ethyl Alcohol; Ethyl Hydrate; Ethyl Hydroxide; Fermentation Alcohol; Grain Alcohol; Methylcarbinol; Molasses Alcohol; Spirits of Wine
General Use :	Extraction of vegetable oils
C A S No. :	64– 17 – 5
U N No. :	1170
Regulated Identification:	Shipping Name: Hazchem Code : 3 [Y] E

2 – Hazards Identification	
Appearance:	colorless clear liquid. Flash Point: 16.6 deg C. Flammable liquid and vapour. May cause central nervous system depression. Causes severe eye irritation. Causes respiratory tract irritation. Causes moderate skin irritation. This substance has caused adverse reproductive and fetal effects in humans. Warning! May cause liver, kidney and heart damage.
Target Organs:	Kidneys, heart, central nervous system, liver.
Potential Health Effects	
Eye:	Causes severe eye irritation. May cause painful sensitization to light. May cause chemical conjunctivitis and corneal damage.
Skin:	Causes moderate skin irritation. May cause cyanosis of the extremities.
Ingestion:	May cause gastrointestinal irritation with nausea, vomiting and diarrhea. May cause systemic toxicity with acidosis. May cause central nervous system depression, characterized by excitement, followed by headache, dizziness, drowsiness, and nausea. Advanced stages may cause collapse, unconsciousness, coma and possible death due to respiratory failure.
Inhalation:	Inhalation of high concentrations may cause central nervous system effects characterized by nausea, headache, dizziness, unconsciousness and coma. Causes respiratory tract irritation. May cause narcotic effects in high concentration. Vapors may cause dizziness or suffocation.
Chronic:	May cause reproductive and fetal effects. Laboratory experiments have resulted in mutagenic effects. Animal studies have reported the development of tumors. Prolonged exposure may cause liver, kidney, and heart damage.

3 – First Aid Measures	
Eyes :	Flush with water for 15 min. Get medical attention.
Skin :	Get medical aid. Flush skin with plenty of water for at least 15 minutes while removing contaminated clothing and shoes. Wash clothing before reuse. Flush skin with plenty of soap and water.
Inhalation :	Remove to fresh air. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. Get medical aid. Do NOT use mouth-to-mouth resuscitation. breathing is difficult, give oxygen. Get medical aid. Do NOT use mouth-to-mouth resuscitation..
Ingestion :	Do not induce vomiting. If victim is conscious and alert, give 2-4 cupfuls of milk or water. Never give anything by mouth to an unconscious person. Get medical aid

4 – Fire Fighting Measures	
Flash Point : 16.6 °C	
Auto ignition Temperature : 363 °C	
LEL : 3.3 %	
UEL :	19 %
Flammability Classification :	Flammable
Extinguishing Media :	Foam, Dry Chemical Powder, CO_2
Unusual Fire or Explosion Heat produces vapours and can cause violent rupture of	
Hazards : containers	
Hazardous Combustion Carbon di oxide, carbon mono oxide	
Products :	
Fire-Fighting Instructions :	Fire fighters should wear self breathing apparatus while fighting fire

5 – Accidental Release Measures	
Spills/ leaks :	Absorb spill with inert material (e.g. vermiculite, sand or earth), then place in suitable container. Remove all sources of ignition. Use a spark-proof tool. Provide ventilation. A vapour suppressing foam may be used to reduce vapors.

6 – Handling and Storage	
Handling Precautions :	Wash thoroughly after handling. Use only in a well-ventilated area. Ground and bond containers when transferring material. Use spark-proof tools and explosion proof equipment. Avoid contact with eyes, skin, and clothing. Empty containers retain product residue, (liquid and/or vapour), and can be dangerous. Keep container tightly closed.
	Avoid contact with heat, sparks and flame. Avoid ingestion and inhalation. Do not pressurize, cut, weld, braze, solder, drill, grind, or expose empty containers to heat, sparks or open flames.
Storage Requirements :	Keep away from heat, sparks, and flame. Keep away from sources of ignition. Store in a tightly closed container.
	Keep from contact with oxidizing materials. Store in a cool, dry, well-ventilated area away from incompatible substances. Flammables-area. Do not store near perchlorates, peroxides, chromic acid or nitric acid

7 – Exposure Controls / Personal Protection	
Engineering Controls :	Use explosion-proof ventilation equipment. Facilities storing or utilizing this material should be equipped with an eyewash facility and a safety shower. Use adequate general or local exhaust ventilation to keep airborne concentrations below the permissible exposure limits
Respiratory Protection :	Use respiratory protection if ventilation is improper
Protective Clothing / Wear appropriate protective clothing to prevent skin exposure.	
Equipment :	Contaminated clothing to be immediately removed

8 – Protection Physical and Chemical Properties	
Physical State :	Liquid

Appearance and Odor :	Colorless and Mild, rather pleasant, like wine or whisky
Vapor Pressure :	59.3 mm Hg @ 20°C
Specific Gravity :	0.790 @ 20°C
Water Solubility :	Miscible
Boiling Point :	63 °C to 70 °C
Freezing Point :	-114.1 °C
Vapour Density :	1.59

9 – Stability and Reactivity

Stability :	Stable under normal temperatures and pressures.
Chemical Incompatibilities :	Strong oxidizing agents, acids, alkali metals, ammonia, hydrazine, peroxides, sodium, acid anhydrides, calcium hypochlorite, chromyl chloride, nitrosyl perchlorate, bromine pentafluoride, perchloric acid, silver nitrate, mercuric nitrate, potassium-tert-butoxide, magnesium perchlorate, acid chlorides, platinum, uranium hexafluoride, silver oxide, iodine heptafluoride, acetyl bromide, disulfuryl difluoride, tetrachlorosilane + water, acetyl chloride, permanganic acid, ruthenium (VIII) oxide, uranyl perchlorate, potassium dioxide
Conditions to Avoid :	Incompatible materials, ignition sources, excess heat, oxidizers.
Hazardous Decomposition	Carbon monoxide, irritating and toxic fumes and gases, carbon Products : dioxide

10 – Toxicological Information

Draize test, rabbit, eye: 500 mg Severe;

Draize test, rabbit, eye: 500 mg/24H Mild;

Draize test, rabbit, skin: 20 mg/24H Moderate;

Inhalation, mouse: LC50 = 39 gm/m3/4H;

Inhalation, rat: LC50 = 20000 ppm/10H;

Oral, mouse: LD50 = 3450 mg/kg;

Oral, rabbit: LD50 = 6300 mg/kg;

Oral, rat: LD50 = 9000 mg/kg;

Oral, rat: LD50 = 7060 mg/kg;

11 – Ecological Information

Ecotoxicity: Fish: Rainbow trout: LC50 = 12900-15300 mg/L; 96 Hr; Flow-through @ 24-24.3°C Rainbow trout: LC50 = 11200 mg/L; 24 Hr; Fingerling (Unspecified) ria: Phytobacterium phosphoreum: EC50 = 34900 mg/L; 5-30 min;

Microtox test When spilled on land it is apt to volatilize, biodegrade, and leach into the ground water, but no data on the rates of these processes could be found. Its fate in ground water is unknown. When released into water it will volatilize and probably biodegrade. It would not be expected to adsorb to sediment or bioconcentrate in fish.

Environmental: When released to the atmosphere it will photodegrade in hours (polluted urban atmosphere) to an estimated range of 4 to 6 days in less polluted areas. Rainout should be significant.

12 – Disposal Considerations

Dispose as per state hazardous waste regulations.

13 – Transport Information

Shipping Name : ETHANOL

14 – Regulatory Information

Non - Toxic/Flammable Substance

Annexure II Past Accident Analysis

Past Accidents involving diesel and motor spirit

The analysis of past events provides some valuable information, which can be used as guidance for design, construction and operation of tank farms. The information also helps in preparing emergency plans for tank farms. The lessons learnt from major events will help in improving the standards of tank farm safety.

Recent Incidents involving fires at storage tank farms

An incident that occurred on 29th October, 2009 at the Indian Oil Corporation's Jaipur Oil Terminal in Sanganer has been described as a massive vapour cloud explosion. In this incident a huge leak of the product took place as a jet of liquid from the "Hammer Blind Valve" on the delivery line of the tank leading to the MS pump. After about an hour and 15 minutes of the leak having started, there was a massive explosion followed by a huge fireball covering the entire installation. It is estimated that in this one hour and 15 or 20 minutes of uncontrolled leak, about 1000 tons of MS could have escaped out, which would have generated enough vapour to cause an explosion equivalent to 20 tons of TNT.

The incident has so far only one established precedent that happened in December 2005 in a very similar oil terminal (Buncefield Oil Terminal) near Heathrow Airport in U.K. In this incident a large quantity of MS (reportedly 300 tons) had leaked because of overflow from a MS tank, which went unnoticed because of malfunction of tank level control and associated safety interlocks.

On 23rd October, 2009, a similar incident occurred in a petroleum oil terminal in the Caribbean Refinery (which was under shutdown) at Puerto Rico. Here too, a massive MS leak due to overflow of MS tank during ship unloading reportedly resulted in loss of containment of around 800 tons which caused a massive explosion. No other such incident i.e. massive unconfined vapour cloud explosion in petroleum product storage has occurred/reported other than above three cases.

Table 2.2.1 Past Accidents Records at Tank farms worldwide

S. No	Date	Location	Description
1	13-Jun-2010	Greensboro, NC	Lightning ignited a gasoline storage tank in a 72-tank battery, closing an Interstate Electrical grounding system failed
2	26-Apr-2010	New London, TX	One person died and another was injured in an oil tank explosion
3	14-Apr-2010	Ingolstadt, Germany	Refinery fire-fighters extinguished a fire when gasoline leaked from pipe work
4	14-Apr-2010	Weleeka, OK	One man died and another was injured in a storage tank explosion
5	13-Mar-2010	Salamanca, Mexico	A gasoline storage tank fire at an oil refinery burned nearly three hours
6	8-Feb-2010	Melbourne, Australia	A 924,600-gallon refinery storage tank of gasoline caught fire and began leaking fuel
7	23-Oct-2009	San Juan, Puerto Rico	The explosion ignited a fire that fed on jet fuel, bunker fuel and gasoline stored at the facility, and produced plumes of thick, black, potentially toxic smoke that could be seen for miles
8	29-Oct-2009	Jaipur, India	An explosion spread fire through an oil installation
9	30-Jul-2009	Mina Abdulla, Kuwait	A storage tank fire shut down one of the country’s largest refineries
10	12-May-2009	Searcy, AR	A gasoline storage tank explosion killed three contract workers
11	23-Apr-2009	Russellville, AL	An above ground storage tank at a fuel transfer station was damaged by fire
12	18-Jan-2009	Plumpang, Indonesia	A storage tank containing five million litres of gasoline caught fire at a fuel installation
13	12-Jan-2009	Woods Cross, UT	Four refinery workers were injured in an explosion and fire in a gasoline storage tank
14	30-Oct-2008	Shreveport, LA	Fire followed an explosion in a storage tank at an oil refinery
15	3-Oct-2008	Cremonia, Italy	A worker was injured in a tank explosion at a refinery
16	18-Aug-2008	Johor, Malaysia	Fire spread through gasoline storage tanks
17	3-Jul-2008	Xinjiang, China	Seven people died in an oil tank explosion

S. No	Date	Location	Description
18	2-Jun-2008	Lalbaug, India	An oil installation was destroyed by fire
19	27-Mar-2008	Makhachkala, Russia	An explosion and fire at an oil installation left one worker burned
20	27-Mar-2008	Port of Corinto, Nicaragua	An explosion rocked a storage tank being filled
21	1-Feb-2008	Slocum, TX	A lightning strike caused an explosion in an oil tank battery
22	12-Jan-2008	Chennai, India	Two workers were killed in an explosion while cleaning a storage tank at an oil refinery
23	6-Dec-2007	Sharjah, U.A.E	Fire destroyed an oil installation, and then spread into nearby glass and paper factories. 4 people were killed
24	6-Dec-2007	Phoenix, AZ	A tank fire broke out at a petroleum products plant
25	19-Sep-2007	Siparia, Trinidad & Tobago	Two workers were injured in an oil storage tank explosion at a refinery
26	4-Aug-2007	Lviv, Ukraine	A fire destroyed 180 tons of gasoline at a storage installation
27	23-Jun-2007	Cadereyta, Mexico	Lightning ignited a gasoline storage tank at an oil refinery
28	24-May-2007	Slovag, Norway	A storage tank fire ignited at a tank farm near the country’s largest refinery
29	27-Mar-2007	Shreveport, LA	An explosion and fire rocked an oil refinery, leaving one worker with second-degree burns
30	22-Mar-2007	Lagos, Nigeria	Fire broke out at a petroleum installation
31	22-Mar-2007	Ngu Hanh, Vietnam	Four people were killed and five injured when a gasoline storage tank exploded
32	14-Feb-2007	Poleglass, U.K.	A major fire broke out at a fuel installation
33	14-Sep-2006	Seminole County, FL	A gasoline tank explosion severely burned 1 worker
34	3-Jul-2006	Bernard Perish, LA	A tank containing 200,000 barrels of gasoline caught fire when it was struck by lightning at an oil refinery
35	26-Jun-2006	Shiraz	One person was killed in a gasoline explosion
36	12-Jun-2006	Harristown, IN	About 71,000 gallons of fuel leaked from a gasoline storage tank at a petroleum plant

S. No	Date	Location	Description
37	12-Jun-2006	Glenpool, OK	Fire broke out in a 150,000 barrel gasoline storage tank
38	11-Dec-2005	Buncefield, U.K.	A massive explosion spread fire through an oil storage installation north of London, destroying 17 tanks.
39	13-Oct-2005	Arkhangelsk, Russia	An oil tank exploded at a storage installation and killed 2 workers
40	17-Jun-2005	Kurkumbh, India	A fire broke out in a tank containing petrochemicals at a petroleum refinery
41	14-May-2005	Ripley , OK	An oil storage tank exploded killing two workers
42	29-Oct-2004	Baroda , India	Sixteen workers were injured in an explosion at a gasoline refinery
43	14-Oct-2004	Martinez , CA	A fire broke out in a holding tank at a refinery, taking three hours to extinguish
44	6-Dec-2003	Temple, OK	Two people were burned after two gasoline storage tanks exploded while the plant manager and owner were checking levels in one of the tanks. Fumes were ignited and touched off the explosion. Nearby residents were evacuated
45	21-Jul-2003	Ponca City, OK	1 of 3 workers injured in an explosion and fire in a oil refinery gasoline processing unit later died
46	3-Jun-2003	Rostov-on-Don, Russia	Eight people were injured, five critically as a result of an explosion and fire at an oil refinery. Officials said the explosion occurred when workers entered a reservoir to clean its interior of gasoline
47	13-Jan-2003	Garyville, La	Fire broke out at a gasoline refinery but was out within 4 hours and no one was hurt. A spokesman said that the cause of the fire unknown. The fire broke out in the crude oil unit, the spokesman said
48	8-Dec-2002	Cabras, Guam	Fire broke out in a tank farm during a typhoon. Two tanks (one of gasoline and one of jet fuel) caught fire and burned out with 24 hours
49	23-Nov-2002	Yokohama, Japan	A gasoline storage tank caught fire several minutes after workers started filling it with unleaded gasoline from an oil tanker. No injuries were reported

S. No	Date	Location	Description
50	24-Jan-2002	Greenville, OH	A gasoline storage tank exploded, causing minor injuries to two workers and damage to three homes. Two workers were preparing to move a 24,000-gallonhorizontal gasoline storage tank when their cutting torch generated sparks and ignited vapors in the tank
51	7-Jan-2002	Superior, WI	A fire that ignited during an inspection destroyed an oil refinery gasoline storage tank. The tank was nearly empty at the time
52	21-Dec-2001	Tula, Mexico	At least 14 workers were injured in an explosion at a Pemex plant in Tula, due to a leak of light gasoline
53	10-Dec-2001	Dartmouth, Nova Scotia	An explosion at an oil refinery sent a 1,400-barrel heating fuel storage tank flying. The tank was only one-tenth full at the time
54	7-Jun-2001	Norco, LA	A world record was set when fire fighters successfully extinguished a full-surface fire in a 270-foot diameter gasoline storage tank, saving almost half the product
55	25-Apr-2001	Sukhodol, Russia	Fire broke out in a 3,000 ton tank at an oil storage refinery. Fire fighters extinguished the blaze in four hours
56	7-Nov-2000	Kingston, Jamaica	An empty storage tank at an oil refinery exploded, igniting a fire that spread to two tanks filled with gasoline
57	22-Mar-2000	Abia State,Nigeria	Fifty people were killed during a pipeline fire that occurred while siphoning gasoline
58	28-Oct-1999	Ponca City, OK	Two workers inspecting a gasoline storage tank at a refinery were critically burned when the tank burst into flames
59	14-Jun-1999	Memphis, TN	Gasoline leaking from an oil refinery storage tank ignited a grass fire. Workers brought the fire under control before it could spread
60	3-May-1999	Bathurst, Australia	An explosion at a fuel installation damaged a tanker truck. More than 5,000 gallons of diesel was transferred from the damaged truck to another vehicle
61	12-Nov-1998	Woods Cross, UT	An explosion in an oil tank with a capacity of 1.5 million gallons resulted in a brief fire but no injuries. Workers were transferring oil to tankers at the time of the blast

S. No	Date	Location	Description
62	11-Nov-1998	Ciudad Madero, Mexico	An explosion at an oil refinery killed one worker and injured six. The explosion was located in a tank used for storing water and gasoline residual
63	17-Oct-1998	Igoumenitsa, Greece	Two seamen suffered minor injuries in an explosion and fire in a petroleum storage tank at a coastal port. The explosion happened after a tanker finished unloading gasoline at the port

Annexure III Information used in the studies

Identification of Sources of Ignition & Safety Review As the availability of an ignition source is essential towards the realisation of any unwanted fire the site was closely examined.

Facilities and operations of this Terminal is designed and maintained to prevent any incidence of fire. All internal electrical facilities in the Installation are designed to prevent the generation of spark. Trucks enter the Installation with Explosive Department approved spark arrestors so that spark cannot come out with exhaust gases from the truck.

Operations are designed to ensure no generation of sparks. Earthing system is provided to dissipate static electrical charge to eliminate the chances of spark during handling of products.

Possible ignition sources and the safeguards in place were identified and the details are given in the table below.

Table III.1 Potential sources of ignition within the BPCL Installation

Location	Safeguards
Inside the Installation	
Pump house	Enclosed; Flameproof motors & junction boxes
Petroleum products Compressor	Enclosed; Flameproof motors & junction boxes
Tank lorry movement at loading Bays	Spark arrestors
MCC room	Enclosed; all electrical cables underground
DG Set room	Enclosed; all electrical armoured cables underground, earthed
Transformer yard	Fenced; Earthing; located in de-licensed area
Fire water Pump house	Enclosed; all electrical cables underground
External to installation area	
Traffic on road	Green belt
High Transmission line	Green belt
Pipeline corridor	Underground
Rail way line	Greenbelt

Tanks, pumps and piping are earthed effectively. All electrical fixtures, drive units and motors within licensed area are flameproof, and conform to IS 2148.

III.2 Population at the site

The population distribution within the facility consists of employees and contract labour working in the installation. Details are listed in Table III.2

Table III.2 Distribution of Personnel within the installation

Activity	No. of persons in day shift
Truck loading activities	
TLF gantry	4
Truck loading bay (driver & cleaner)	32
Others	
Administration	8
Security	4 (including night shift)
Maintenance	4
Electrical shed	2
Total	**54**

Since the area has been designated for industrial purposes, the density of habitation is relatively low in the vicinity.

Annexure IV Identifying Independent Protection layers (IPLs) – Layers for Defense against a Possible Accident

Safeguards or Independent Protection Layers (IPL) have been classified as active or passive and preventive (pre-release) or mitigating (post-release) depending on how and when they act and their efficacy in reducing the frequency or consequence of an initiating event.

The classification of layers of safeguards is given in Table below.

Table IV.1 Types of Safeguards / IPLs used in the analysis[7]

Layer no.	Type	Description
1.	Process design	Inherently safe designs are implemented to eliminate possible scenarios.
2.	Basic Process Control Systems (BPCS)	Including normal manual controls is the first level of protection during normal operation and is designed to maintain the process within the safe operating region.
3.	Critical alarms and human intervention	Systems that are normally activated by the BPCS form the second level of protection during normal operation.
4.	Safety Instrumented Systems (SIF)	A combination of sensors, logic solvers and final elements with a specified integrity level that detects an out-of-limit or abnormal condition independent of the BPCS and brings the process to a functionally safe state.
5.	Physical protection	Can be provided to a high degree by devices such as relief valves, rupture disks, etc. These however require appropriate design and maintenance, and their effectiveness can be impaired in fouling/corrosive conditions.
6.	Post-release protection	Afforded by passive devices such as dykes, blast walls, etc. These provide a high degree of protection if designed and maintained correctly.
7.	Installation and community emergency responses	Features such as fire brigades, manual deluge systems, facility and community evacuation, shelters, etc., are activated after an initial release. These are not normally considered IPL as there are too many variables affecting their effectiveness in mitigating scenarios, and in the case of Community Emergency Responses, they provide no protection for installation personnel.

In order to be considered an IPL, a device, system or action must be

- Effective in preventing the consequence, when it functions as designed;
- Independent of the initiating event and the components of any other IPL already claimed for the same scenario;
- Auditable or capable of validation by documentation, review, testing, etc.

The efficiency of an IPL is quantified in terms of its probability of failure on demand (PFD). This is the probability that a system will fail to perform a specified function on demand. The smaller the value of the PFD, the larger the reduction in frequency of the consequence for a given initiating event.

[7] Layer of Protection Analysis – Simplified Process Risk Assessment' published by Center for Chemical Process Safety of the American Institute of Chemical Engineers, New, York, New York, 2001