Bharat Petroleum Corporation Limited,

Karur Receiving Terminal, Athur & Kadapparai Village, Athur Post, Karur 639 002 TN

PROPOSED INCREASE IN TANKAGE FOR ETHANOL & INTRODUCTION OF TANKAGE FOR BIODIESEL

RISK ANALYSIS REPORT

February 2017

Submitted by:

RiskChem Engineering

#4 First Street
VGP Golden Beach South Part III
Off East Coast Read
Chennai 600119
TN, INDIA

Tel: (+91 44) 2453 0699
Mob: (+91) 98401 44908

Project Summary Page

Report No.	1615
Report date	FEBRUARY 2017
Project Title & subtitle	PROPOSED INTRODUCTION OF NEW STORAGE TANKS FOR BIODIESEL AND ETHANOL AT BPCL'S KARUR OIL RECEIVING TERMINAL, TAMIL NADU RISK ANALYSIS STUDIES
Project Consultant	Dr. A. KOSHY (*Chem. Engg*.)
Reporting organization name & address **Ph:** **Fax:** **email:**	RISKCHEM ENGINEERING #4, FIRST CROSS ST., VGP GOLDEN BEACH SOUTH PART III CHENNAI 600 119 044 2453 0699/ 98401 44908 044 2453 0699 consultancy@riskchem.com
Supporting organization name & address	BHARAT PETROLEUM CORPORATION LTD., 1, RANGANATHAN GARDENS OFF 11TH MAIN ROAD, POST BAG 1212, 1213 ANNA NAGAR, CHENNAI 600 040
Sponsoring organization reference(s)	Email dated 31.01.2017
No. of pages	MAIN REPORT – 36 PAGES APPENDICES – 19 PAGES

Summary

1. The report discusses the risk & safety aspects relating to the proposed introduction of storage of ethanol and biodiesel at the BPCL Karur Oil Receiving Terminal, located at Athur & Kadapparai Village, Karur Dist., Tamil Nadu
2. This exercise has been undertaken in compliance with the rules and regulations that govern installations involving hazardous chemicals
3. The overall approach and methodology employed for the study was based on the guidelines given in IS 15656 : 2006, Indian Standard – Hazard Identification and Risk Analysis – Code of Practice, May 2006
4. Various risk assessment tools such as Fire & Explosion Indexing, Consequence & Probability Analysis were used to assess the risk posed by the proposed modification
5. The results of the Risk Analysis and appropriate risk reduction measures are provided in the report
6. The assessment was based on chemical data and process related information provided by the company.
7. 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.

DR. A. KOSHY (PROJECT CONSULTANT)
FEBRUARY 2017

Table of Contents

LIST OF ABBREVIATIONS

A/G	Above Ground
b.p	Boiling Point
BIS	Bureau of Indian Standards
BPCL	Bharat Petroleum Corporation Limited
CCPS	Center For Chemical Process Safety
CPQRA	Chemical Process Quantitative Risk Assessment
DCP	Dry Chemical Powder
F&EI	Fire & Explosion Index
FLP	Flameproof
GPH	General Process Hazard
HSD	High Speed Diesel
LFL	Lower Flammable Limits
MCAC	Maximum Credible Accident & Consequence
MF	Material Factor
MSIHC	Manufacture, Storage & Import Of Hazardous Chemicals Rules
MOV	Motor Operated Valve
MS	Motor Spirit
MSDS	Material Safety Data Sheet
NFPA	National Fire Protection Agency
OISD	Oil Industry Safety Directorate
OWS	Oil Water Separator
P&ID	Piping And Instrumentation Diagram
PHA	Preliminary Hazard Analysis
ppm	parts per million
QRA	Quantitative Risk Assessment
ROSOV	Remotely Operated Shut Off Valve
SPH	Special Process Hazard
TLFG	Tank Lorry Filling Gantry
TT	Tank Truck
TWFG	Tank Wagon Filling Gantry
U/G	Underground
UFL	Upper Flammable Limits
VCE	Vapor Cloud Explosion

Chapter 1 Introduction

1.1 Preamble

Bharat Petroleum Corporation Limited (BPCL) has an oil receiving terminal at Karur in Karur district of Tamil Nadu State for the purpose of receipt, storage and dispatch of petroleum products such as motor spirit (MS), high speed diesel (HSD) and superior kerosene (SKO).

The Karur oil receiving terminal receives petroleum products from PETRONET CCK (Cochin - Coimbatore - Karur) pipeline distribution network. The existing storage units consist of different types of aboveground tanks. Dispatch from the installation is done by road tankers and train wagons.

In compliance with the directives of the Govt. of India, the company has undertaken to supply blended fuels that serve to reduce the import burden on account of crude petroleum and also to reduce vehicle exhaust emissions. Petrol is to be blended with ethanol and diesel with biodiesel for supply to retail outlets in accordance with appropriate BIS standards.

To this end, BPCL proposes to increase the onsite storage capacity of ethanol and introduce storage of biodiesel within the site. The proposed above ground storage tanks are BHC construction type with fixed roof. Land acquisition is neither required nor envisaged, as the tanks will be located within the premises, adjacent to the existing storage tanks.

As the proposed modification involves flammable materials, and the activities undertaken at the site are classified as hazardous, risk analysis studies were conducted to assess the degree of risk arising from the increase in tankage. The report contains the results of the risk assessment study carried out for the proposed enhancement of storage and associated activities.

1.2 Description of facilities

The oil receiving terminal, commissioned in 2002, is located about 5 km from Karur railway station along the State Highway SH-8 and covers an area of approximately 220 acres. To the north and east is the Southern Railway line between Karur and Murthypalayam junctions, while the state highway SH-8 lies on the south and west. Athur village is located south-west of the facility. The Petronet CCK facility is located in the north-west side of the oil storage terminal.

The key plan of the site is given in Fig 1.1, while Fig 1.2 shows the satellite image of the location.

Fig 1.1 Key plan of BPCL Karur Oil Receiving Terminal

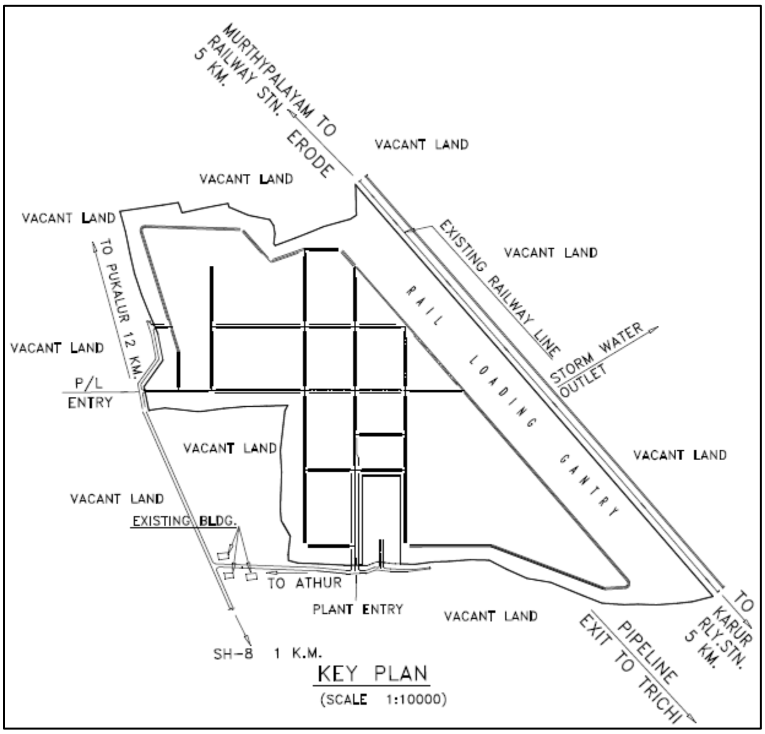


Fig 1.2 Satellite map of BPCL Karur Oil Receiving Terminal

The facility comprises of above ground and underground storage for MS, HSD, SKO & ethanol, and loading facilities for tank trucks. MS, HSD & SKO are received from Petronet CCK Kochi-Coimbatore-Karur pipeline via pipeline receipt manifold and then transferred via pipeline to the dedicated storage tanks in the hydrocarbon tank farm area. From the storage tanks the petroleum products are transferred at the loading gantry to trucks for dispatch to retail outlets within the distribution circle for public use.

The details of the storage units currently available at the installation are given in the table 1.1 below. The storage units are grouped within dykes / tank farms (TF 1 – 4) with fire break walls between the tanks. Each dyke is designed to contain any leak of petroleum product and limit the spread of the product from the tanks in the event of leak or failure of tanks.

Table 1.1 Existing storage units at the site

Tank No	**Product Stored**	**Storage Capacity**	**Tank Type**		**Tank dimensions**	**Location**	**Area of dyke**
		KL		**Roof Type**	**Dia x H (m)**		**(m^2)**
T-001A	HSD	8740	BHC	Floating	28.0 x 16.0	T1	9415
T-001B	HSD	8740	BHC	Floating	28.0 x 16.0		
T-001C	HSD	8740	BHC	Floating	28.0 x 16.0		
T-001D	HSD	8740	BHC	Floating	28.0 x 16.0		
T-002A	SKO	4440	BHC	Floating	22.0 x 13.5	T2	6338
T-002B	SKO	4440	BHC	Floating	22.0 x13.5		
T-002C	MS	4440	BHC	Floating	22.0 x 13.5		
T-003A	MS	38160	BHC	Floating	22.0 x 13.5	T3	26002
T-003B	HSD	38160	BHC	Floating	58.5 x 16.0		
T-003C	MS	9380	BHC	Floating	58.5 X 16.0		
T-004A	SLOP	1075	BHC	Cone roof	13.0 x 9.0	T4	1320
T-004B	SLOP	1075	BLC	Cone roof	13.0 x 9.0		
T-006A	ETHANOL	100	A/G - H	Dished end	3.2 x 13.2		
T-006B	HI SPEED HSD	100	A/G - H	Dished end	3.2 x 13.2		
T-007B	MS (SPEED)	200	A/G - H	Dished end	4.0 x 16.4		
T-008A	BIO-DIESEL	200	A/G - H	Dished end	4.0 x 16.4		
T-0010A	Sample collection tank	10	A/G - H	Dished end	2.0 x 8.5		
T-0010B	Sample collection tank	10	A/G - H	Dished end	2.0 x 3.5		
U/G	TL fueling tank	20	U/G - H	Dished end	7.8 x 3.5		

1.2.1 Proposed additions in storage

Under the proposed enhancement of storage project, new above ground (A/G) fixed roof tanks for Ethanol and Biodiesel are proposed to be introduced. The products will be brought to the site in road tank lorries, unloaded and stored at the site for blending.

The new tanks for storage of Biodiesel and Ethanol are proposed to be located within the existing tank farm T2 and T1 respectively along with existing storage tanks.

The details of the proposed new storage units are given in the table 1.2 below.

Table 1.2 New storage units proposed at the site

Tank ID	Product Stored	Licensed Capacity	Tank Type		Tank dimensions	Area of Dyke	Location
		KL		Roof type	Dia x H (m)	m^2	
T-011A	Ethanol	858	A/G	Fixed roof	9.0 x 13.5	9415	T1
T-011B	Ethanol	858	A/G	Fixed roof	9.0 x 13.5		
T-012A	Biodiesel	2600	A/G	Fixed roof	16.0 x 13.5	6338	T2
T-012B	Biodiesel	2600	A/G	Fixed roof	16.0 x 13.5		

The existing tank farm T2 dyke area shall be increased to ensure 110% capacity of the largest tank.

The proposed tanks will be provided with auto level indicators, limit switches, temperature transmitters, and connected to the existing rainwater drain system and oil water separator.

The existing firefighting facilities at the tank farm will be extended to the proposed new tanks as per OISD STD 117. Automatic medium velocity sprinkler system will be provided for all fixed roof tanks. The operational activities for normal operations as well as emergency services for the new tanks will be integrated within the existing plant management system.

The proposed tanks for Biodiesel and Ethanol will tie-in to the existing hydrocarbon receiving and transfer suction lines.

Fig 1.3 shows the layout of the site and proposed location of the new additional storage units. A description of the proposed activities at the site is given in Appendix 1.

1.3 Objectives of Risk Assessment Study

The objectives of the study are to provide:

- Preliminary identification of hazards and hazardous scenarios that could produce an undesirable consequence arising from the proposed increase in tankage.
- Assessment of consequences of leak or spill of petroleum products from proposed increase in storage within the installation in terms of radiation, blast waves or dispersion.
- Determination of the magnitude of all major accidents arising due to the proposed increase in storage that have the potential to cause damage to life, property and environment 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.
- Review of existing safety features (organizational systems & safety equipment)
- Recommendations for prevention, control and mitigation measures for any identified risk

The overall aim of the study is to provide a degree of predictability on the risk of the operation as a result of the proposed increase in storage.

1.4 Methodology & Approach employed

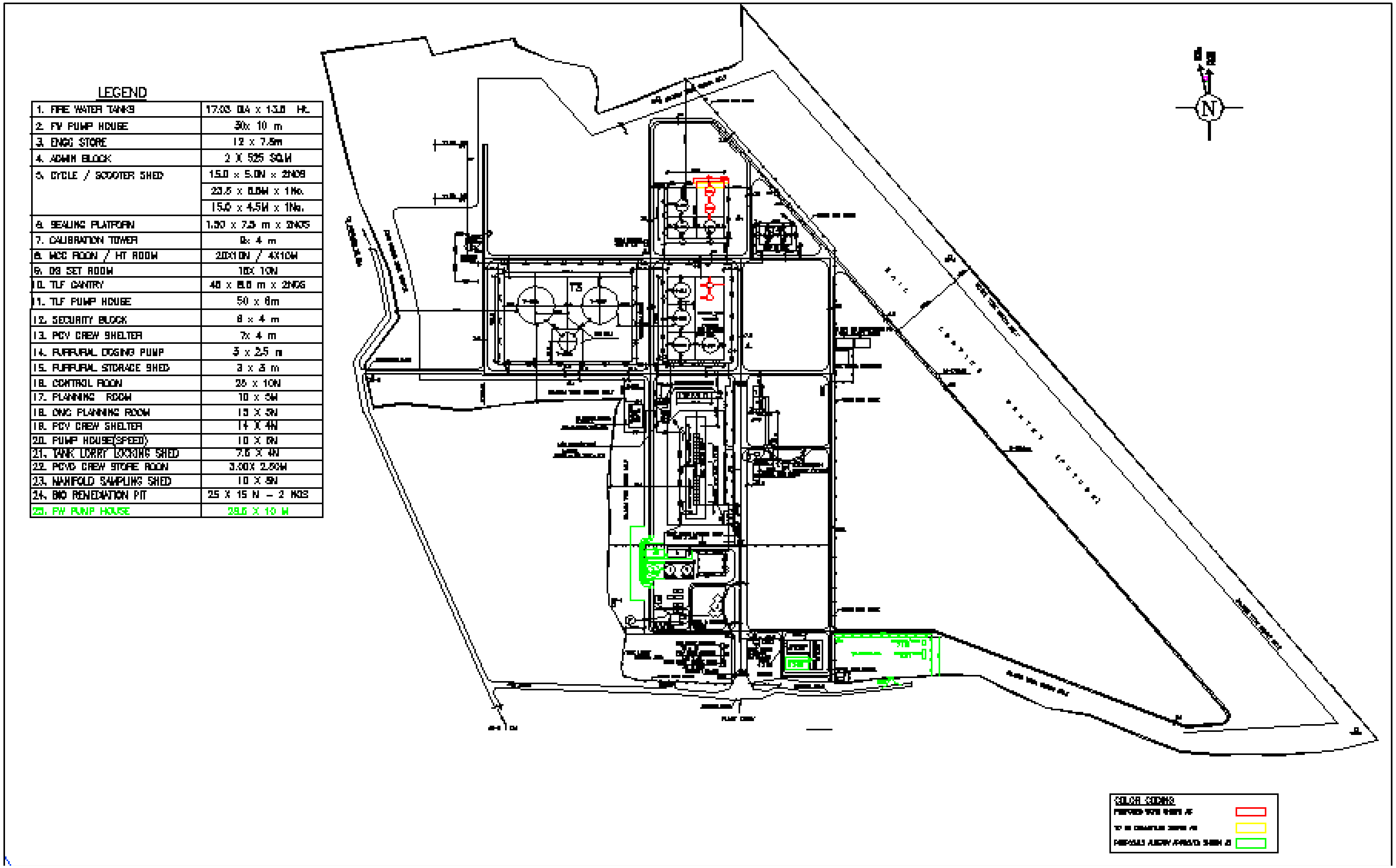
Risk analysis consists of hazard identification studies to provide an effective means to identify different types of hazard during the operation of the facility. This is followed by an assessment of the impacts of these hazards.

The assessment was based on MCAC (Maximum Credible Accident & Consequence) approach. This technique identifies the worst-case and most credible accident scenarios and assesses its consequences on personnel and property inside and outside the terminal.

The present studies were 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 studies are described in the subsequent chapters.

Fig 1.3 Layout of the Oil Receiving Terminal showing locations of proposed additional tanks



Appendix 1 Activities associated with Ethanol & Biodiesel at the Karur receiving terminal

The main operational activities in the installation are receipt of MS, HSD and SKO, storage in designated tanks and truck loading for distribution.

In addition to existing operations, receipt, transfer and storage of ethanol and biodiesel are envisaged.

The operation details for the proposed additional operations are given below:

a. <u>For receipt of Biodiesel & Ethanol (Tanker unloading)</u>

1) For Ethanol

Ethanol is received at the TLF pump house and transferred to proposed 858 KL Tank via 10” pipeline

Temperature: 30 °C

Pressure: 1 atm

Flowrate: 75 m^3/hr [if one pump (at Ethanol pump house TLF) operates].

2) For Biodiesel

Biodiesel is received at the TLF gantry pump house and transferred to proposed 2600 KL Tanks via 10’’pipeline

Temperature: 30 °C

Pressure: 1 atm

Flowrate: 200 m^3/hr [if one pump operates]

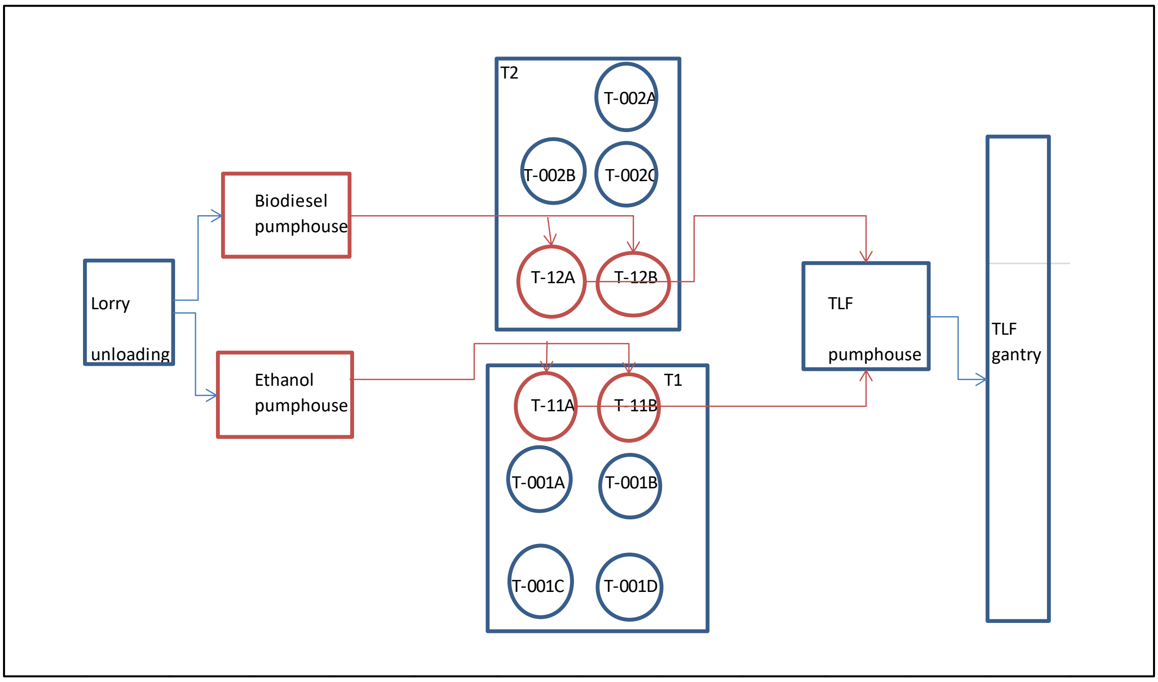
b. <u>For storage of Biodiesel & Ethanol (new dedicated tanks in existing dykes)</u>

Proposed Tanks are to be filled to 90% level (during normal operation).

The unloading operation will be conducted during day hours on daily basis.

Fig 1.4 shows the Simplified Flow Diagram showing proposed activities involving receipt and storage of Biodiesel and Ethanol.

Fig 1.4 Simplified Flow Diagram showing proposed activities involving receipt and storage of Biodiesel and Ethanol



LEGEND

Existing Operations

Proposed Operations

Chapter 2 Preliminary Hazard Assessment

2.1 Preamble

Hazard is present in any system, plant 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 to be adopted for risk to be evaluated.

The hazard assessment was based on the following methodologies

A) Hazard classification based on properties of petroleum products

B) Past accident analysis;

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

2.2 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 biodiesel and Ethanol

Table 2.1 Hazardous Properties of Ethanol and Biodiesel,

Property		**Ethanol**	**Biodiesel**
Boiling point (°C)		63 – 70	>200
Density		0.79	0.88
Flash point (°C)		16.6	130
Auto ignition (°C)		363	NA
Lower Flammable Limits (%)		3.3	NA
Upper Flammable Limits (%)		19	NA
National Fire Protection Agency (NFPA) rating *	NH	2	0
	NF	3	1
	NR	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 Ethanol is easily ignitable and will burn rapidly while Biodiesel is less flammable. 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[1] Schedule 1, Part 1(b), Ethanol can be classified as Very Highly Flammable Liquid.

Biodiesel is essentially derived from used vegetable oil with flash point of 130 deg C. While it is a combustible liquid, it requires considerable heating before ignition occurs. Further, biodiesel would require a much higher temperature to produce vapor than petroleum products.

OISD classifies Biodiesel as excluded petroleum as it has a flash point above 93°C. As per OISD, excluded petroleum products are to be stored in a separate dyked enclosure and shall not be stored along with Class-A, Class-B or Class-C petroleum.

Comparing densities of the products, it is noted that values lie within a very narrow range between 0.8 and 0.9. Failure of the density meter may allow product into the wrong tank and contamination of product. This could lead to safety hazards such as high vapor pressure within the storage unit.

[1] The Manufacture, Storage & Import of Hazardous Chemicals (Amendment) Rules, 2000 of the Environment (Protection) Act, 1986

2.3 Past Accident Analysis.

The possibility of fire and/or explosion in hydrocarbon tank farms has been largely confirmed from accounts of past incidents. *Annexure 2* 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 incidents of fires in tanks

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

- The predominant causes of fires in fixed roof tanks are lightning, external fires and ignition during maintenance.
- Fixed roof tanks have been involved in relatively more cases of total collapse than in the case of floating roof tanks.
- Of the total number of fixed roof tanks involved in accidents, 46% of were completely destroyed with an additional 50% suffering major damage to the roof supports, ring or shell.
- The damage potential of fires/ explosions is considerably different depending on the types of tanks used for storage.

2.3.2 Findings of analysis of design characteristics of fixed cone roof tanks

BPCL proposes to use cone roof type of storage tanks for storage of Ethanol and Biodiesel at its terminal in Karur. Fixed cone-roof tanks are commonly used for storage of petroleum products with vapor pressures close to atmospheric pressure. The tanks have their own advantages and disadvantages and tend to introduce unequal risk to the operation.

- The tanks have permanently attached cone shaped roof. Fixed roof tanks have a weak roof-to-shell seam. In the event of internal overpressure from an explosion, the design allows the roof to separate from the vertical shell to prevent failure of bottom seams and the tank being propelled upward.
- These tanks have venting capability to allow tank to “breathe” during loading, unloading and extreme temperature changes.

The types of potential consequences intrinsic to cone roof tanks are listed below

1. Full surface Tank fire
2. Internal explosion
3. Boilover
4. Transmission of external fire through vent
5. Dyke fire

It must be mentioned that the type of consequence is also determined by the type of product stored in the vessel. For example, internal explosion in cone roof tanks is a potential consequence in the storage of products with high volatility.

Annexure 2 provides a brief description of recent accidents involving bulk storage of ethanol and biodiesel.

2.4 Fire & Explosion Index (F&EI)

This stage of hazard identification involves the estimation of Fire & Explosion Index for the units under the present project to give the relative severity of the units from the fire angle.

F&EI index has been calculated for the additional storage tanks of 858 KL capacity for ethanol and 2500 KL capacity tanks for Biodiesel.

2.4.1 Conduct of F&EI

F&EI for the individual tanks are evaluated from the knowledge of the Material 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. Detailed fire and explosion indexing were carried out to give the relative degree of severity of the units 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 additional storage units is given in *Appendix 2.* The results are summarized in the following section.

2.4.2 Analysis of F&EI Results

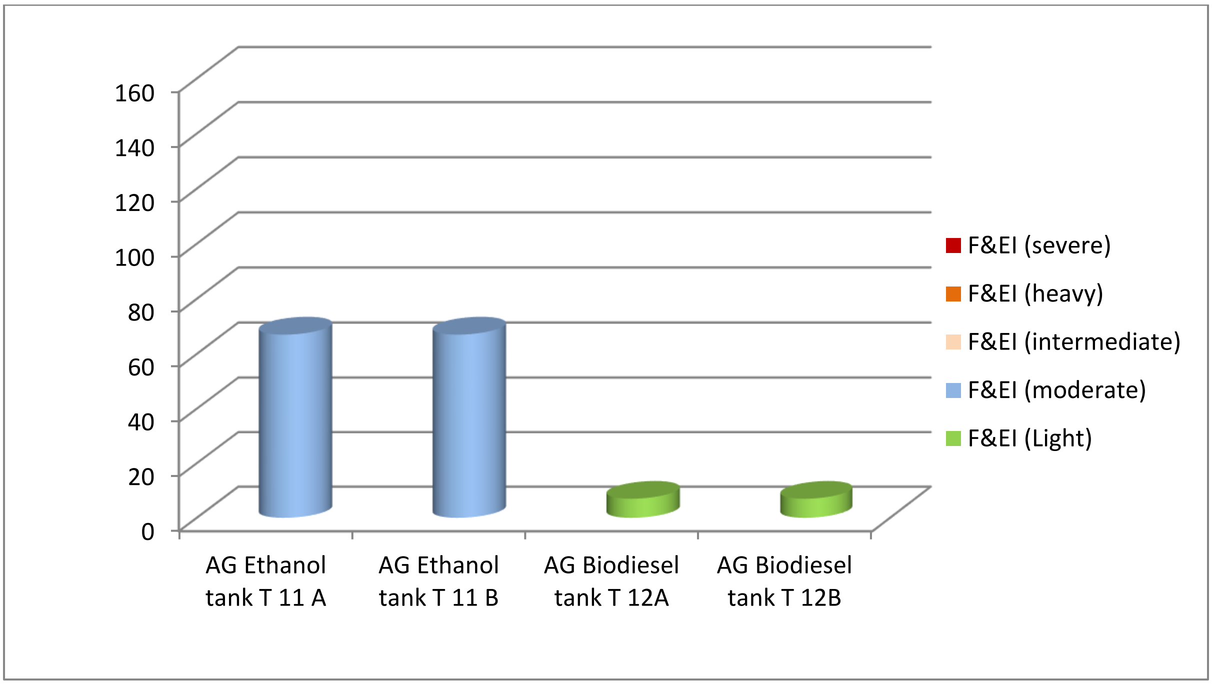
A summary of the results including the material factors for each of the hydrocarbons proposed to be stored on site is given in Table 2.4.

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
Above ground Ethanol tank new T11A	858 KL	16	62	*Moderate*
Above ground Ethanol tank new T11B	858 KL	16	62	*Moderate*
Above ground Biodiesel tank new T12A	2600 KL	4	8	*Light*
Above ground Biodiesel tank new T12B	2600 KL	4	8	*Light*

The following figure displays the relative degree of fire hazard arising from the new and modified units

Fig 2.1 Relative ranking of Fire & Explosion hazard from proposed new storage units



Of the storage units considered under the current project, ethanol units display moderate degree of hazard, while biodiesel storage presents a very low degree of hazard.

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. Among the products under consideration in the present expansion in the installation, ethanol is relatively more hazardous than biodiesel.

Further, accidents have been reported in the past involving fixed-roof tanks storing both ethanol and biodiesel. The findings have established that there is a need for further investigation for 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) Additional Storage at Oil Receiving Terminal Ethanol & Biodiesel Karur, Karur Dist., T.N.		Date 28/11/2016	
State of Operation	Normal operation			
Storage Unit			**Above ground ethanol tank new**	**Above ground Biodiesel tank new**
Quantity			858 KL	2600 KL
Material Factor			**16**	**4**
General Process Hazards		***Penalty Factor Range***	*Penalty Factor Used*	*Penalty Factor Used*
Base Factor		1.00	1.00	1.00
A)	Exothermic Chemical Reactions	0.30 – 1.25	0.00	0.00
B)	Endothermic Processes	0.20 – 0.40	0.00	0.00
C)	Material Handling and transfer	0.25 – 1.05	0.50	0.00
D)	Enclosed or Indoor process units	0.25 – 0.90	0.00	0.00
E)	Access	0.20 – 0.35	0.00	0.00
F)	Drainage and spill control	0.25 – 0.50	0.00	0.00
General Process Hazards Factor (F_1)			**1.50**	**1.00**
Special Process Hazards		***Penalty Factor Range***	*Penalty Factor Used*	*Penalty Factor Used*
Base Factor		1.00	1.00	1.00
A)	Toxic Material(s)	0.20 – 0.80	0.00	0.20
B)	Sub-Atmospheric Pressure	0.50	0.00	0.00
C)	Operation in or near Flammable Range			
1. Tank Farms Storage Flammable Goods		0.50	0.50	0.50
2. Process Upset or Purge Failure		0.30	0.00	0.00
3. Always in Flammable Range		0.80	0.00	0.00
D)	Dust Explosion	0.25 – 2.00	0.00	0.00
E)	Relief Pressure	0	0.00	0.00
F)	Low Pressure	0.20 – 0.30	0.00	0.00
G)	Quantity of Flammable/ Unstable Material			
1. Liquids or Gases in Process		0.10 – 10.00	0.00	0.00
2. Liquids or Gases in Storage		0.10 – 10.00	0.89	0.00
3. Combustible Solids in Storage, Dust in Process		0.10 – 10.00	0.00	0.00
H)	Corrosion and Erosion	0.10 – 0.75	0.20	0.20
I)	Leakage - Joints and Packing	0.10 – 1.50	0.00	0.00
J)	Use of Fired Equipment	0.10 – 1.00	0.00	0.00
K)	Hot Oil Heat Exchange System	0.15 – 1.15	0.00	0.00
L)	Rotating Equipment	0.50	0.00	0.00
		Special Process Hazards Factor (F_2)	**2.59**	**1.90**
		Process Unit Hazards Factor ($F_1 \times F_2 = F_3$)	3.89	1.90
		Fire and Explosion Index (F_3 x MF)	**62.16**	**7.60**
		Degree of Hazard	**Moderate**	**Light**

Chapter 3 Assessment of Hazardous Scenarios

3.1 Preamble

The units and activities connected with additional storage of ethanol and biodiesel 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 study areas. 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 vapor cloud in event of leak is assumed to disperse in the most probable wind direction (South west to North 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 a facility 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 vapor 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 product which could lead to loss of life and/ or damage to property. The range of leak sizes representative for small and large leaks 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.

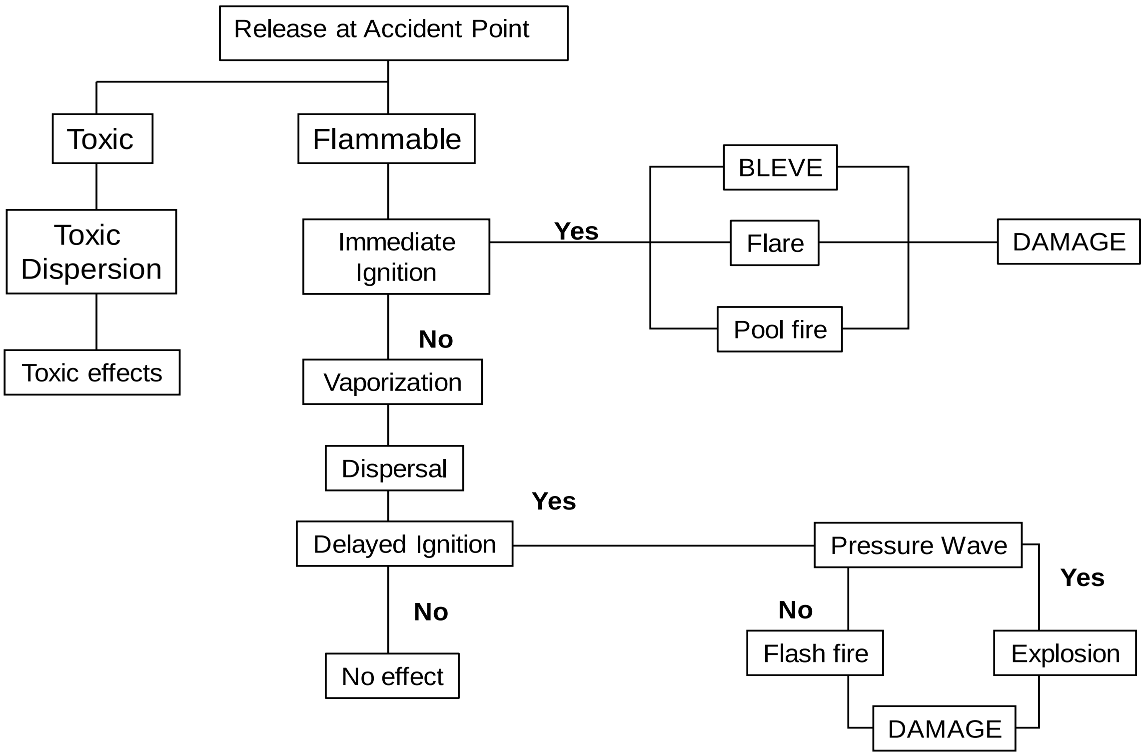
In addition to the potential for a fire as a result of a spill, there is also the potential for a tank fire scenario. A full tank surface fire may occur as a result of lightning strike.

Depending on the type of the storage 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. Pool Fire
2. Flash Fire
3. Vapor 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



As ethanol is a volatile product, the potential for dispersion of flammable vapor from spills of ethanol to atmosphere was also considered during the analysis. The distance to which flammable vapors would extend is dependent on the response time for all cases. Flash fires and Vapor Cloud Explosion were therefore also analysed further in the risk assessment.

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

Table 3.1 Identified Scenarios and possible outcomes

Event no.	Location/ Activities	Scenario	Product considered	Credible consequence
1	Tank Farm 1	Ethanol	Liquid spill from leak on outlet pipe (10%) on T11A/ T11B	Pool fire/flash fire/VCE
2			Overfilling of tank T11A/11B	Dyke fire/ VCE
3			Tank fire on cone roof tank T11A/11B	Tank fire

Event no.	Location/ Activities	Scenario	Product considered	Credible consequence
4	Tank Farm 2	Biodiesel	Liquid spill from leak on outlet pipe (10%) on T12A/ T12B	Pool fire
5			Overfilling of tank 12A/12B	Pool fire
6			Tank fire on cone roof tank T12A/12B	Tank fire
7	At TLF Pump house/ open area	Ethanol	Gasket leak on pipeline	Pool fire/ Flash fire/ VCE
8	At TLF Gantry	Ethanol	Spill at gantry during unloading	Pool fire/ Flash fire/ VCE

3.4 Potential Ignition Sources

Fire or explosion scenarios are possible only if spilled/ leaked material in sufficient quantities comes in contact with an ignition source. Several ignition sources are generally available in an installation such as lightning, static charges, vehicle exhaust, electrical spark, smoking material, etc. Hence the site was closely examined for potential sources of ignition.

It is expected that all the electrical units within the operating area such as motors of pumps, light fittings & switches in pump house, gantry and tank farm are FLP type and have the required earthing to avoid becoming a source of ignition. The Oil Receiving Terminal has considered segregation of the product handling area from other areas with a gate to regulate the entry of personnel, vehicles, etc. The product handling area shall be licensed area and entry will be restricted to authorized persons only.

External ignition sources include vehicles or electrical transmission lines. Vehicles are restricted to areas sufficiently distanced from the storage area and sufficient protective measures are enforced in the truck gantry area.

The possibility of ignition from above ground lines power lines is not present since all licensed power connections inside the site shall use cabling and termination with FLP glanding.

Compression ignition engines with spark arrestor on exhaust line shall be permitted inside the licensed area.

A list of probable ignition sources and safeguards is given in Table 3.2.

Table 3.2 Location of Sources of Ignition within BPCL Karur Terminal

Sl no	Sources of Ignition	Safeguards
1.	Pump house	Flameproof motors & junction boxes
2.	Lighting in gantry & pump area	Flameproof equipment
3.	Tank lorry movement at loading bays	Spark arrestors, TT engine turned off during loading/ unloading operations, electrical fittings of the TT are checked for proper insulation before induction of the TT.
4.	DG Set room (located in de-licensed area)	Enclosed; all electrical armored cables underground, earthed
5.	Switch Room	Fenced; Earthing; located in de-licensed area
6.	General facility area	Personnel entering the Oil Receiving Terminal are checked for matchboxes, cigarette lighters, mobiles, etc., before allowing entry. Restricted entry

Sl no	Sources of Ignition	Safeguards
7.	Accumulation of Static Electricity Maintenance Hot work	Earthing of tankers, underground storage vessels & pipelines Non-sparking tools used Work Permit system in place
8.	Instrument cable inside the dyke	Fireproof instrument cable

3.5 Distribution of personnel within the site

The population distribution within the facility will consist of employees working in the installation. All activities are restricted to day-time. Details are listed in Table 3.3

Table3.3 Distribution of personnel inside the facility at Karur

Activity	No. of persons in General shift
Pipeline receipt and unloading activities	
Exchange pit	3
Truck loading/unloading activities	
TLF gantry	4
Truck loading bay (driver & cleaner)	64
Others	
Administration	15
Security	7
Maintenance	1
Electrical shed	1
Firefighting	4
Total	**99**

3.6 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 petroleum products storage facility 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, vapors 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.

3.6.1 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 3.4 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 1% fatality for exposure above 60 secs
37.5	Sufficient to cause damage to process equipment 99% fatality for exposure above 60 secs

3.6.2 Damage Criteria for overpressure effects

Explosion damage is estimated based on recorded peak overpressures and corresponding potential damage effects. A Vapor 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 vapor.

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 vapor cloud will start to burn. It is assumed that fatality will be 100% in the projected area of the vapor cloud.

The factors that affect VCEs are:

a. Shape of the cloud
b. Composition of the cloud
c. Mass of the combustible vapor in the explosive range
d. Type of ignition
e. Flame acceleration
f. Surroundings

The shock wave model, used for a wide range of flammable vapor 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 3.5 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

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

3.7 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 Oil Receiving Terminal. These contours are shown in Figs. 3.2 to 3.9

LEGEND for Figures

Code for Pool Fire	Thermal Radiation in kW/m2
	37.5
	21.5
	12.5
	4
Code for Overpressures	Overpressures in bar
	0.3
	0.1
	0.03
	CODE For Flash Fire/ Spill area

Fig 3.2 Damage contours due to Pool fire from leak (10%) on ethanol inlet pipeline/ overfilling of tank T11A/11B within Tank Farm 1 (Event no 1 / 2)

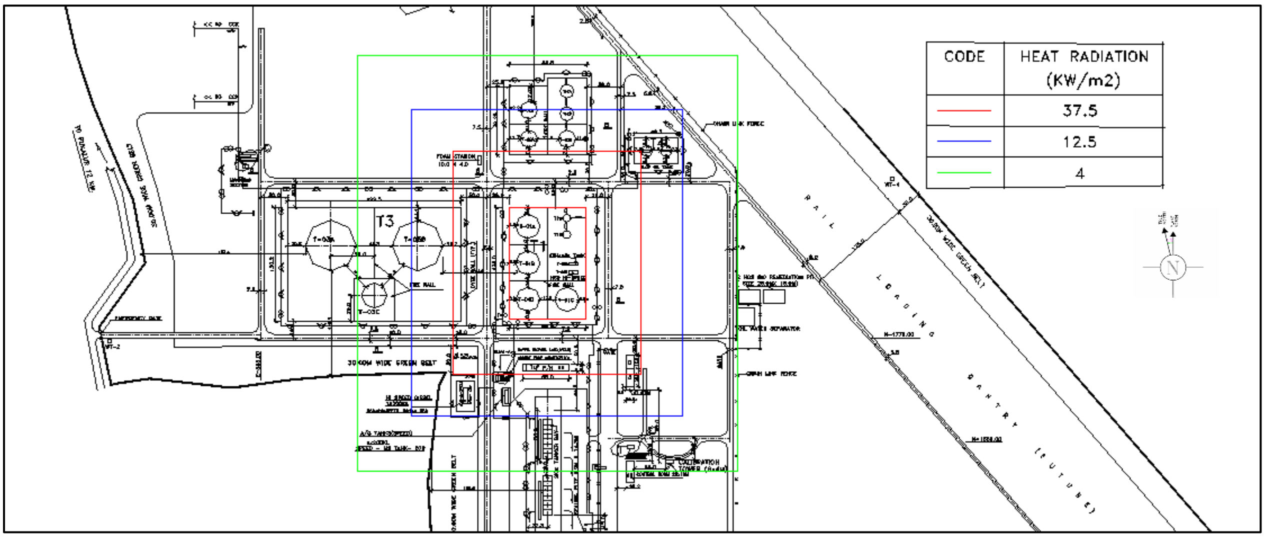


Fig 3.3 Damage contours due to tank fire on Ethanol tank T11B within Tank Farm T1 (Event no 3)

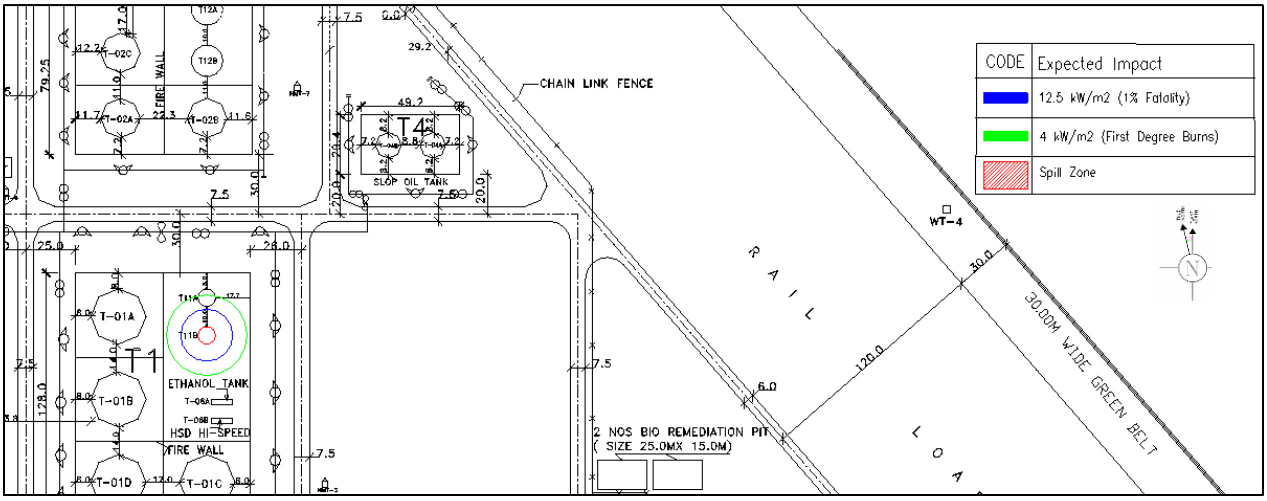


Fig 3.4 Damage contours due to pool fire from leak (10%) on Biodiesel inlet pipeline/ overfilling of tank T12A/T12B at Tank Farm T2 (Event nos 4/ 5)

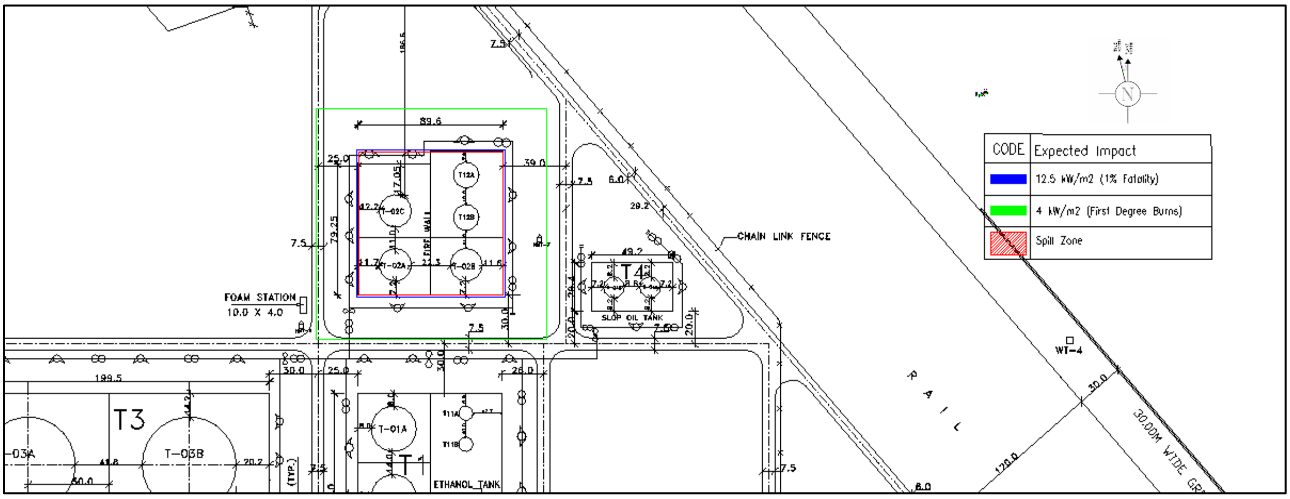


Fig 3.5 Damage contours due to tank fire on Biodiesel tank T12B within Tank Farm 2(Event no 6)

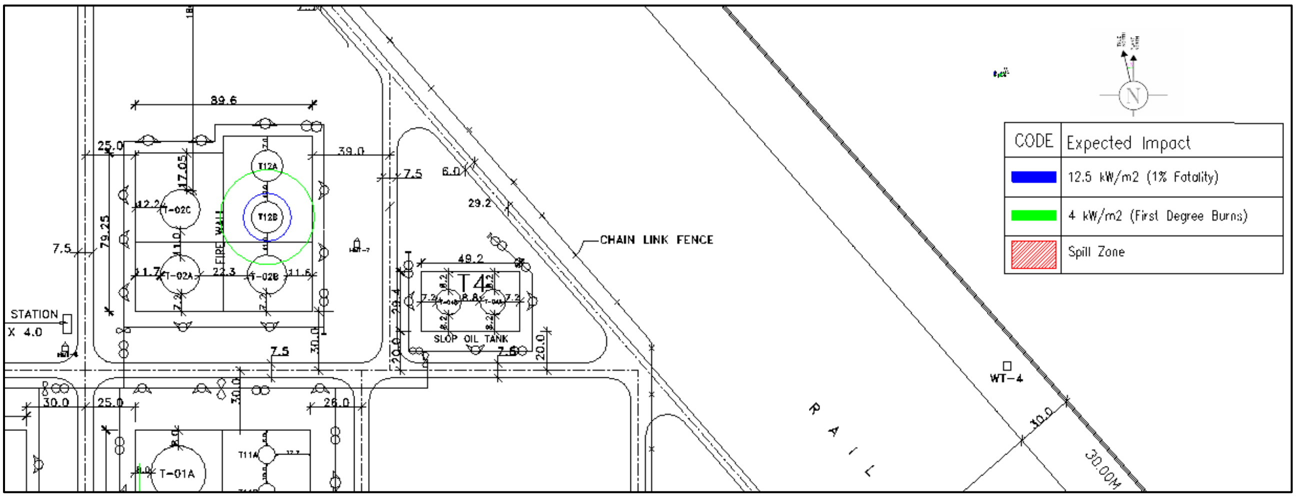


Fig 3.6 Damage contours due to Ethanol pool fire at Ethanol Pump house (Event no 7)

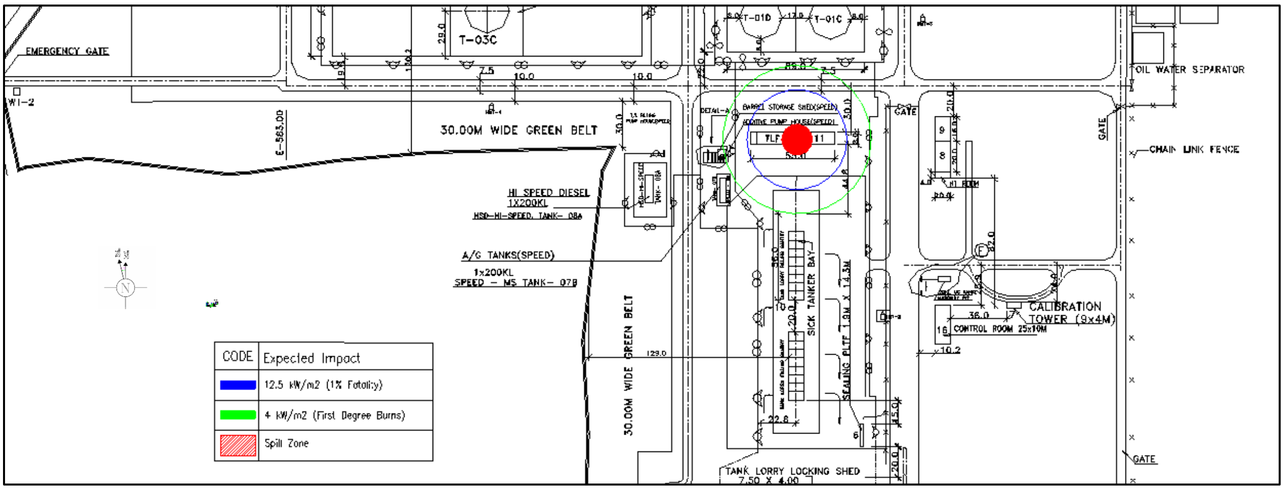
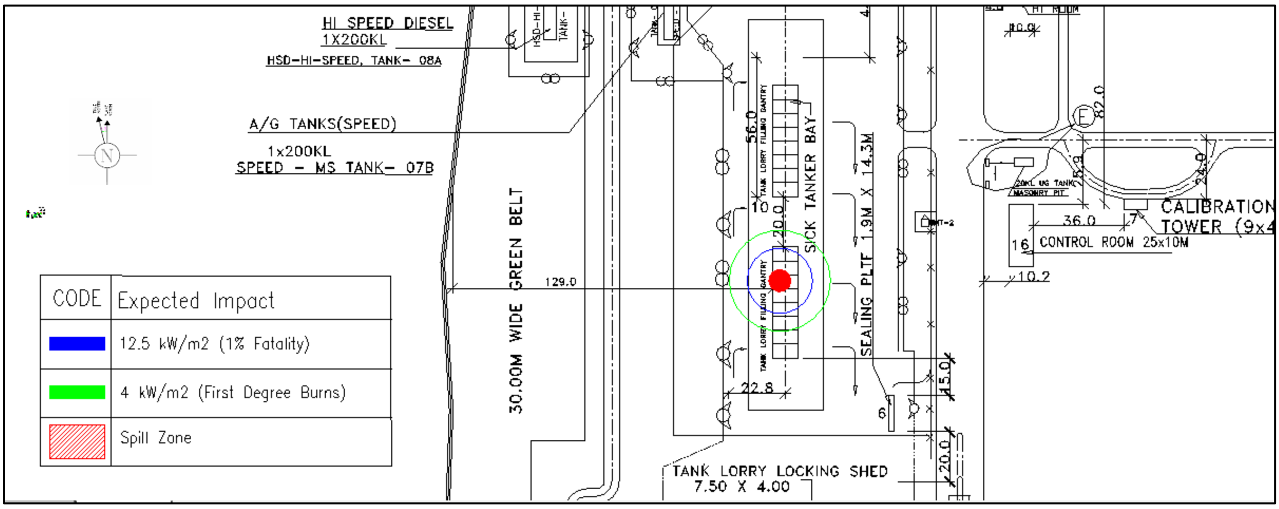


Fig 3.7 Damage contours due to Ethanol pool fire at TLF Gantry (Event no 8)



3.8 Summary

A total of eight 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.

Storage of ethanol was also assessed for its potential to generate significant quantities of vapor that could result in flash fire or VCE. Two scenarios were considered to have potential for occurrence of flashfire; however, occurrence of VCE was ruled out based on the estimation of quantity available for vapor generation, which was found to be low.

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.

It was noted that scenarios involving ethanol have impact on personnel and potential to damage property within the terminal and outside the boundaries. Impacts of scenarios involving Biodiesel are localised and contained within the dykes.

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	Tank Dia (m)	Radiation Intensity inside tank (kW/ m²)	Distance from the edge of the tank (m)			
						37.5 kW/m²	21.5 kW/m²	12.5 kW/m²	4 kW/m²
3	TF1	Ethanol	Tank fire on cone roof tank, T11A/ 11B	9	51.2	Within pool	6	8.7	15.9
6	TF2	Bio-diesel	Tank fire on cone roof tank, T12A/ T12B	16	37.6	Within pool	1.1	4.2	16

B) POOL FIRE RESULTS

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

Event no.	Location/ Activities	Product	Scenario	Dyke/ pool Area (m²)	Radiation Intensity inside dyke (kW/ m²)	Distance from the edge of the dyke/ pool (m)			
						37.5 kW/m²	21.5 kW/m²	12.5 kW/m²	4 kW/m²
1	Tank farm TF 1	Ethanol	Liquid spill from gasket leak on outlet pipe on T11A/ T11B	9415	89.7	64.90	53.0	112.1	175.8
2			Overfilling of tank T11A/ T11B	9415	89.7	64.90	53.0	112.1	175.8
4	Tank farm TF 2	Biodiesel	Liquid spill from gasket leak on outlet pipe on T12A/ T12B	6338	20.03	not attained	not attained	1.5	27

Event no.	Location/ Activities	Product	Scenario	Dyke/ pool Area	Radiation Intensity inside dyke	Distance from the edge of the dyke/ 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
5			Overfilling of tank T12A/ T12B	6338	20.03	not attained	not attained	1.5	27
7	At Ethanol Pump house/ open area	Ethanol	Gasket leak (10%) on pipeline	379.9	63.4	Within pool	16.1	22.4	38.1
8	At Gantry	Ethanol	Spill at gantry during unloading	63.5	51.2	Within pool	6	8.7	15.9

C) VCE RESULTS

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

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	TF 1	Ethanol	Liquid spill from gasket leak on inlet/ outlet pipe on T11A/ T11B	9415	6.6	14	8.1	4	3.7	50	Quantity low. Explosion unlikely			
2			Overfilling of tank T11A/ T11B	9415	6.6	14	8.1	4	3.7	50	Quantity low. Explosion unlikely			
7	At TLF Pump house/ open area	Ethanol	Gasket leak on pipeline	379.9	0.32	2	1.2	0	0.3	1	Quantity low. Explosion unlikely			
8	At Gantry	Ethanol	Spill at gantry during unloading	63.6	0.06	0	0.1	0	0	<1	Quantity low. Explosion unlikely			

[2] DW- Down wind

[3] CW- Cross wind

Chapter 4 Probability Assessment of Hazardous Scenarios

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 terminal 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 Safety and Automation Features

Location	Existing Automation features
1. At storage tanks	• ROSOV and MOV are present on inlet and outlet lines for all storage tanks • Level switch, Radar type level gauge, temperature transmitter, manual measurement of level are provided • Radar type level transmitter is used for alarms and trips • Level, temperature signals are sent to control room • H,HH,HHH are configured with HHH to trigger ESD • Hydrocarbon detectors are provided for MS tank
2. Tanks dyke capacity	• 110 % of the largest tank
3. Firefighting at tank farms	Compliant with OISD 117 standard
4. Tank lorry gantry unloading	• 2 no. of ESD are provided one at each end • Double earthing provided for tankers; in case of failure, the filling will be stopped

The 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 vapor 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. Due 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.

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
1	TF 1	Ethanol	Liquid spill from leak on outlet pipe on T11A/11B	9.00E-11	4.50E-11
2			Overfilling of tank T 11A/11B	9.00E-15	4.50E-15

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

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

Event no.	Location/ Activities	Product	Scenario	PROBABILITY OF FIRE (Tank/ Pool)	PROBABILITY OF FLASHFIRE
3			Tank fire on fixed roof tank	9.00E-08	-
4	TF 2	Biodiesel	Liquid spill from leak on outlet pipe on T12A/ T12B	9.00E-12	-
5			Overfilling of tank T12A/12B	9.00E-15	-
6			Tank fire on fixed roof tank T12A/12B	9.00E-08	-
7	At TLF Pump house/ open area	Ethanol	Gasket leak on pipeline	1.19E-11	5.94E-12
8	At TLF Gantry	Ethanol	Spill at gantry during unloading	3.00E-12	1.50E-12

4.4 Observations

The frequency of each individual credible event at the proposed additional storage units was estimated considering representative cases from Class A (ethanol) and Class B products (biodiesel). The highest frequency of occurrence of an unwanted event with the activation of safety features is of the order of 10^{-8} per year, i.e., the chance of occurrence is once in a hundred million years.

Chapter 5 Evaluation of Risk to Personnel within and outside the Oil Receiving Terminal

5.1 Preamble

The risk to personnel located within and outside the Oil Receiving Terminal 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 at manned locations.

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 or flash fire within the Oil Receiving Terminal.

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

Since explosions have been ruled out due to insufficient quantities, effects of thermal radiation have been considered. The impact on the individual was estimated at locations where personnel are stationed.

Table 5.2 Scenarios with potential for fatal effects on personnel

<table>
<tr><th>Event no.</th><th>Location</th><th>Product</th><th>Scenario</th><th>Potential Fatal Effects arising from Thermal radiation of 12.5 kW/m^2</th></tr>
<tr><td>1</td><td rowspan="3">At TF 1</td><td rowspan="3">Ethanol</td><td>Liquid spill from leak on outlet pipe on T11A/11B</td><td rowspan="3">100 % fatality and severe damage: Neighbouring dyke walls of TF 2 and TF 3 and TLF pump house
1% fatality : TLF pump house and gantry</td></tr>
<tr><td>2</td><td>Overfilling of tank T 11A/11B</td></tr>
<tr><td>3</td><td>Tank fire on fixed roof tank</td></tr>
<tr><td>4</td><td rowspan="3">At TF 2</td><td rowspan="3">Biodiesel</td><td>Liquid spill from leak on outlet pipe on T12A/ T12B</td><td>nil</td></tr>
<tr><td>5</td><td>Overfilling of tank T12A/12B</td><td>nil</td></tr>
<tr><td>6</td><td>Tank fire on fixed roof tank T12A/12B</td><td>nil</td></tr>
<tr><td>7</td><td>At TLF Pump house/ open area</td><td>Ethanol</td><td>Gasket leak on pipeline</td><td>1 % fatality: TLF pump house</td></tr>
<tr><td>8</td><td>At TLF Gantry</td><td>Ethanol</td><td>Spill at gantry during unloading</td><td>1 % fatality: TLF Gantry. The radiation will be</td></tr>
</table>

Event no.	Location	Product	Scenario	Potential Fatal Effects arising from Thermal radiation of 12.5 kW/m²
				experienced up to 8 m around the gantry area

5.3 Risk Matrix

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 terminal 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 Oil Receiving Terminal

Table 5.4 Risk levels from various credible scenarios at manned locations arising from the proposed storage

Sl no	Initiating event/ location	Scenario	Frequency rating	Severity rating	Risk Rating
1	Liquid spill from leak on outlet pipe on T11A/11B	Pool fire	1	3	Low
		Flash fire	1	1	Low
2	Overfilling of tank T 11A/11B	Pool fire	1	3	Low
		Flash fire	1	1	Low
3	Tank fire on fixed roof tank	Tank fire	2	1	Low
4	Liquid spill from leak on outlet pipe on	Pool fire	1	1	Low

[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

Sl no	Initiating event/ location	Scenario	Frequency rating	Severity rating	Risk Rating
	T12A/ T12B				
5	Overfilling of tank T12A/12B	Pool fire	1	1	Low
6	Tank fire on fixed roof tank T12A/12B	Tank fire	2	1	Low
7	Gasket leak on pipeline (Ethanol)	Pool fire	1	3	Low
8	Ethanol Spill at gantry during unloading	Pool fire	1	3	Low

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

5.4 Summary

The maximum individual risk arising from primary events for the proposed operation at areas inside and outside the Oil Receiving Terminal 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 6 Findings & Recommendations

6.1 Preamble

The changes in risk level from the introduction of the additional storages at the BPCL Karur Oil Receiving Terminal were evaluated through a process involving hazard identification, consequence analysis and probability assessment. The assessment was carried out assuming full implementation of safety systems as recommended by M B Lal Committee.

Risk levels were evaluated on manned locations inside the terminal and in the vicinity.

The main findings of the assessments are discussed in the sections given below.

6.2 Main Findings of Consequence Analysis

Consequence analysis was conducted for eight scenarios arising out of the proposed additional storage. The results of the analysis on life and property are summarized below.

1. **Impacts of introducing ethanol storage in the site (located within the existing tank farm TF 1)**

   a. **Dyke fire in Tank farm 1:** The impacts of critical radiation levels of a spill and fire from the new cone-roof tanks for ethanol is described:

      - Radiation corresponding to severe property damage (37.5 kW/m^2) will be experienced up to 64 m from the dyke, which includes the walls of the neighboring dykes TF 2, TF 3 and TLF pump house and filling shed towards south. There is potential for cascade effects.

      - Radiation corresponding to 1% fatality (up to 12.5 kW/m^2) will be experienced to 112 m from the edge of dyke which includes tanks in neighboring dykes TF 2, TF 3, TF 4, TLF pump house, additive pump house, Tanks 08A, 07B, DG set room and MCC room. Personnel at these locations may be affected

   b. Ethanol Tank fire: The radiation level due to tank fire of Ethanol corresponding to 1% fatality will be experienced at 8.7 m from the edge of tank.

   c. **Pool fire at TLF pump house**: The effects of leak and spill of ethanol during pumping was considered at the TLF pump house.
      - The radiation corresponding to 100% fatality/ severe damage will be experienced within the pump house.

      - The radiation corresponding to 1% fatality was found to extend up to a radius of 22m from the edge of pool

   d. **Pool fire at the TL unloading gantry**: The effects of leak and spill of ethanol during unloading was considered at the TL unloading gantry
      - Thermal radiation corresponding to severe damage will be confined to the vicinity of the spill.

      - Radiation up to 1% fatality will be experienced up to 9 m from the edge of pool.

2. **Impacts of introducing Biodiesel in Tank farm TF 2**

   a. **Pool fire:** The thermal radiation effects corresponding to 1% fatality and 4 KW/m^2 were seen to be confined within the immediate proximity of the tank for Biodiesel.

b. **Tank fire:** The radiation level due to tank fire of Biodiesel corresponding to 1% fatality will be experienced at 4 m from the edge of tank.

3. **Potential for Cascade or secondary events**:

a. Radiation levels of Ethanol pool fires are of the order of 90 kW/ m^2 and have the potential to trigger secondary/ cascade events. The tanks and locations that are likely to be involved in secondary events are the following
   - All tanks in TF3
   - T1 containing MS in TF 1
   - Ethanol unloading point
   - SPEED Pump house
   - 3 bays at TLFG

   Firefighting equipment within the zone may be rendered incapacitated

b. Radiation levels for Biodiesel fires are of the order of 20 kW/m^2 .The impacts will be localized and hence no cascade effects are expected from these units

6.3 Probability Analysis for new units

As part of the probability analysis, individual frequencies of occurrence were determined for each hazardous outcome (tank fire, pool fire, flash fire) quantified in the consequence assessment. The probabilities of these hazardous outcomes were assessed considering the sequence of development of the event, proposed safety systems, and available measures for detection and control. The frequencies of occurrence of the incidents are summarised below

a) The probability of a **tank fire** is of the order of 10^{-8} per year.

b) The probability of **pool fire** ranges from 10^{-11} to 10^{-15} per year.

The occurrence of pool fires are seen to be extremely low due to the provision of several safety features and redundancies.

6.4 Evaluation of Risk from additional storage units

Risk is the product of consequence and probability, and is evaluated on the basis of impacts on people. Hence Individual Risk levels inside the depot 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. The criteria used for the IR is 1% fatality or extent of thermal radiations up to 12.5 kW/m^2.

While most of the manned locations were found to lie beyond the damage zones of the hazardous events identified for the additional storage units, the pump house and gantry have been found to be vulnerable to thermal radiations from incidents involving ethanol transfer operations. The risk to manned locations at the Oil Receiving Terminal from the additional storage units may be summarized in Table 6.1.

Table 6.1 Individual Risk at manned locations

	Manned Location	Individual risk (IR)/yr
Within the Oil Receiving Terminal	TLF Pump house	**1.78E-11**
	Gantry	**1.40E-10**

The individual risk is found to be extremely low and may not alter the existing risk at the terminal.

6.5 Risk Reduction Measures for additional storage units

While the risk evaluated for the proposed additional storage at BPCL's site in Karur has been found to be negligible, risk numbers for different locations within the Oil Receiving Terminal should be considered in relative terms. BPCL should therefore continue its risk reduction programs to lower the risk levels further.

Measures for reduction of risk are directed at the proposed tanks.

6.5.1 Measures for Biodiesel storage

a. Location of Biodiesel tanks

Biodiesel has a flash point of 130 º C falls under excluded petroleum category as per OISD codes. The code states that such excluded petroleum products shall be located in a separate dyke enclosure and shall not be stored along with Class A, Class B or Class C petroleum. This is to reduce the potential for cascade events.

At tank farm (T2), 2 nos. of Biodiesel tanks are to be introduced in a common dyke along with an MS tank and two SKO tanks. Biodiesel shall therefore be treated as Class A on par with MS. The firefighting measures for biodiesel tanks shall be as provided for class A product.

b. Control of hazards related to biodiesel storage

Under NFPA classification biodiesel is classified as NF 1 with low flammability. However, due to wrong line-up the possibility of contamination with higher class products such as MS/ ethanol exists. This may lead to change in the volatility/ flammability characteristics and increase the risk of fires.

i. Hence, inclusion of additional pressure cum vacuum valve for atmospheric storage tanks is recommended

ii. To avoid inadvertent mixing and contamination within the tanks, calibration and maintenance of instruments must be ensured

iii. To ensure adequate level control level gauges should be suitable for the range of materials with different densities including biodiesel

6.5.2 Measures for Ethanol Storage

a. Location of ethanol tanks

The heat radiation from ethanol fires was noted to be very high (90 KW/m^2). At such level chances of severe damage to the firefighting equipment and other tanks in the vicinity are very high. The two new ethanol tanks may be located in a separate dyke to prevent cascade effects on other storage tanks located in same dyke.

However, if the ethanol tanks cannot be located in a separate dyke, BPCL should consider all the tanks within the tank farm (T1), as Class A product for firefighting purposes

b. Control of hazards related to ethanol storage

In the light of the introduction of aboveground storage for ethanol, the following points may be emphasized.

i. Tanks for ethanol should be equipped with flame arrestors on pressure release equipment

ii. Ethanol tanks may be equipped with fusible links for isolation of piping from tanks in the event of a fire

iii. All work/equipment used in ethanol receipt/ storage/ dosing areas should be non-spark generating and intrinsically safe as per applicable code

c. Control of hazards from ethanol transfer operations

Due to the nature of ethanol fires, which may not be visible, special precautions need to be taken at locations where ethanol is transferred

1. Personnel working in ethanol pump house or approaching ethanol pump house to attend a leak shall wear fire retardant clothing.

2. A caution board to wear such fire retardant clothing shall be placed in the approach to the pump house and unloading gantry.

3. A safety shower shall be located near the ethanol pump house and unloading gantry.

d. Ethanol fire control and mitigation

As the zone of maximum damage (37.5kW/m^2) from pool fire at ethanol A/G tank falls beyond the bund of T1, there is a possibility that the fire fighting system consisting of hydrants and monitors may be damaged and rendered unserviceable during a fire at tanks T11A/T11B. The following recommendations may be considered for the ethanol tanks

1. Installation of a fire detection system to be located outside the 37.5 kW/m^2 damage zone of 40m from the edge of the bund (shown in Fig 3.2);
2. Installation of a fog screen between the bunds;
3. Installation of alcohol and fuel detectors;
4. Construction of the tanks with ventable roofs;
5. Installation of foam pourer on each bund;
6. Inerting of the tanks with nitrogen.

6.5.3 Control of hazards related to mixed storage

As per OISD, if a Class B or Class C product is located in a common dyke along with Class A product, the Class C or Class B product shall be treated as Class A, and the firefighting system shall be the same as provided for Class A products.

a. Since the new tanks are proposed within the existing dykes along with storage of Class A or Class B products, all the tanks should be provided with fire fighting arrangements for the highest class product within the dyke.

b. The foam/ fire water requirement may need to be reevaluated

6.5.4 Site specific emergency planning

Mitigation measures have been considered in absolute terms in the risk assessment. Safe zones for firefighting have been indicated based on the calculations. However, in the event of a fire, there is potential for exposure of firefighting personnel due to variables such as weather conditions, wind speed, etc. These factors are to be considered in the Emergency Response Plan.

The oil receiving terminal will extend the existing emergency management system to cover the additional storage within the Terminal. However, due attention is to be given to the suitability of firefighting media especially when dealing with ethanol and biodiesel fires.

a) High quality AR-foam (Alcohol Resistant) media must be considered for fighting ethanol fires

b) The use and delivery of foam in the event of a biodiesel fire is effective if gentle application is used.

It may be noted that for tank fires, foam monitor (Type III) application is not likely to be successful, even at increased application rates.

6.5.5 Fire water requirements

The fire water demand set to increase due to addition of several new storage tanks. Hence the new fire water demand calculation needs to be conducted and review of design parameters of pumps and fire water network to be carried out.

- For fire water demand calculations, all the tank farms shall be treated as a single fire zone as there is a potential for cascade effects (since fire can spread from one tank farm to other tank farms).

6.6 Conclusion

Risk analysis studies were carried out for the proposed additions at BPCL's terminal at Karur covering the storages of ethanol and biodiesel. 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 terminal. The risk was assessed considering the full implementation of the MB Lal Committee recommendations.

The main findings of the assessment are summarized here

- Risk from the proposed additional storage was found to be negligible and will not alter the current risk levels of the existing terminal and its operations.
- The damage zones from events involving ethanol and biodiesel storage will be mainly confined within the terminal site and will not have any effect on persons outside the terminal.
- While the probability of occurrence of fires on personnel was found to be negligible, the consequence of fires from ethanol storage and transfer operations can affect personnel within the depot.

The safety measures and other suggestions made in this report will further decrease the risks and ensure the long-term safe operation of the oil-receiving terminal.

Annexure I Material Safety Data Sheets

1. **Ethanol**
2. **Biodiesel**

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 vapor. 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 vapors 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 vapor 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 vapor), 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
Vapor 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 dioxide	Carbon monoxide, irritating and toxic fumes and gases, carbon Products :

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

BIODIESEL

Chemical Product General Product Name: Biodiesel Synonyms: Methyl Soyate, Rapeseed Methyl Ester (RME) , Methyl Tallowate Product Description: Methyl esters from lipid sources CAS Number: Methyl Soyate: 67784-80-9; RME: 73891-99-3; Methyl Tallowate: 61788-71-2

Composition/ information on ingredients
This product contains no hazardous materials

Hazards identification Potential Health Effects:

INHALATION: Negligible unless heated to produce vapors. Vapors or finely misted materials may irritate the mucous membranes and cause irritation, dizziness, and nausea. Remove to fresh air.

EYE CONTACT: May cause irritation. Irrigate eye with water for at least 15 to 20 minutes. Seek medical attention if symptoms persist.

SKIN CONTACT: Prolonged or repeated contact is not likely to cause significant skin irritation. Material is sometimes encountered at elevated temperatures. Thermal burns are possible.

INGESTION: No hazards anticipated from ingestion incidental to industrial exposure.

First Aid Measures

EYES: Irrigate eyes with a heavy stream of water for at least 15 to 20 minutes.

SKIN: Wash exposed areas of the body with soap and water.

INHALATION: Remove from area of exposure; seek medical attention if symptoms persist.

INGESTION: Give one or two glasses of water to drink. If gastro-intestinal symptoms develop, consult medical personnel. (Never give anything by mouth to an unconscious person.)

Fire Fighting Measures

Flash Point (Method Used): 130.0 C min

Flammability Limits: None known

EXTINGUISHING MEDIA: Dry chemical, foam, halon, CO_2, water spray (fog). Water stream may splash the burning liquid and spread fire.

SPECIAL FIRE FIGHTING PROCEDURES: Use water spray to cool drums exposed to fire.

UNUSUAL FIRE AND EXPLOSION HAZARDS: Oil soaked rags can cause spontaneous combustion if not handled properly. Before disposal, wash rags with soap and water and allowed to dry in well ventilated areas. Fire-fighters should use self-contained breathing apparatus to avoid exposure to smoke and vapor.

Accidental Release Measures Spill Clean-Up Procedures

Remove sources of ignition, contain spill to smallest area possible. Stop leak if possible. Pick up small spills with absorbent materials such as paper towels, “Oil Dry”, sand or dirt. Recover large spills for salvage or disposal. Wash hard surfaces with safety solvent or detergent to remove remaining oil film. Greasy nature will result in a slippery surface.

Handling and Storage

Store in closed containers between 15°C and 50°C. Keep away from oxidizing agents, excessive heat, and ignition sources. Store and use in well ventilated areas. Do not store or use near heat, spark, or flame, store out of sun. Do not puncture, drag, or slide this container. Drum is not a pressure vessel; never use pressure to empty.

Exposure Control /Personal Protection

RESPIRATORY PROTECTION: If vapors or mists are generated, wear a NIOSH approved organic vapor/mist respirator.

PROTECTIVE CLOTHING: Safety glasses, goggles, or face shield recommended to protect eyes from mists or splashing. PVC coated gloves recommended to prevent skin contact.

OTHER PROTECTIVE MEASURES: Employees must practice good personal hygiene, washing exposed areas of skin several times daily and laundering contaminated clothing before re-use.

Physical and Chemical Properties

Boiling Point, 760 mm Hg:>200°C

Volatiles, % by Volume: <2

Specific Gravity (H2O=1): 0.88

Solubility in H2O, % by Volume: insoluble

Vapor Pressure, mm Hg: <2

Evaporation Rate, Butyl Acetate=1: <1

Vapor Density, Air=1:>1

Appearance and Odor: pale yellow liquid, mild odor

Stability and Reactivity

GENERAL: This product is stable and hazardous polymerization will not occur.

INCOMPATIBLE MATERIALS AND CONDITIONS TO AVOID: Strong oxidizing agents

HAZARDOUS DECOMPOSITION PRODUCTS: Combustion produces carbon monoxide, carbon dioxide along with thick smoke.

Disposal Considerations

WASTE DISPOSAL: Waste may be disposed of by a licensed waste disposal company. Contaminated absorbent material may be disposed of in an approved landfill. Follow local, state and federal disposal regulations.

Transport Information

UN HAZARD CLASS: N/A

NMFC (National Motor Freight Classification):

PROPER SHIPPING NAME: Fatty acid ester

IDENTIFICATION NUMBER: 144920 SHIPPING CLASSIFICATION: 65

Regulatory Information:

OSHA STATUS: This product is not hazardous under the criteria of the Federal OSHA Hazard Communication Standard 29 CFR 1910.1200. However, thermal processing and decomposition fumes from this product may be hazardous as noted in Sections 2 and 3. TSCA STATUS: This product is listed on TSCA. CERCLA (Comprehensive Response Compensation and Liability Act): NOT reportable. SARA TITLE III (Superfund Amendments and Reauthorization Act): Section 312 Extremely Hazardous Substances: None Section 311/312 Hazard Categories: Non-hazardous under Section 311/312 Section 313 Toxic Chemicals: None RCRA STATUS: If discarded in its purchased form, this product would not be a hazardous waste either by listing or by characteristic. However, under RCRA, it is the responsibility of the product user to determine at the time of disposal, whether a material containing the product or derived from the product should be classified as a hazardous waste,

Other Information:

This information relates only to the specific material designated and may not be valid for such material used in combination with any other materials or in any other process. Such information is to the best of the company's knowledge and believed accurate and reliable as of the date indicated. However, no representation, warranty or guarantee of any kind, express or implied, is made as to its accuracy, reliability or completeness and we assume no responsibility for any loss, damage or expense, direct or consequential, arising out of use. It is the user's responsibility to satisfy himself as to the suitableness and completeness of such information for his own particular use.

Annexure II Past Accident Analysis

Past Accidents involving ethanol

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.

Table 2.1.1 Past accidents involving Ethanol

Location & date	Qty	Cause for explosion	Consequences/ Damages	Probable Source of Ignition
Port Kembla, NSW, Australia 3 Mar 2004	7000 KL (7 million litres)	Ethanol Tank Fire	One man received minor burns and hundreds of workers were evacuated. The roof was blown off the tank and was lifted some 30 meters into the air, only to land next to the tank and damage the firefighting equipment for the whole installation Major concerns were that the 50m high flames could spread to other fuel storage tanks containing both ethanol and oil	The fire, which burned for 20 hours, was sparked by an explosion which blew the lid off the ethanol tank about 10am (AEDT) on 28 Jan 2004
Lillers (Nord-Pas-de-Calais), France 3 Sept 2001	15m3	After cleaning and degassing of empty alcohol tank F10 Explosion of tank F10 was to due to the ignition of an explosive atmosphere (ATEX) made up of alcohol vapors and air, present in the void of alcohol tank	Alcohol Tank exploded projecting its roof more than 10 m into the air. The roof fell onto the roof of neighbouring tank . Bund B and tank F10 caught fire Series of explosions caused the roofs of other empty tanks in the bund to be blown off.	Strongly exothermic reaction between a surplus of oxidizing agent, the potassium permanganate ($KMnO_4$), and the aqueous ethanol solution at 96%. Owing to the domino effect, the consequences of the accident were worsened by the damage caused to the other tanks

Hazards identified in ethanol storage

Recent research found the headspace vapors of denatured ethanol to be flammable at room temperature (20°C) and all temperatures down to approximately -5°C. Flammable liquids, including ethanol and high ethanol content fuels, may form ignitable vapor-air mixtures inside tanks at normal handling temperatures[7].

Fires fueled by ethanol are particularly challenging because they are not easily extinguished by traditional firefighting methods. Some commonly used fire suppression foams (e.g., those used to extinguish gasoline fires) are ineffective on ethanol fires, so special alcohol-resistant foams must be used.

Past Accidents involving biodiesel

A recent accident involving bulk storage of biodiesel is reported below

Table 2.1.2 Past accidents involving Biodiesel

Location & date	Qty involved	Description	Consequences/ damage	Probable cause
Visakhapatnam SEZ 26 -28 Apr 2016	12 tanks filled with 15-20 tonnes	A major fire erupted at a bio-diesel manufacturing unit around 7.30 pm on 26th April 2016. It engulfed 12 out of the 18 storage tanks.	No loss of life About 40 fire engines and additional fire engines with chemical foam were requisitioned to fight the blaze. The storage tanks exploded one after other, as the raging fire spread from one tank to other. Firefighting extended over three days	Short circuit in a motor sparked off the blaze Required safety distance between the storage tanks was not maintained; as a result the fire quickly spread from one tank to another. There was no proper captive fire control system, automated drenching system and sprinklers

[7] An Experimental and Modeling Study of the Flammability of Fuel Tank Headspace Vapors from High Ethanol Content Fuels D. Gardiner, M. Bardon, and G. Pucher Nexum Research Corporation Mallorytown, K0E 1R0, Canada, NREL/SR-540-44040 October 2008

Table 2.1.3 Past Accidents Records at Tank farms worldwide

Sl no	Date	Location	Description
1.	26-Apr-2010	New London, TX	One person died and another was injured in an oil tank explosion
2.	14-Apr-2010	Weleeka, OK	One man died and another was injured in a storage tank explosion
3.	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
4.	29-Oct-2009	Jaipur, India	An explosion spread fire through an oil installation
5.	30-Jul-2009	Mina Abdulla, Kuwait	A storage tank fire shut down one of the country's largest refineries
6.	23-Apr-2009	Russellville, AL	An above ground storage tank at a fuel transfer station was damaged by fire
7.	30-Oct-2008	Shreveport, LA	Fire followed an explosion in a storage tank at an oil refinery
8.	3-Oct-2008	Cremonia, Italy	A worker was injured in a tank explosion at a refinery
9.	3-Jul-2008	Xinjiang, China	Seven people died in an oil tank explosion
10.	2-Jun-2008	Lalbaug, India	An oil installation was destroyed by fire
11.	27-Mar-2008	Makhachkala, Russia	An explosion and fire at an oil installation left one worker burned
12.	27-Mar-2008	Port of Corinto, Nicaragua	An explosion rocked a storage tank being filled
13.	1-Feb-2008	Slocum, TX	A lightning strike caused an explosion in an oil tank battery
14.	12-Jan-2008	Chennai, India	Two workers were killed in an explosion while cleaning a storage tank at an oil refinery
15.	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
16.	6-Dec-2007	Phoenix, AZ	A tank fire broke out at a petroleum products plant
17.	19-Sep-2007	Siparia, Trinidad & Tobago	Two workers were injured in an oil storage tank explosion at a refinery
18.	24-May-2007	Slovag, Norway	A storage tank fire ignited at a tank farm near the country's largest refinery

Sl no	Date	Location	Description
19.	27-Mar-2007	Shreveport, LA	An explosion and fire rocked an oil refinery, leaving one worker with second-degree burns
20.	22-Mar-2007	Lagos, Nigeria	Fire broke out at a petroleum installation
21.	14-Feb-2007	Poleglass, U.K.	A major fire broke out at a fuel installation
22.	11-Dec-2005	Buncefield, U.K.	A massive explosion spread fire through an oil storage installation north of London, destroying 17 tanks.
23.	13-Oct-2005	Arkhangelsk, Russia	An oil tank exploded at a storage installation and killed 2 workers
24.	17-Jun-2005	Kurkumbh, India	A fire broke out in a tank containing petrochemicals at a petroleum refinery
25.	14-May-2005	Ripley , OK	An oil storage tank exploded killing two workers
26.	29-Oct-2004	Baroda , India	Sixteen workers were injured in an explosion at a gasoline refinery
27.	14-Oct-2004	Martinez , CA	A fire broke out in a holding tank at a refinery, taking three hours to extinguish
28.	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
29.	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
30.	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
31.	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
32.	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
33.	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

Sl no	Date	Location	Description
34.	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
35.	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

Annexure III Information used in the studies

A) Proposed additions:

- 2 x 858 kl ethanol tank
- 2 x 2600 kl biodiesel tanks

Details of proposed storage tanks as follows:

Tank ID	Product Stored	Licensed Capacity	Tank Type		Tank dimensions	Area of Dyke	Location
		KL		Roof type	Dia x H (m)	m^2	
T-011A	Ethanol	858	A/G	Fixed roof	9.0 x 13.5	9415	T1
T-011B	Ethanol	858	A/G	Fixed roof	9.0 x 13.5		
T-012A	Biodiesel	2600	A/G	Fixed roof	16.0 x 13.5	6338	T2
T-012B	Biodiesel	2600	A/G	Fixed roof	16.0 x 13.5		

A/G – Above Ground

.

Details of proposed unloading point for Biodiesel and Ethanol:

Location	Parameter required	Input value
TANKER UNLOADING FOR ETHANOL AND BIODIESEL	No. of bays in each gantry	1
	No. of tank lorries unloaded per day	*20 tanks per day (approximately)*
	No. of pumps	
	Pumping rate TLF Pumps, kl/hr	• Ethanol – 75 kl/hr • Biodiesel – 200 kl/hr
	Inlet pipeline size, inch	• Ethanol 10'' • Biodiesel 10''
	Outlet pipeline size, inch	• Ethanol 8'' • Biodiesel 8''
	Drain/ OWS	

B) Existing facility

Tank No	Product Stored	Storage Capacity	Tank Type		Tank dimensions	Location	Area of dyke
		KL		Roof Type	Dia x H (m)		(m^2)
T-001A	HSD	8740	BHC	Floating	28.0 x 16.0	T1	9415
T-001B	HSD	8740	BHC	Floating	28.0 x 16.0		
T-001C	HSD	8740	BHC	Floating	28.0 x 16.0		
T-001D	HSD	8740	BHC	Floating	28.0 x 16.0		
T-002A	SKO	4440	BHC	Floating	22.0 x 13.5	T2	6338

Tank No	Product Stored	Storage Capacity	Tank Type		Tank dimensions	Location	Area of dyke
		KL		Roof Type	Dia x H (m)		(m^2)
T-002B	SKO	4440	BHC	Floating	22.0 x13.5		
T-002C	MS	4440	BHC	Floating	22.0 x 13.5		
T-003A	MS	38160	BHC	Floating	22.0 x 13.5	T3	26002
T-003B	HSD	38160	BHC	Floating	58.5 x 16.0		
T-003C	MS	9380	BHC	Floating	58.5 X 16.0		
T-004A	SLOP	1075	BHC	Cone roof	13.0 x 9.0	T4	1320
T-004B	SLOP	1075	BLC	Cone roof	13.0 x 9.0		
T-006A	ETHANOL	100	A/G - H	Dished end	3.2 x 13.2		
T-006B	HI SPEED HSD	100	A/G - H	Dished end	3.2 x 13.2		
T-007B	MS(SPEED)	200	A/G - H	Dished end	4.0 x 16.4		
T-008A	BIO-DIESEL	200	A/G - H	Dished end	4.0 x 16.4		
T-0010A	Sample collection tank	10	A/G - H	Dished end	2.0 x 8.5		
T-0010B	Sample collection tank	10	A/G - H	Dished end	2.0 x 3.5		
U/G	TL fueling tank	20	U/G - H	Dished end	7.8 x 3.5		

C) Distribution of personnel inside the terminal

Activity	No. of persons in General shift
Pipeline receipt and unloading activities	
Exchange pit	3
Truck loading/unloading activities	
TLF gantry	4
Truck loading bay (driver & cleaner)	64
Others	
Administration	15
Security	7
Maintenance	1
Electrical shed	1
Firefighting	4
Total	**99**

D) Details of Population in the vicinity of the oil receiving terminal

Population distribution up to 1 km radius outside the plant:

Adjoining to BPCL, Karur

North Side - 600

East side - NIL

West side - 400

South Side - 200

E) Safety features at Dykes T1 and T2

Location	*Item*	*Existing features*
Plant area	1. Location & number of MCP	Total - 15 Security room, Front side Admin, Old FWPH, Control room, T03A and T03B, Between TLFG 1 and 2, TLF PH, MCC room, Between 1C-1D, Near 1A, near T02B, Near T03C, Reciept manifold, Dyke 4
	2. Location & number of ESD	Total- 15 IM Room, New FWPH, Control room, TLFG 1 and 2, TLF PH, MCC room, Between 1C-1D, Near 1A, near T02B, Near T03C, Reciept manifold,T03B Corner, Dyke 4, PCCK CR (future)
	3. Locations and number of Gas Detectors	At pump house, OWS. Exchange pit, MS Dykes
	4. Firefighting system	OISD 117 Compliant
New Tanks	5. SRV settings	Floating roof - HLS
	6. Trips and Interlocks	SIL 3 PLC
	7. Location and Number of ROV - Sequence of operation of ROV	Automation
	8. Indicators and alarms/ signals - Level - Temperature - Pressure	Radar guage, HLS, Temperature transmitter present for all above ground tanks
	9. Locks on Drain Valves	Automated
	10. Automatic medium velocity sprinkler system	For all tanks
	11. Locations of CV	
TT Gantry	12. Indicators and alarms	Radar, HLS
	13. Trips and Interlocks	SIL 3 PLC
	14. Hooter/ other alarms/ signals	SIL 3 PLC
	15. Locations of EFCV	

F) Summary of Automation features at Dykes T1 and T2

Location	Existing Automation features
1. At storage tanks	Radar, HLS, Temperature transmitter
2. Tanks dyke capacity	Limit switches
3. Firefighting at tank farms	As per OISD 117
4. Tank lorry gantry unloading	PD meters, Gantry automation

I. Summary of interlocking system

Activation of safety features results in the sequence described in the table below:

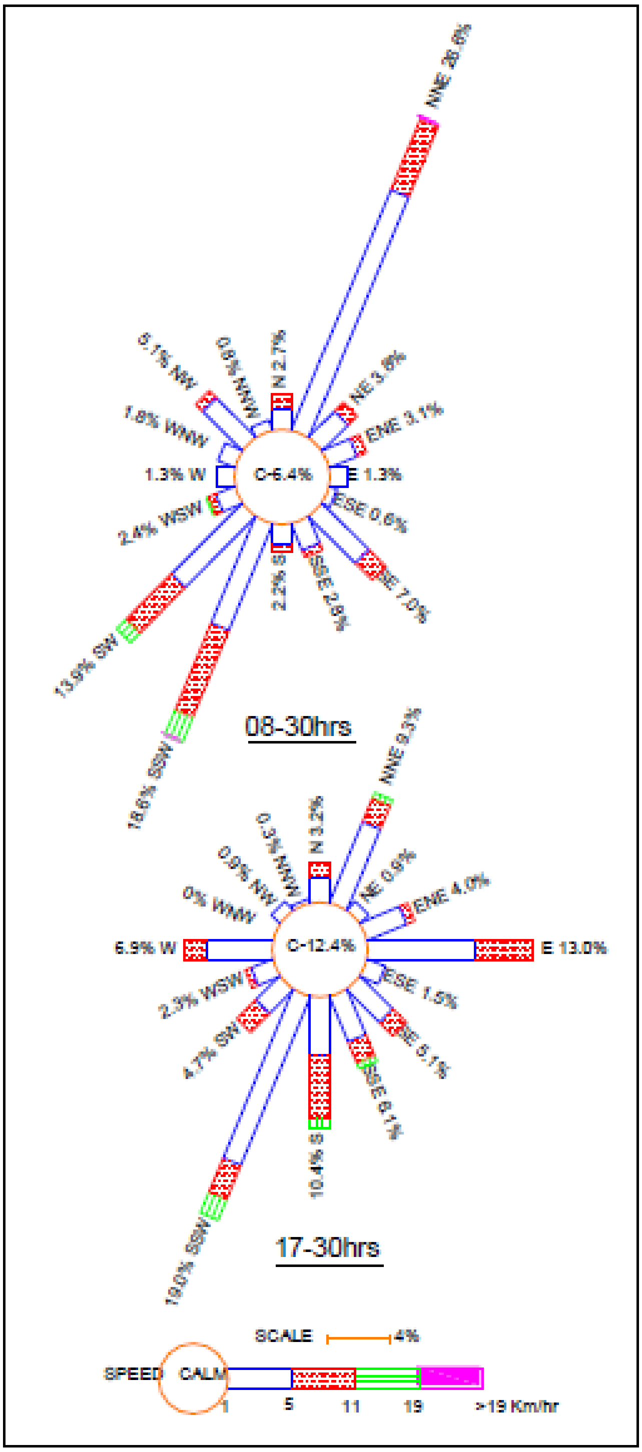
SL no	Description	Sequence of operation
1.	ESD activated	• Alarm shall be displayed in all operator station • Dedicated hooter for ESDs shall be activated in control room • All tank MOV and ROSOV shall get closed • All hooters provided shall get activated • All operations in terminal shall be stopped • TLF operation and TLF pumps shall be stopped • Generate ESD command for pipeline control room • Fire siren to be activated • Gate barriers to be open
2.	Dyke valve open position	• Alarm shall be displayed in all operator station
3.	Rim seal activated on Tank 3C and 3A-MS tanks	• Alarm shall be displayed in all operator station • Dedicated hooter for ESDs shall be activated in control room
4.	HHH alarms activated	HHH alarms shall be displayed on all operator station Tank inlet ROSOV and MOV gets closed All hooters provided shall get activated Product pump used for receipt of product in this particular tank shall be stopped Present in all tanks

J. Meteorological Data

Coimbatore district as a tropical wet and dry climate, with the wet season lasting from October to December due to the northeast monsoon. The mean maximum temperature ranges from 35.9 °C to 29.2 °C and the mean minimum temperature ranges from 24.5 °C to 19.8 °C .

Fig III.1 shows the Wind rose diagrams for Karur district

Fig III.1 Wind rose diagrams for Karur Dist.



The consequences of releases of flammable materials into the atmosphere are strongly dependent upon the rate at which the released material is diluted and dispersed to safe concentrations. The rate of dispersion is dependent on the meteorological conditions prevailing at the time of release, particularly the wind speed and the degree of turbulence in the atmosphere.

The wind direction is also of importance as it determines the direction in which the cloud of material will travel.

Annexure IV Models used in Consequence Analysis

Consequence analysis was conducted based on the following models and equations, mentioned in the IS 15656: 2006. The most appropriate model(s) applicable for the project have been used.

POOL FIRE MODEL

Guidelines for Evaluating the Characteristics of Vapor Cloud Explosions, Flash fires and BLEVEs, (1994) by Center for Chemical Process Safety of the American Institute of Chemical Engineers[8] , NY.

SPILL MODEL

Spreading and Evaporation, Shell SPILLS model (Fleischer 1980)

Guidelines for use of VAPOR CLOUD DISPERSION MODELS by Hanna and Drivas, (1996) by Center for Chemical Process Safety of the American Institute of Chemical Engineers*, NY

VAPOR CLOUD EXPLOSION

Shock wave model

a) TNO, Methods for the Determination of Possible Damage (Green Book), CPR 16E, 1st ed. (1992).

b) Hanna, S. R., Drivas, P. J.

Guidelines for use of VAPOR CLOUD DISPERSION MODELS by Hanna and Drivas (1996) by Center for Chemical Process Safety of the American Institute of Chemical Engineers*, NY

DENSE GAS MODELLING

Heavy gas dispersions based on Thorney Island Observations (1985).

Guidelines for use of VAPOR CLOUD DISPERSION MODELS by S R Hanna and P J Drivas (1996) by Center for Chemical Process Safety of the American Institute of Chemical Engineers*, NY

EFFECTS OF THERMAL RADIATION

World Bank (1985) Manual of Industrial Hazard Assessment techniques Office of Environmental and Scientific Affairs, World Bank, Washington, D. C.

EXPLOSION DAMAGES

Guidelines for Evaluating the Characteristics of Vapor Cloud Explosions, Flash fires and BLEVEs, (1994) by Center for Chemical Process Safety of the American Institute of Chemical Engineers*, NY

[8] Cited by Environmental Protection Agency, US in its 1996 Document “Off-Site Consequence” Analysis Guidance

Annexure V 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[9]

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.

[9] 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