RAPID RISK ANALYSIS STUDY

OF

CAUVERY BASIN REFINERY PROJECT

CHENNAI PETROLEUM CORPORATION LIMITED

Rev No	Date	Purpose	Prepared By	Reviewed By	Approved By
1	31/05/2019	Issued As Final (Additional Facilities Included)	GGR	DK	DK
0	29/04/2019	Issued As Final	GGR	DK	DK

PREFACE

M/s Engineers India Limited (EIL) has been engaged by M/s Chennai Petroleum Corporation Limited (CPCL) for carrying out Detailed Feasibility studies for the proposed 9 MMTPA refinery at Nagapattinam. As a part of project, EIL carried out RRA study of the facilities coming under Cauvery Basin Refinery Project.

Rapid Risk Analysis study identifies the hazards associated with the facility, analyses the consequences, draws suitable conclusions and provides necessary recommendations to mitigate the hazard/ risk.

This Rapid Risk Analysis study is based on the information made available at the time of this study and EIL's own data source for similar plants. EIL has exercised all reasonable skill, care and diligence in carrying out the study. However, this report is not deemed to be any undertaking, warrantee or certificate.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1 EXECUTIVE SUMMARY

1.1 INTRODUCTION

M/s Chennai Petroleum Corporation Limited (CPCL), a group company of Indian Oil Corporation Limited (IOCL) has planned to set up a grassroot refinery of capacity 9 MMTPA at Nagapattinam, Tamilnadu at the same location of the existing Cauvery Basin Refinery after dismantling the existing facilities. This new refinery which will produce the fuels of BS-VI specifications will able to meet the growing demands of fuels in southern region and nearby location.

M/s Engineers India Limited (EIL) has been engaged by CPCL for carrying out Detailed Feasibility studies for the proposed 9 MMTPA refinery at Nagapattinam. As a part of project, EIL carried out RRA study of the said facility.

This executive summary covers major findings arising out of the Rapid Risk Analysis study and recommendations for the safe operation. The detailed analysis is given in Section –6.

1.2 APPROACH METHODOLOGY

RRA study evaluates the consequences of potential failure scenarios, assess extent of damages, based on damage criteria's and suggest suitable measures for mitigating the Hazard.

RRA involves identification of various potential hazards & credible failure scenarios for various units and other facilities including off-site storages & pumping, etc., based on their frequency of occurrence & resulting consequence. Basically two types of scenarios are identified spanning across various process facilities; Cases with high chance of occurrence but having low consequence, e.g., Instrument Tapping Failure (20 & 10 mm) and cases with low chance of occurrence but having high consequence, e.g., Catastrophic Rupture of Pressure Vessels. Effect zones for various outcomes of failure scenarios (Flash Fire, Jet Fire, Pool Fire, Blast overpressure, etc.) are studied and identified in terms of distances on plot plan. Based on effect zones, measures for mitigation of the hazard/risk are suggested.

1.3 MAJOR FINDINGS AND RECOMMENDATIONS

The detailed consequence analysis of release of hydrocarbon in case of major credible scenarios are modeled in terms of release rate, dispersion, flammability and toxic characteristics, which have been discussed in detail in the report. The major findings and recommendations arising out of the Rapid Risk Analysis study are summarized below:

- Consequence modeling of various credible scenarios for CDU/VDU Block is carried out and it is observed that the Cooling Towers present on the eastern side of the unit & adjacent MS Block unit may get affected from Radiation & Explosion effects emanating from the unit, depending upon the prevalent wind conditions & ignition source encountered at the time of release.

It is recommended to install Fire & Gas detectors at suitable location within the unit. Utilize Low frequency failure scenarios such as 50 mm leak scenarios for preparation of Emergency Response & Disaster Management Plan.

- Flammable & Toxic failure scenarios are modeled for NHT, CCR & ISOM and their Explosion, Radiation & Toxic effects are studied. It is observed that the adjacent Tank Farm, CDU/VDU, SRR-2 and S/S-2 may get affected on account of leakage scenarios (Explosion & Radiation effects) from these units, depending upon the equipment location in the unit and prevalent weather conditions at the time of release. Moreover, H_2S, Benzene & Toluene IDLH concentration from toxic failure scenarios may also affect operators present in these plants and may extend up to CDU/VDU, Offsite area, SRR-2, S/S-2, SRR-1, S/S-1 and S/S-11. In the event of 20 mm leak from NHT stripper reflux pump, the IDLH concentration of H_2S may reach up to 217 m leak source and it may cross Refinery compound wall towards North West side depending upon the prevalent weather conditions at the time of release and equipment locations within unit.

  It is recommended to maintain at least 217 m distance between NHT Stripper Reflux Pump and Refinery Compound Wall while finalizing equipment layout during detailed engineering stage.

  It is recommended to make SRR-2 & SRR-1 positive pressurized with HC, H_2S detectors at inlet of HVAC duct which shall close inlet damper on actuation of HC/H_2S detector.

  It is also recommended to install Fire & Gas (Flammable & Toxic) detectors at strategic locations within these units along with remotely operated isolation valves for inventory isolation in the event of any leakage. Utilize low frequency failure scenarios such as 50 mm leak *scenarios for preparation of Emergency Response & Disaster Management Plan.*

- Flammable & Toxic failure scenarios are modeled for the DHDT Unit, it is observed that affect zones arising out of the high & low frequency credible scenarios for HP & Toxic sections of the DHDT shall cross the unit B/Ls and may affect the nearby VGO HDT, INDMAX GDS, LPG Treating Unit (Train II), Offsite area, OMS Control Room 6, SRR-4, S/S-4, SRR-5 and S/S-5 depending upon the prevalent weather conditions at the time of release and equipment locations within unit.

  It is recommended to make OMS Control Room 6, SRR-4 and SRR-5 positive pressurized with HC & H_2S detectors at inlet of HVAC duct which shall close inlet damper on actuation of HC/H_2S detector

  It is recommended to install Fire & Gas (Flammable & Toxic) detectors at strategic locations within unit along with remotely operated isolation valves for inventory isolation in the event of any leakage. Utilize low frequency failure scenarios such as 50 mm leak scenarios for preparation of Emergency Response & Disaster Management Plan.

- Various credible leak scenarios are modeled for the VGO-HDT unit and it is observed that Radiation, Explosion & Toxic effect zones may cross the B/Ls of the unit. H_2S IDLH concentration in the event of 20 mm Leak at LPG Product Pump discharge circuit may affect nearby DHDT, INDMAX GDS, INDMAX, OCTAMAX, CDU/VDU, MS Block, LPG Treating Unit (Train II), Offsite area , OMS Control Room 6, OMS Control Room 5, SRR-1, S/S-1, SRR-4, S/S-4, SRR-3, S/S-3, SRR-5, S/S-5, SRR-2 & S/S-2 and it may cross Refinery compound wall depending upon the equipment location & prevalent weather conditions at the time of the release.

  It is recommended to maintain at least 450 m distance between LPG product pump and Refinery Compound Wall while finalizing equipment layout during detailed engineering stage.

  It is recommended to make OMS Control Room 6, OMS Control Room 5, SRR-1, SRR-2, SRR-3, SRR-4 and SRR-5 positive pressurized with HC & H_2S detectors at inlet of HVAC duct which shall close inlet damper on actuation of HC/H_2S detector.

  It is recommended to install Fire & Gas (Flammable & Toxic) detectors at strategic locations within the unit along with remotely operated isolation valves for inventory isolation in the event of any leakage. Utilize low frequency failure scenarios such as 50 mm leak scenarios for preparation of Emergency Response & Disaster Management Plan.

- Toxic Scenarios are modeled for the SRU / ARU(1 & 2)/ SWS (1&2) and it is observed that the H2S IDLH concentration may cross the unit's B/Ls and affect the nearby facilities and personnel present, depending upon the prevalent weather conditions at the time of the release.

  Hence, it is recommended to install Toxic gas detectors at strategic locations within the unit along with remotely operated isolation valves for inventory isolation in the event of any leakage. The outcomes of these scenarios to be also utilized for preparation of Emergency Response & Disaster Management Plan.

- Flammable scenarios are modeled for PPU and it is observed that the hazard effect zone may cross the unit's B/L and may affect the nearby facilities depending upon the prevalent weather conditions at the time of the release.

  Hence it is recommended to install HC gas detectors at strategic locations within the unit.

- Various credible Flammable & Toxic failure scenarios are modeled for the DCU and it is observed that Radiation & Explosion effect zones may cross the unit's B/L and may affect Control Room-8 (Circulating Fluidized Bed Combustion Boiler), Control Room-3 (Air & N2 Plant) and SRR-6 (DCU & PPU). H_2S IDLH concentration in the event of 20 mm Leak at WGC discharge, Stripper Charge Pump and LPG Product Pump discharge circuit may affect HGU, CFBC, PPU, Polymer Lab, PP Ware House, Cooling Tower, Air & N2 Plant,

SRR-1, S/S-6, SRR-8, S/S-7, S/S-16, SRR-6, Control Room-3 (Air & N2 Plant), Control Room-8 (CFBC) and it may cross the Refinery Compound Wall, depending upon the operating conditions, prevalent weather conditions at the time of release.

Hence it is recommended to relocate DCU unit or toxic handling section of DCU in such a way that the IDLH contours of H_2S are contained within the facility.

Hence it is recommended to relocate the Control Room-8 (CFBC), Control Room-3 (Air & N2 Plant) to alternate safe location to safeguard the persons. Ensure that SRR--6 (DCU & PPU) shall be made blast resistant.

It is recommended to make Control Room-8 (CFBC), Control Room-3 (Air & N2 Plant), Polymer Lab, SRR-1, SRR-8 and SRR-6 (DCU & PPU) positive pressurized with HC & H_2S detectors at inlet of HVAC duct which shall close inlet damper on actuation of HC/H_2S detector.

It is also recommended to install Fire & Gas (Flammable & Toxic) detectors at strategic locations within the unit along with remotely operated isolation valves for inventory isolation in the event of any leakage. Utilize low frequency failure scenarios such as 50 mm leak scenarios for preparation of Emergency Response & Disaster Management Plan.

- Credible Failure scenarios are modeled for the INDMAX FCC unit and it is observed that affect zones (Flammable & Explosion) arising out of the high & low frequency credible scenarios may cross the unit B/Ls and may affect the nearby units, depending upon the prevalent weather conditions at the time of release and equipment locations within unit.

  It is recommended to install Fire & Gas detectors at suitable location within the unit. Utilize Low frequency failure scenarios such as 50 mm leak scenarios for preparation of Emergency Response & Disaster Management Plan.

- Flammable scenarios are modeled for Hydrogen Generation Unit (HGU), it is observed that the consequence outcomes for the Naphtha handling section of the unit may cross the unit's B/L and affect the nearby offsite area and CFBC, depending upon equipment location & prevalent weather conditions at the time of the release.

  It is recommended to install Fire & Gas detectors at suitable location within the unit. Utilize Low frequency failure scenarios such as 50 mm leak scenarios for preparation of Emergency Response & Disaster Management Plan.

- Various credible leak scenarios are modeled for the INDMAX GDS unit and it is observed that Radiation, Explosion & Toxic effect zones may cross the B/Ls of the unit. Benzene IDLH concentration in the event of 20 mm Leak at MCN Splitter Reflux Pump discharge circuit may affect nearby DHDT, VGO HDT, LPG Treating Unit (Train II), Offsite area, OMS Control Room 5, SRR-4, SRR-5, S/S-5, SRR-2 depending upon the equipment location & prevalent weather conditions at the time of the release.

It is recommended to make OMS Control Room 5, SRR-2, SRR-4 and SRR-5 positive pressurized with HC detectors at inlet of HVAC duct which shall close inlet damper on actuation of HC/H_2S detector.

It is recommended to install Fire & Gas detectors at strategic locations within the unit along with remotely operated isolation valves for inventory isolation in the event of any leakage. Utilize low frequency failure scenarios such as 50 mm leak scenarios for preparation of Emergency Response & Disaster Management Plan.

- Credible Flammable & Toxic scenarios are modeled for the LPG Amine Treating Unit and it is observed that the hazard effect zone may cross the unit's B/L and may affect the nearby facilities depending upon the prevalent weather conditions at the time of the release.

  Hence it is recommended to install HC/H_2S gas detectors at strategic locations within the unit.

- Flammable scenarios are modeled for the LPG Treating Unit (Train I & II) and it is observed that the hazard effect zone may cross the unit's B/L and may affect the nearby facilities depending upon the prevalent weather conditions at the time of the release.

  Hence it is recommended to install HC gas detectors at strategic locations within the unit.

- Toxic scenarios are modeled for the FGTU unit and it is observed that the H_2S IDLH concentration may cross the unit's B/L and affect the nearby CDU/VDU, MS block, CWTP, Offsite area, S/S-2, S/S-1, SRR-1, MCR-1, S/S-8 and SRR-9 depending upon the prevalent weather conditions at the time of the release.

  It is recommended to make SRR-1, MCR-1, and SRR-9 positive pressurized with HC & H_2S detectors at inlet of HVAC duct which shall close inlet damper on actuation of HC/H_2S detector.

  It is also recommended to install Toxic gas detectors at strategic locations within the unit.

- Credible Failure scenarios are modeled for the OCTAMAX unit and it is observed that affect zones (Flammable & Explosion) arising out of the high & low frequency credible scenarios may cross the unit B/Ls and may affect the nearby units, depending upon the prevalent weather conditions at the time of release and equipment locations within unit.

  It is recommended to install Fire & Gas detectors at suitable location within the unit. Utilize Low frequency failure scenarios such as 50 mm leak scenarios for preparation of Emergency Response & Disaster Management Plan.

- Flammable failure scenarios are modeled for the hydrocarbon Pumps in the Offsite and it is observed that Radiation & Explosion effects may affect the nearby Storage Tanks.

Hence it is recommended to provide the Fire & Gas detectors at strategic locations in the Offsite pump houses with adequate fire protection system for tankages & pump houses.

- Tank on fire case modeled for storage tanks and it is observed that the Radiation effects may affect the nearby storage tanks and flare trestle. In case of tank on fire in TF-16, TF-18, TF-20, TF-9, and TF-12, 8 kW/m2 radiations from one tank may affect next immediate Tank located in the same tank TF and, possibly resulting in their failure.

  Hence it is recommended to increase the distance between TF-8 dyke wall and supports of Flare trestle further by 15m to prevent damage of flare trestle supports due to any accidental pool fire in TF-8 dyke.

  It is recommended to increase the inter distance between the tanks located TF-16, TF-18, TF-20, TF-9, and TF-12 or provide adequate fire fighting protective devices to prevent further escalation.

- Credible Failure scenarios are modeled for Pipeline Terminal and it is observed that affect zones (Flammable & Explosion) arising out of the high & low frequency credible scenarios may affect SRR-16, S/S-20, depending upon the prevalent weather conditions at the time of release and equipment locations within unit. 1

  Hence it is recommended to make SRR-16 blast resistant building.

  It is recommended to install Fire & Gas detectors at suitable location within the terminal. Utilize Low frequency failure scenarios such as 50 mm leak scenarios for preparation of Emergency Response & Disaster Management Plan.

- Credible Failure scenarios are modeled for LFP and it is observed that affect zones (Flammable & Explosion) arising out of the high & low frequency credible scenarios may cross the facility B/Ls and may affect the nearby population and temple, depending upon the prevalent weather conditions at the time of release and equipment locations within unit. 1

  Hence it is recommended to locate the Booster Pump discharge & associated facility such that hazard distance of 128 m is not reaching to the populated area in the village and nearby temple.

  It is recommended to install Fire & Gas detectors at suitable location within the facility with provision for isolating inventory in case of detection of any leakage. Utilize Low frequency failure scenarios such as 50 mm leak scenarios for preparation of Emergency Response & Disaster Management Plan.

- In case of 20 mm leak of MS from pipeline, it is observed that LFL may reach up to a distance of 95 m from leak source. However, this appears to have a very low likelihood of occurrence as far as the pipeline under study is considered, since it will run underground 1 all over its length. The major contribution of pipeline leaks can be attributed to third-party interference – digging, ploughing or tampering.

It is advisable to maintain at least 95 m distance from any nearby habitation / village / any other manned facility along the pipeline route.

In view of this; it is therefore recommended that regular inspections be undertaken in the vicinity of the pipeline, along its length, so that all third party activity in the area may be obviated or curtailed before harm ensues from the same. 1

The major contribution of pipeline ruptures or large holes (50mm) can be attributed to third-party interference – digging, ploughing or tampering. Though the possibility of rupture of a pipeline is remote, but the consequence distances are high. Regular inspection of the pipeline is the sole way to forestall such a problem. And also it is recommended to include the scenario of pipeline rupture/ large hole scenarios in disaster management plan.

- Various credible scenarios are modeled for Karaikal Port Terminal and it is observed that the hazard effect zone may cross the terminal B/L and may affect the nearby facilities depending upon the prevalent weather conditions at the time of the release. In case of 20 mm leak from MS pipeline, it is observed that the 5 & 3 psi blast wave may reach up to a distance of 104 m and 113 m respectively from leak source. 1

  Hence it is recommended to maintain a buffer zone of 113 from Terminal pipeline and associated equipments. Safety distances to be reverified based upon finalized plot plan during detail engineering.

  It is recommended to install Fire & Gas detectors at suitable location within the facility with provision for isolating inventory in case of detection of any leakage. Utilize Low frequency failure scenarios such as 50 mm leak scenarios for preparation of Emergency Response & Disaster Management Plan.

General Recommendations

- ✓ Detailed Quantitative Risk Analysis needs to be carried out for entire facility for overall risk assessment.
- ✓ No Operator Cabin to be located inside battery limits of units. Detailed QRA required to be carried out prior to fixing the location of any Operator Cabin in the close vicinity of Process units.
- ✓ For positively pressurized building, both Hydrocarbon & Toxic detectors need to be placed at suction duct of HVAC. HVAC to be tripped automatically in event of the detection of any Hydrocarbon / toxic material by detector.
- ✓ In order to prevent secondary incident arising from any failure scenario, it is recommended that sprinklers and other protective devices provided on the tanks to be regularly checked to ensure that they are functional.

- ✓ Proper checking of contract people for Smoking or Inflammable materials to be ensured at entry gates to avoid presence of any unidentified source of ignition.
- ✓ It shall be ensured that all the vehicles entering the plant shall be provided with spark arrestors at the exhaust.
- ✓ The critical operating steps shall be displayed on the board near the location where applicable.
- ✓ Mock drills to be organized at organization level to ensure preparation of the personnel's working in premises for handling any hazardous situation.
- ✓ Active fire protection system shall be provided throughout the plant for preventing escalation of fire.
- ✓ Recommended to use portable HC/H_2S detector during sampling and maintenance etc.
- ✓ It is recommended for usage of safer oxidizing agents (Chlorine free) in Cooling Water circuit.
- ✓ Cognizance must be taken of the fact that the area bordering the pipeline will have to be kept free of habitation, and means to discourage the growth of such must be incorporated in the offsite disaster management plan.
- ✓ Since most incidents on buried pipelines are caused by external interference (digging, ploughing or drilling in the vicinity of the pipeline, it is recommended that frequent patrolling and pipeline inspection be instituted to enable early detection and cession of all such activities near the pipeline.
- ✓ Ensuring that the public in vicinity of the pipeline is made aware of the hazards and also the hazards of unplanned and irregular third party activities- this may be done through frequent safety awareness programmes, warning signage, explicit display of Do's and Don'ts etc.
- ✓ Line patrolling: Line patrolling is a visual inspection of the pipeline along the whole of its length. It involves verification of: 1
  - General condition of the pipeline.
  - Any breaches and soil erosion along the route of the pipeline, especially earth washed out at road and channel crossings.
  - Growth of vegetation, which needs to be curtailed to ensure the free movement of vehicles to attend to any incident.
  - All digging, ploughing and dredging in the vicinity of the pipeline, which may damage the pipeline.
  - General condition of the cathodic protection at various locations.

Mitigating Measures

Mitigating measures are those measures in place to minimize the loss of containment event and, hazards arising out of Loss of containment. These include:

- ✓ Early detection of an undesirable event (HC/ toxic leak, Flame etc.) and development of subsequent quick isolation mechanism.
- ✓ Measures for controlling / minimization of Ignition sources inside the operating area.
- ✓ Active and Passive Fire Protection for critical equipment's and major structures
- ✓ Effective Emergency Response plans to be in place

Ignition Control

- ✓ Ignition control will reduce the likelihood of fire events. This is the key for reducing the risk within facilities processing flammable materials. As part of mitigation measure it is strongly recommended to consider minimization of the traffic movement in the vicinity of operating area.

Escape Routes

- ✓ Ensure sufficient escape routes from the site are available to allow redundancy in escape from all areas.
- ✓ Ensure sufficient number of windsocks throughout the site to ensure visibility from all locations. This will enable people to escape upwind or crosswind from flammable / toxic releases.
- ✓ Provide sign boards marking emergency/safe roads to be taken during any exigencies.

Preventive Maintenance for Critical Equipment

- ✓ In order to reduce the failure frequency of critical equipment, the following are recommended:

  a. High head pumps and Compressors, which are in flammable/ toxic services, are needed to be identified.
     i. Their seals, instruments and accessories are to be monitored closely
     ii. A detailed preventive maintenance plan to be prepared and followed.

  b. High inventory vessels whose rupture may lead to massive consequences are needed to be identified and following to be ensured:
     i. Monitoring of vessel internals during shut down.
     ii. A detailed preventive maintenance plan to be prepared and followed.
     iii. Emergency inventory isolation valves shall be provided for vessel/column having large inventory and containing flammable/ toxic compound

2 INTRODUCTION

2.1 STUDY AIMS AND OBJECTIVE

The objectives of the Rapid Risk Analysis study are to identify and quantify all potential failure modes that may lead to hazardous consequences and extent. Typical hazardous consequences include fire, explosion and toxic releases.

The Rapid Risk Analysis will also identify potential hazardous consequences having impacts on population and property in the vicinity of the facilities, and provides information necessary in developing strategies to prevent accidents and formulate the Disaster Management Plan.

The Rapid Risk Analysis includes the following steps:

a) Identification of failure cases within the process and off-site facilities
b) Evaluate process hazards emanating from the identified potential accident scenarios.
c) Analyze the damage effects to surroundings due to such incidents.
d) Suggest mitigating measures to reduce the hazard / risk.

The Risk analysis study has been carried out using the risk assessment software program 'PHAST ver. 7.22 developed by DNV Technica.

2.2 SCOPE OF WORK

The study addresses the hazards that can be realized due to operations associated with the facilities coming under Cauvery Basin Refinery Project. It covers the following facilities:

- CDU/VDU
- MS Block (NHT, ISOM, CCR & ROG PSA)
- DHDT
- VGO HDT
- Sulphur Block (ARU/SWS/SRU)
- PPU
- DCU
- INDMAX FCC Unit
- HGU
- INDMAX GDS Unit
- LPG Amine Treating Unit
- LPG Treating Unit (Train-I)
- LPG Treating Unit (Train-II)
- FGTU
- OCTAMAX
- Offsite and Utilities
- Pipeline Terminal

- Pipeline
- LFP
- Karaikal Port Terminal

1

3 SITE CONDITION

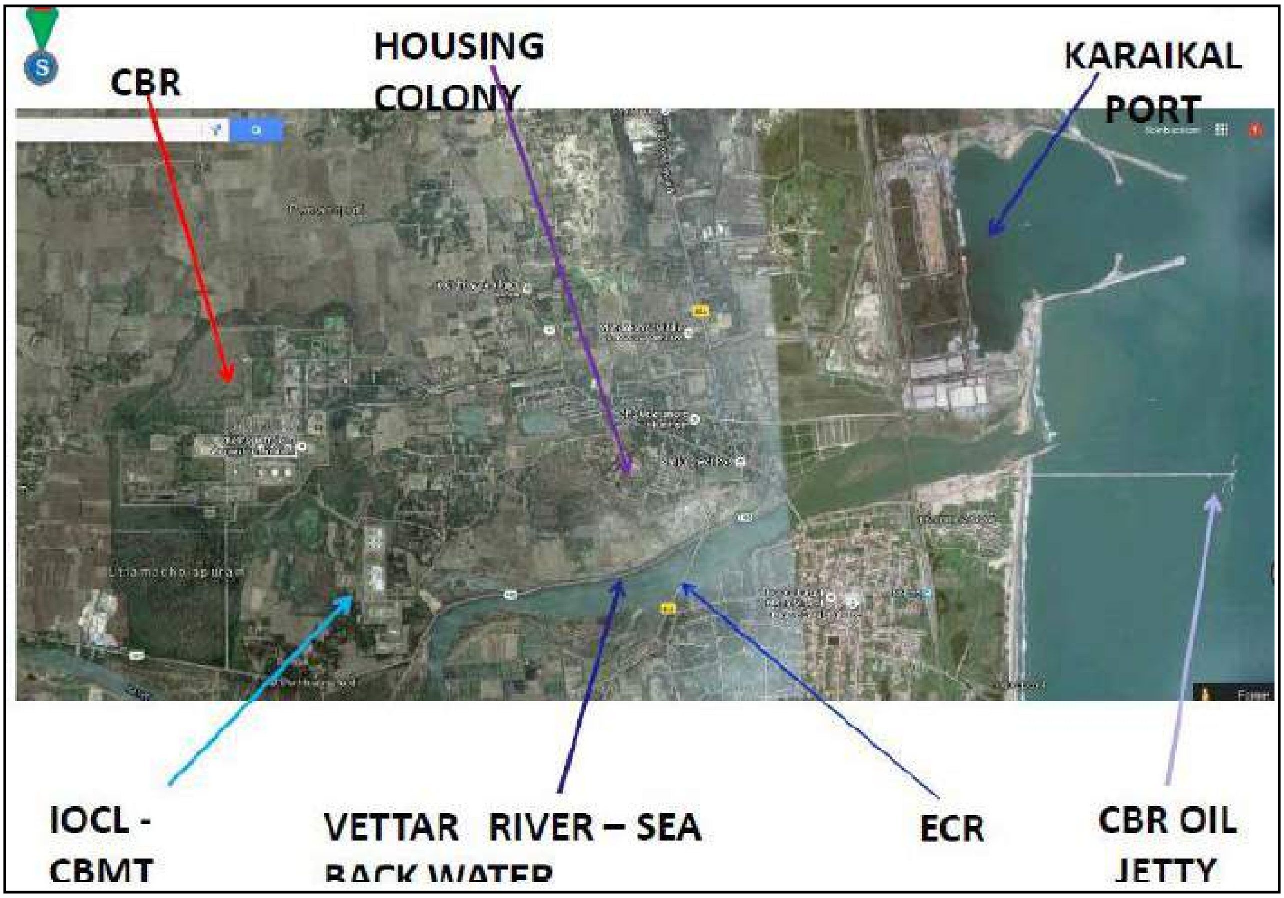
3.1 GENERAL

This chapter describes the location of Cauvery Basin Refinery and meteorological data, which have been used for the Rapid Risk Analysis study.

3.2 SITE, LOCATION AND VICINITY

The proposed Cauvery Basin Refinery Project is located in Nagapattinam in Tamilnadu. The site is located approximately at Latitude of 10.829 and longitude of 79.813. Nearest Railway station is Nagore and nearest Airport is Thiruchirappalli.

Figure 1: Cauvery Basin Refinery



3.3 METEOROLOGICAL CONDITIONS

The consequences of released toxic or flammable material are largely dependent on the prevailing weather conditions. For the assessment of major scenarios involving release of toxic or flammable materials, the most important meteorological parameters are those that affect the atmospheric dispersion of the escaping material. The crucial variables are wind direction, wind speed, atmospheric stability and temperature. Rainfall does not have any direct bearing on the results of the risk analysis; however, it can have beneficial effects by absorption / washout of released materials. Actual behavior of any release would largely depend on prevailing weather condition at the time of release.

For the Risk Analysis study, Meteorological data of Nagapattinam has been taken from the Climatological Tables of Observatories in India (1981-2010) published by Indian Meteorological Department, Pune.

Atmospheric Parameters

The Climatological data which have been used for the Risk Analysis study is summarized below:

Table 1: Atmospheric Parameter

Sl. No.	Parameter	Average Value Considered For Study
1.	Ambient Temperature (^{O}C)	29
2.	Atmospheric Pressure (mm Hg)	760
3.	Relative Humidity (%)	75
4.	Solar Radiation flux (kW/m^2)	0.70

Wind Speed and Wind Direction

The meteorological data considered for the study is based on the location Nagapattinam from the IMD Table. Based on the Meteorological data provided in IMD table, it is observed that average wind speed of magnitude of around 2-3 m/s blows for around 66% of the time, in a year. And for rest of time period average wind speed is around 3-4 m/s. Hence predominant wind speed for complex considered for RRA Study is 2 & 3.5 m/s.

Table 2: Average Mean Wind Speed (m/s)

Jan	Feb	Mar	April	May	June	July	Aug	Sep	Oct	Nov	Dec
2.67	2.44	2.44	2.78	3.44	3.75	3.5	3.42	2.83	2.2	2.36	2.83

Weather Category

One of the most important characteristics of atmosphere is its stability. Stability of atmosphere is its tendency to resist vertical motion or to suppress existing turbulence. This tendency directly influences the ability of atmosphere to disperse pollutants emitted into it from the facilities. In most dispersion scenarios, the relevant atmospheric layer is that nearest to the ground, varying in thickness from a few meters to a few thousand meters. Turbulence induced by buoyancy forces in the atmosphere is closely related to the vertical temperature gradient.

Temperature normally decreases with increasing height in the atmosphere. The rate at which the temperature of air decreases with height is called Environmental Lapse Rate (ELR). It will vary from time to time and from place to place. The atmosphere is said to be stable, neutral or unstable according to ELR is less than, equal to or greater than Dry Adiabatic Lapse Rate (DALR), which is a constant value of 0.98°C/100 meters.

Pasquill stability parameter, based on Pasquill – Gifford categorization, is such a meteorological parameter, which decreases the stability of atmosphere, i.e., the degree of convective turbulence. Pasquill has defined six stability classes ranging from `A' (extremely unstable) to `F' (stable). Wind speeds, intensity of solar radiation (daytime insulation) and nighttime sky cover have been identified as prime factors defining these stability categories. Below Table indicates the various Pasquill stability classes.

Table 3: Pasquill Stability Classes

Surface Wind Speed (meter/s)	Day time solar radiation			Night time cloud cover		
	Strong	Medium	Slight	Thin < 3/8	Medium 3/8	Overcast >4/5
< 2	A	A – B	B	-	-	D
2 – 3	A – B	B	C	E	F	D
3 – 5	B	B – C	C	D	E	D
5 – 6	C	C – D	D	D	D	D
> 6	C	D	D	D	D	D

Legend: A = Very unstable, B = Unstable, C = Moderately unstable, D = Neutral, E = Moderately stable, F = stable

When the atmosphere is unstable and wind speeds are moderate or high or gusty, rapid dispersion of pollutants will occur. Under these conditions, pollutant concentrations in air will be moderate or low and the material will be dispersed rapidly. When the atmosphere is stable and wind speed is low, dispersion of material will be limited and pollutant concentration in air will be high. In general worst dispersion conditions (i.e. contributing to greater hazard distances) occur during low wind speed and very stable weather conditions, such as that at 1F weather condition (i.e. 1 m/s wind speed and Pasquill Stability F).

Stability category for the present study is identified based on the cloud amount and wind speed. For risk analysis the representative average annual weather conditions are assessed based on the following:

Average Wind speed in order of 2-3 m/s would be experienced for around 66% of time in a year and Wind speed of 3-4 m/s can be realized in rest of the time. Based on weather analysis, predominant weather stability of “F”& “B/C” was selected with wind speed 2 m/s & 3.5 m/s for consequence analysis, respectively.

The consequence results are reported in tabular form for all the weather conditions and are represented graphically for worst weather condition.

Table 4: Weather Conditions

Wind Speed	Pasquill Stability
2	F
3.5	B/C

Note: For RRA Study Plot Plan (Doc. No.: B145-000-17-44-0001 Rev G) has been used.

4 HAZARDS ASSOCIATED WITH THE FACILITIES

This chapter describes in brief the hazards associated with the materials being handled in the Plant. Refinery complex handles a number of hazardous materials like LPG, Hydrogen, Naphtha, Benzene and other hydrocarbons which have a potential to cause fire and explosion hazards. The toxic chemicals like Benzene, Ammonia and Hydrogen sulfide are also being handled in the Refinery Complex. This chapter describes in brief the hazards associated with these materials.

4.1 HAZARDS ASSOCIATED WITH FLAMMABLE MATERIALS

4.1.1 LIQUIFIED PETROLEUM GAS

LPG is a colorless liquefied gas that is heavier than air and may have a foul smelling odorant added to it. It is a flammable gas and may cause flash fire and delayed ignition.

LPG is incompatible to oxidizing and combustible materials. It is stable at normal temperatures and pressure. If it is released at temperatures higher than the normal boiling point it can flash significantly and would lead to high entrainment of gas phase in the liquid phase. High entrainment of gas phase in the liquid phase can lead to jet fires. On the other hand negligible flashing i.e. release of LPG at temperatures near boiling points would lead to formation of pools and then pool fire. LPG releases may also lead to explosion in case of delayed ignition.

Inhalation of LPG vapors by human beings in considerable concentration may affect the central nervous system and lead to depression. Inhalation of extremely high concentration of LPG may lead to death due to suffocation from lack of oxygen. Contact with liquefied LPG may cause frostbite. Refer to below table for properties of LPG.

Table 5: Hazardous Properties of LPG

Sl. No.	Properties	Values
1.	LFL (%v/v)	1.7
2.	UFL (%v/v)	9.0
3.	Auto ignition temperature (°C)	420-540
4.	Heat of combustion (Kcal/Kg)	10960
5.	Normal Boiling point (°C)	-20 to –27
6.	Flash point (°C)	- 60

4.1.2 HYDROGEN

Hydrogen (H_2) is a gas lighter than air at normal temperature and pressure. It is highly flammable and explosive. It has the widest range of flammable concentrations in air among all common gaseous fuels. This flammable range of Hydrogen varies from 4% by volume (lower flammable limit) to 75% by volume (upper flammable limit). Hydrogen flame (or fire) is nearly invisible even though the flame temperature is higher than that of hydrocarbon fires and hence poses greater hazards to persons in the vicinity.

Constant exposure of certain types of ferritic steels to hydrogen results in the embrittlement of the metals. Leakage can be caused by such embrittlement in pipes, welds, and metal gaskets.

In terms of toxicity, hydrogen is a simple asphyxiant. Exposure to high concentrations may exclude an adequate supply of oxygen to the lungs. No significant effect to human through dermal absorption and ingestion is reported. Refer to below table for properties of hydrogen.

Table 6: Hazardous Properties of Hydrogen

Sl. No.	Properties	Values
1.	LFL (%v/v)	4.12
2.	UFL (%v/v)	74.2
3.	Auto ignition temperature (°C)	500
4.	Heat of combustion (Kcal/Kg)	28700
5.	Normal Boiling point (°C)	-252
6.	Flash point (°C)	N.A.

4.1.3 NAPHTHA AND OTHER HEAVIER HYDROCARBONS

The major hazards from these types of hydrocarbons are fire and radiation. Any spillage or loss of containment of heavier hydrocarbons may create a highly flammable pool of liquid around the source of release.

If it is released at temperatures higher than the normal boiling point it can flash significantly and would lead to high entrainment of gas phase in the liquid phase. High entrainment of gas phase in the liquid phase can lead to jet fires. On the other hand negligible flashing i.e. release at temperatures near boiling points would lead to formation of pools and then pool fire.

Spillage of comparatively lighter hydrocarbons like Naphtha may result in formation of vapor cloud. Flash fire/ explosion can occur in case of ignition. Refer to below table for properties of Naphtha.

Table 7: Hazardous Properties of Naphtha

S. No.	Properties	Values
1.	LFL (%v/v)	0.8
2.	UFL (%v/v)	5.0
3.	Auto ignition temperature (°C)	228
4.	Heat of combustion (Kcal//Kg)	10,100
5.	Normal Boiling point (°C)	130 -155
6.	Flash point (°C)	38 - 42

4.2 HAZARDS ASSOCIATED WITH TOXIC/CARCINOGENIC MATERIALS

4.2.1 HYDROGEN SULPHIDE

Hydrogen sulfide is a known toxic gas and has harmful physiological effects. Accidental release of hydrocarbons containing hydrogen sulfide poses toxic hazards to exposed population. Refer to below table for hazardous properties of Hydrogen Sulphide.

Table 8: Toxic Effects of Hydrogen Sulphide

Sl. No.	Threshold Limits	Concentration (PPM)
1.	Odor threshold	0.0047
2.	Threshold Limit Value(TLV)	10
3.	Short Term Exposure Limit (STEL)(15 Minutes)	15
4.	Immediately Dangerous to Life and Health (IDLH) level (for 30 min exposure)	100

4.2.2 BENZENE

The hazards associated with benzene are both toxic and flammable hazards. Benzene has a very low flash point (-11.1°C), indicating that its vapor cloud easily gets ignited. The vapor which is about to 3 times heavier than air may originate flash fire and explosions.

If it is released at temperatures higher than the normal boiling point it can flash significantly and would lead to high entrainment of gas phase in the liquid phase. High entrainment of gas phase in the liquid phase can lead to jet fires. On the other hand negligible flashing i.e. release of Benzene at temperatures near boiling points would lead to formation of pools and then pool fire.

Inhaling very high concentration of Benzene vapors can result in death, while inhalation of lower concentration can cause drowsiness, dizziness, rapid heart rate, headaches and unconsciousness. The major effect of exposure to Benzene for a prolonged period (365 days or longer) may adversely affect bone marrow and cause a decrease in red blood cells leading to anemia. Benzene is a recognized carcinogenic. Refer to below tables for hazardous properties of benzene.

Table 9: Hazardous Properties of Benzene

Sl. No.	Properties	Values
1.	LFL (%v/v)	1.4
2.	UFL (%v/v)	8
3.	Auto ignition temperature (°C)	562
4.	Flash point (°C)	- 11.1
5.	Heat of combustion (KCAL/Kg)	9700
6.	Normal Boiling point (°C)	80

Table 10: Toxic effects of Benzene

Sl. No.	Threshold Limits	Concentration (PPM)
1.	Odor threshold	0.16-320 ppm
2.	Threshold Limit Value(TLV)	10
3.	Short Term Exposure Limit (STEL) (15 Minutes)	5
4.	Immediately Dangerous to Life and Health (IDLH) level (for 30 min exposure)	500

4.2.3 AMMONIA

Ammonia is likely to be present in sour gas produced from Sour water stripper unit (SWSU). The hazard associated with ammonia is both toxic and flammable hazards. Toxic hazards being more pronounced. Vapors of ammonia may cause severe eye or throat irritation and permanent injury may result. Contact with the liquid freezes skin and produces a caustic burn. Below table indicates the toxic properties of ammonia.

Table 11: Toxic Effects of Ammonia

Sl. No.	Threshold Limits	Concentration (PPM)
1.	Threshold Limit Value (TLV)	25
2.	Short Term Exposure Limit (STEL)(15 Minutes)	35
3.	Immediately Dangerous to Life and Health (IDLH) level (for 30 min exposure)	300

4.2.4 TOLUENE

The hazards associated with Toluene are both toxic and flammable hazards. Toluene has a very low flash point (4.4^{0}C), indicating that its vapor cloud easily gets ignited. If it is released at temperatures higher than the normal boiling point it can flash significantly and would lead to high entrainment of gas phase in the liquid phase. High entrainment of gas phase in the liquid phase can lead to jet fires. On the other hand negligible flashing i.e. release of Toluene at temperatures near boiling points would lead to formation of pools and then pool fire.

Inhaling very high concentration of Toluene vapors can result in death, while inhalation of lower concentration can cause drowsiness, dizziness, rapid heart rate, headaches and unconsciousness. The major effect of exposure to Toluene for a prolonged period (365 days or longer) may adversely affect bone marrow and cause a decrease in red blood cells leading to anemia. Toluene is a recognized carcinogenic. Refer Table below for hazardous properties of Toluene

Table 12: Hazardous Properties of Toluene

Sl. No.	Properties	Values
1.	LFL (%v/v)	1.1
2.	UFL (%v/v)	7.1
3.	Normal Boiling point (°C)	111.11

Table 13: Toxic effects of Toluene

Sl. No.	Threshold Limits	Concentration (PPM)
1.	Threshold Limit Value(TLV)	10
2.	Short Term Exposure Limit (STEL) (15 Minutes)	5
3.	Immediately Dangerous to Life and Health (IDLH) level (for 30 min exposure)	500

5 HAZARD IDENTIFICATION

5.1 GENERAL

A classical definition of hazard states that hazard is in fact the characteristic of system/plant/process that presents potential for an accident. Hence all the components of a system/plant/process need to be thoroughly examined in order to assess their potential for initiating or propagating an unplanned event/sequence of events, which can be termed as an accident.

In Risk Analysis terminology a hazard is something with the potential to cause harm. Hence the Hazard Identification step is an exercise that seeks to identify what can go wrong at the major hazard installation or process in such a way that people may be harmed. The output of this step is a list of events that need to be passed on to later steps for further analysis.

The potential hazards posed by the facility were identified based on the past accidents, lessons learnt and a checklist. This list includes the following elements.

- Catastrophic Rupture of Pressure vessel
- Large hole on outlet of process vessel
- “Guillotine-Breakage” of pipe-work
- Small hole, cracks or small bore failure (i.e. instrument tapping failure, drains/vents failure etc.) in piping and vessels.
- Flange leaks.
- Storage Tank on fire
- Leaks from pump glands and similar seals.

5.2 MODES OF FAILURE

There are various potential sources of large leakage, which may release hazardous chemicals and hydrocarbon materials into the atmosphere. These could be in form of gasket failure in flanged joints, bleeder valve left open inadvertently, an instrument tubing giving way, pump seal failure, guillotine failure of equipment/ pipeline or any other source of leakage. Operating experience can identify lots of these sources and their modes of failure. A list of general equipment and pipeline failure mechanisms is as follows:

Material/Construction Defects

- Incorrect selection or supply of materials of construction
- Incorrect use of design codes
- Weld failures
- Failure of inadequate pipeline supports

Pre-Operational Failures

- Failure induced during delivery at site
- Failure induced during installation
- Pressure and temperature effects

- Overpressure
- Temperature expansion/contraction (improper stress analysis and support design)
- Low temperature brittle fracture (if metallurgy is incorrect)
- Fatigue loading (cycling and mechanical vibration)

Corrosion Failures

- Internal corrosion (e.g. ingress of moisture)
- External corrosion
- Cladding/insulation failure (e.g. ingress of moisture)
- Cathodic protection failure, if provided

Failures due to Operational Errors

- Human error
- Failure to inspect regularly and identify any defects

External Impact Induced Failures

- Dropped objects
- Impact from transport such as construction traffic
- Vandalism
- Subsidence
- Strong winds

Failure due to Fire

- External fire impinging on pipeline or equipment
- Rapid vaporization of cold liquid in contact with hot surfaces

5.3 SELECTED FAILURE CASES

A list of selected failure cases was prepared based on process knowledge, engineering judgment, experience, past incidents associated with such facilities and considering the general mechanisms for loss of containment. A list of cases has been identified for the consequence analysis study based on the following.

- Cases with high chance of occurrence but having low consequence: Example of such failure cases includes two-bolt gasket leak for flanges, seal failure for pumps, instrument tapping failure, etc. The consequence results will provide enough data for planning routine safety exercises. This will emphasize the area where operator's vigilance is essential.
- Cases with low chance of occurrence but having high consequence (The example includes Large hole on the outlet of pressure vessels, Catastrophic Rupture of Pressure Vessels, etc.)

  This approach ensures at least one representative case of all possible types of accidental failure events, is considered for the consequence analysis. Moreover, the list below includes at least one accidental case comprising of release of different sorts of highly hazardous materials handled in the facility. Although the list does not give complete failure incidents considering all equipment's, units, but the consequence of a similar incident considered in the list below could be used to foresee the consequence of that particular accident.

6 CONSEQUENCE ANALYSIS

6.1 GENERAL

Consequence analysis involves the application of the mathematical, analytical and computer models for calculation of the effects and damages subsequent to a hydrocarbon / toxic release accident.

Computer models are used to predict the physical behavior of hazardous incidents. The model uses below mentioned techniques to assess the consequences of identified scenarios:

- Modeling of discharge rates when holes develop in process equipment/pipe work
- Modeling of the size & shape of the flammable/toxic gas clouds from releases in the atmosphere
- Modeling of the flame and radiation field of the releases that are ignited and burn as jet fire, pool fire and flash fire
- Modeling of the explosion fields of releases which are ignited away from the point of release

The different consequences (Flash fire, pool fire, jet fire and Explosion effects) of loss of containment accidents depend on the sequence of events & properties of material released leading to the either toxic vapor dispersion, fire or explosion or both.

6.2 CONSEQUENCE ANALYSIS MODELLING

6.2.1 DISCHARGE RATE

The initial rate of release through a leak depends mainly on the pressure inside the equipment, size of the hole and phase of the release (liquid, gas or two-phase). The release rate decreases with time as the equipment depressurizes. This reduction depends mainly on the inventory and the action taken to isolate the leak and blow-down the equipment.

6.2.2 DISPERSION

Releases of gas into the open air form clouds whose dispersion is governed by the wind, by turbulence around the site, the density of the gas and initial momentum of the release. In case of flammable materials the sizes of these gas clouds above their Lower Flammable Limit (LFL) are important in determining whether the release will ignite. In this study, the results of dispersion modeling for flammable materials are presented LFL quantity.

6.2.3 FLASH FIRE

A flash fire occurs when a cloud of vapors/gas burns without generating any significant overpressure. The cloud is typically ignited on its edge, remote from- the leak source. The combustion zone moves through the cloud away from the ignition point. The duration of the flash fire is relatively short but it may stabilize as a continuous jet fire from the leak source. For flash fires, an approximate estimate for the extent of the total effect zone is the area over which the cloud is above the LFL.

6.2.4 JET FIRE

Jet fires are burning jets of gas or atomized liquid whose shape is dominated by the momentum of the release. The jet flame stabilizes on or close to the point of release and continues until the release is stopped. Jet fire can be realized, if the leakage is immediately ignited. The effect of jet flame impingement is severe as it may cut through equipment, pipeline or structure. The damage effect of thermal radiation is depended on both the level of thermal radiation and duration of exposure.

6.2.5 POOL FIRE

A cylindrical shape of the pool fire is presumed. Pool-fire calculations are then carried out as part of an accidental scenario, e.g. in case a hydrocarbon liquid leak from a vessel leads to the formation of an ignitable liquid pool. First no ignition is assumed, and pool evaporation and dispersion calculations are being carried out. Subsequently late pool fires (ignition following spreading of liquid pool) are considered. If the release is bunded, the diameter is given by the size of the bund. If there is no bund, then the diameter is that which corresponds with a minimum pool thickness, set by the type of surface on which the pool is spreading.

6.2.6 VAPOR CLOUD EXPLOSION

A vapor cloud explosion (VCE) occurs if a cloud of flammable gas burns sufficiently quickly to generate high overpressures (i.e. pressures in excess of ambient). The overpressure resulting from an explosion of hydrocarbon gases is estimated considering the explosive mass available to be the mass of hydrocarbon vapor between its lower and upper explosive limits.

6.2.7 TOXIC RELEASE

The aim of the toxic risk study is to determine whether the operators in the plant, people occupied buildings and the public are likely to be affected by toxic substances. Toxic gas cloud e.g. H_2S, chlorine, Benzene etc. was undertaken to the Immediately Dangerous to Life and Health concentration (IDLH) limit to determine the extent of the toxic hazard Created as the result of loss of containment of a toxic substance.

6.3 SIZE AND DURATION OF RELEASE

Leak size considered for selected failure cases are listed below[1].

Table 14: Size of Release

Failure Description	Leak Size
Flange gasket failure	10 mm hole size
Instrument tapping failure	20 mm hole size
Large Hole	50 mm, complete rupture of 2” drain line
Catastrophic Rupture	Complete Rupture of the Pressure Vessels

[1] Refer to Guideline for Quantitative Risk assessment ‘Purple Book’.

The discharge duration is taken as 10 minutes for continuous release scenarios as it is considered that it would take plant personnel about 10 minutes to detect and isolate the leak[2].

6.4 DAMAGE CRITERIA

In order to appreciate the damage effect produced by various scenarios, physiological/physical effects of the blast wave, thermal radiation or toxic vapor exposition are discussed.

6.4.1 LFL OR FLASH FIRE

Hydrocarbon vapor released accidentally will spread out in the direction of wind. If a source of ignition finds an ignition source before being dispersed below lower flammability limit (LFL), a flash fire is likely to occur and the flame will travel back to the source of leak. Any person caught in the flash fire is likely to suffer fatal burn injury. Therefore, in consequence analysis, the distance of LFL value is usually taken to indicate the area, which may be affected by the flash fire.

Flash fire (LFL) events are considered to cause direct harm to the population present within the flammability range of the cloud. Fire escalation from flash fire such that process or storage equipment or building may be affected is considered unlikely.

6.4.2 THERMAL HAZARD DUE TO POOL FIRE, JET FIRE AND FIRE BALL

Thermal radiation due to pool fire, jet fire or fire ball may cause various degrees of burn on human body and process equipment. The damage effect due to thermal radiation intensity is tabulated below.

Table 15: Damage Due to Incident Thermal Radiation Intensity

Incident Radiation Intensity (kWm^2)	Type of Damage
37.5	Sufficient to cause damage to process equipment
32.0	Maximum flux level for thermally protected tanks containing flammable liquid
12.5	Minimum energy required for piloted ignition of wood, melting of plastic tubing etc.
8.0	Maximum heat flux for un-insulated tanks
4.0	Sufficient to cause pain to personnel if unable to reach cover within 20 seconds. However blistering of skin (1^{st}degree burns) is likely.

The hazard distances to the 37.5 kW/m^2, 12.5 $kW/m^2$and 4 kW/m^2 radiation levels, selected based on their effect on population; buildings and equipment were modeled using PHAST.

6.4.3 VAPOR CLOUD EXPLOSION

In the event of explosion taking place within the plant, the resultant blast wave will have damaging effects on equipment, structures, building and piping falling within the overpressure distances of

[2] Release duration is based on Chemical Process Quantitative Risk Analysis, CCPS.

the blast. Tanks, buildings, structures etc. can only tolerate low level of overpressure. Human body, by comparison, can withstand higher overpressure. But injury or fatality can be inflicted by collapse of building of structures. The damage effect of blast overpressure is tabulated below.

Table 16: Damage Effects of Blast Overpressure

Blast Overpressure (PSI)	Damage Level
5.0	Major structure damage
3.0	Oil storage tank failure
2.5	Eardrum rupture
2.0	Repairable damage, pressure vessels remain intact, light structures collapse
1.0	Window pane breakage possible, causing some injuries

The hazard distances to the 5 psi, 3 psi and 2 psi overpressure levels, selected based on their effects on population; buildings and equipment were modeled using PHAST.

6.4.4 TOXIC HAZARD

The inhalation of toxic gases can give rise to effects, which range in severity from mild irritation of the respiratory tract to death. Lethal effects of inhalation depend on the concentration of the gas to which people are exposed and on the duration of exposure. Mostly this dependence is nonlinear and as the concentration increases, the time required to produce a specific injury decreases rapidly.

The hazard distances to Immediately Dangerous to Life and Health concentration (IDLH) limit is selected to determine the extent of the toxic hazard Created as the result of loss of containment of a toxic substance.

6.5 CONSEQUENCE ANALYSIS FOR UNITS

This section discusses the consequences of selected failure scenarios for various units. The consequence distances are reported in tabular form for all weather conditions in **Annexure-I** and are represented graphically in **Annexure-II** for the all failure scenarios in a unit for worst weather conditions.

6.5.1 CDU/VDU

NOTE: Refer Figures 6.5.1.1 to 6.5.1.7 in Annexure-II

<u>20 mm leak at Crude Charge Pump:</u> From the consequence analysis of selected failure scenario it can be observed that LFL may be travelling up to a distance of 94 m and may be extended beyond the B/L's of the unit. The Jet Fire radiation intensity of 37.5 & 12.5 kW/m^2 would extend up

to a distance of 44 m & 55 m respectively. The 5 & 3 psi blast overpressures travel up to a distance of 113 m & 121 m respectively.

50 mm leak at Naphtha Stabilizer Reflux Drum bottom: From the consequence modeling of the selected failure scenario, it can be observed that LFL may be spreading up to a distance of 129 m from leak source and may extend beyond B/L. The Jet Fire Radiation Intensity of 37.5 & 12.5 kW/m^2 would extend up to a distance 83 m & 99 m respectively. The 5 & 3 psi blast waves for this leakage scenario would be extended up to a distance of 148 m & 158 m respectively.

20 mm leak at LPG Product Pump: From the consequence results and graphs of the selected credible scenario, it can be observed that LFL may be extended up to a distance of 56 m. The Jet Fire radiation intensity of 37.5 & 12.5 kW/m^2 would spread up to a distance of 46 m & 55 m respectively. The 5 & 3 psi blast overpressures travel up to a distance of 63 m & 68 m respectively.

20 mm leak at Stabilizer Feed Pump: From the event outcome of the selected failure scenario it can be observed that LFL may be extended up to a distance of 104 m from the leak source. The Jet Fire radiation intensity of 37.5 & 12.5 kW/m^2 would be getting extended up to 46 m & 55 m respectively. The Pool Fire radiation intensity of 37.5 & 12.5 kW/m^2 would extend up to a distance of 22 m & 34 m respectively. The 5 & 3 psi blast waves may reach up to a distance of 123 m & 132 m respectively and may extend up to Cooling Tower CT-1.

20 mm leak at Naphtha Splitter Bottom Pump: From the incident outcome analysis of the selected failure scenario it is observed that LFL hazard distance is extended up to 60 m. The Jet Fire radiation intensity of 37.5 & 12.5 kW/m^2 would spread up to a distance of 43 m & 53 m respectively. The 5 & 3 psi blast waves may reach up to a distance of 64 m & 69 m respectively.

20 mm leak at Light Naphtha Product Pump: From the event outcome of the selected failure scenario it can be observed that LFL may be extended up to a distance of 97 m. The Jet Fire radiation intensity of 37.5 & 12.5 kW/m^2 would be getting extended up to 47 m & 57 m respectively. The Pool Fire radiation intensity of 37.5 & 12.5 kW/m^2 would extend up to a distance of 27 m & 38 m respectively. The 5 & 3 psi blast waves may reach up to a distance of 110 m & 118 m respectively.

20 mm leak at Heavy Naphtha Product Pump: From the event outcome of the selected failure scenario it can be observed that LFL may be extended up to a distance of 53 m. The Jet Fire radiation intensity of 37.5 & 12.5 kW/m^2 would be getting extended up to 42 m & 51 m respectively. The 5 & 3 psi blast waves may reach up to a distance of 63 m & 67 m respectively.

6.5.2 NHT

NOTE: Refer Figures 6.5.2.1 to 6.5.2.8 in Annexure-II

20mm leak at NHT Feed Pump: From the incident outcome analysis of the selected failure scenario it is observed that LFL hazard distance is extended up to 93 m. The Jet Fire radiation intensity of 37.5 & 12.5 kW/m^2 would spread up to a distance of 55 m & 67 m respectively. The 5 & 3 psi blast wave may spread up to a distance of 111 m & 119 m respectively.

50mm leak at Stripper Receiver bottom - Toxic: From the consequence results and graphs of the selected credible scenario, it can be concluded that LFL may be extended up to a distance of 282 m. The Jet Fire radiation intensity of 37.5 & 12.5 kW/m^2 would spread up to a distance of 98 m & 121 m respectively. The Pool Fire radiation intensity of 37.5 & 12.5 kW/m^2 would extend up to a distance of 60 m & 84 m respectively. The 5 & 3 psi blast overpressures travel up to a distance of 343 m & 367 m respectively. The IDLH concentration for H_2S can reach up to 525 m from the leak source depending upon the prevailing weather conditions at the time of release. Based on consequence results it is observed that the hazardous affect zone for this failure case may cross refinery boundary limit towards east side.

20mm leak at Stripper Reflux Pump - Toxic: From the consequence results and graphs of the selected credible scenario, it can be concluded that LFL may be extended up to a distance of 93 m. The Jet Fire radiation intensity of 37.5 & 12.5 kW/m2 would spread up to a distance of 46 m & 56 m respectively. The Pool Fire radiation intensity of 37.5 & 12.5 kW/m^2 would extend up to a distance of 23 m & 30 m respectively. The 5 & 3 psi blast overpressures travel up to a distance of 111 m & 119 m respectively. The IDLH concentration for H_2S can reach up to 217 m from the leak source depending upon the prevailing weather conditions at the time of release. Based on consequence results it is observed that the hazardous affect zone for this failure case may cross unit boundary limit an all directions.

20mm leak at Stripper bottom: From the event outcome of the selected failure scenario it can be observed that LFL may be extended up to a distance of 72 m. The Jet Fire radiation intensity of 37.5 & 12.5 kW/m2 would be getting extended up to 39 m & 42 m respectively. The 5 & 3 psi blast waves may reach up to a distance of 86 m & 92 m respectively.

20mm leak at HDT Separator bottom: From the incident outcome analysis of the selected failure scenario it is observed that LFL hazard distance is extended up to 106 m. The Jet Fire radiation intensity of 37.5 & 12.5 kW/m2 would spread up to a distance of 48 m & 59 m respectively. The 5 & 3 psi blast waves may reach up to a distance of 124 m & 132 m respectively.

20mm leak at Light Naphtha Pump – Toxic: From the consequence results and graphs of the selected credible scenario, it can be concluded that LFL may be extended up to a distance of 92 m. The Jet Fire radiation intensity of 37.5 & 12.5 kW/m2 would spread up to a distance of 45 m & 54 m respectively. The Pool Fire radiation intensity of 12.5 kW/m^2 would extend up to a distance of 31 m. The 5 & 3 psi blast overpressures travel up to a distance of 112 m & 120 m respectively. The IDLH concentration for benzene can reach up to 30 m from the leak source depending upon the prevailing weather conditions at the time of release.

20mm leak at Heavy Naphtha Pump: From the event outcome of the selected failure scenario it can be observed that LFL may be extended up to a distance of 58 m. The Jet Fire radiation intensity of 37.5 & 12.5 kW/m^2 would be getting extended up to 42 m & 51 m respectively. The 5 & 3 psi blast waves may reach up to a distance of 63 m & 68 m respectively.

6.5.3 ISOM

NOTE: Refer Figures 6.5.3.1 to 6.5.3.6 in Annexure-II

20mm leak at ISOM Charge Pump: From the consequence analysis of selected failure scenario it can be observed that LFL shall be travelling up to a distance of 94 m. The Jet Fire radiation intensity of 37.5 & 12.5 kW/m2 would extend up to a distance of 57 m & 68 m respectively. The 5 & 3 psi blast overpressures travel up to a distance of 111 m & 119 m respectively.

50mm leak at Stabilizer Receiver bottom: From the incident outcome analysis of the selected failure scenario it is observed that LFL hazard distance is extended up to 202 m. The Jet Fire radiation intensity of 37.5 & 12.5 kW/m^2 would spread up to a distance of 111 m & 122 m respectively. The 5 & 3 psi blast wave may spread up to a distance of 246 m & 264 m respectively. Based on consequence results it is observed that the hazardous affect zone for this failure case may cross unit boundary limit an all directions.

20mm leak at Stabilizer Reflux Pump: From the results of consequence analysis, it was observed that LFL may reach up to a distance of 75 m from leak source. The Jet Fire radiation intensity of 37.5 & 12.5 kW/m^2would spread up to a distance of 48 m & 57 m respectively.The 5 & 3 psi blast wave may spread up to a distance of 87 m & 94 m respectively.

50mm leak at Stabilizer bottom: From the results of consequence analysis, it was observed that LFL may reach up to a distance of 103 m from leak source. The Jet Fire radiation intensity of 37.5 & 12.5 kW/m^2would spread up to a distance of 83 m & 100 m respectively. The 5 & 3 psi blast wave may spread up to a distance of 123 m & 131 m respectively.

20mm leak at Stabilizer bottom: From the results of consequence analysis, it was observed that LFL may reach up to a distance of 32 m from leak source. The Jet Fire radiation intensity of 37.5 & 12.5 kW/m^2would spread up to a distance of 36 m & 44 m respectively. The 5 & 3 psi blast wave may spread up to a distance of 38 m & 41 m respectively.

6.5.4 CCR

NOTE: Refer Figures 6.5.4.1 to 6.5.4.5 in Annexure-II

20mm leak at Separator Bottom Pumps: From the results of consequence analysis, it was observed that LFL may reach up to a distance of 94 m from leak source. The Jet Fire radiation intensity of 37.5 & 12.5 kW/m^2 would spread up to a distance of 55 m & 67 m respectively. The 5 & 3 psi blast wave may spread up to a distance of 112 m & 120 m respectively. The IDLH concentration of Toluene may reach up to a distance of 298 m from the leak source.

<u>20mm leak at Stabilizer Reflux Pump:</u> From the consequence analysis results for this failure scenario, it can be realized that LFL may travel up to a distance of 48m. The Jet Fire radiation intensity of 37.5 & 12.5 kW/m^2 would spread up to a distance of 46 m & 55 m respectively. The 5 & 3 psi blast overpressures travel up to a distance of 51 m & 56 m respectively.

<u>50mm leak at Stabilizer Overhead Receiver Bottom</u>: From the event outcome of the selected failure scenario it can be observed that LFL may be extended up to a distance of 122 m. The Jet Fire radiation intensity of 37.5 & 12.5 kW/m^2would spread up to a distance of 88 m & 106 m respectively. The 5 & 3 psi blast overpressures travel up to a distance of 147 m & 157 m respectively.

<u>20mm leak at Stabilizer Bottom:</u> From the results of consequence analysis, it was observed that LFL may reach up to a distance of 71 m from leak source. The Jet Fire radiation intensity of 37.5 & 12.5 kW/m^2would spread up to a distance of 40 m & 42 m respectively. The 5 & 3 psi blast wave may spread up to a distance of 86 m & 92 m respectively.

6.5.5 DHDT

NOTE: Refer Figures 6.5.5.1 to 6.5.5.11 in Annexure-II

<u>20mm leak at Feed Pumps</u>: From the consequence results and graphs of the selected credible scenario, it can be concluded that LFL may be extended up to a distance of 77 m. The Jet Fire radiation intensity of 37.5 & 12.5 kW/m^2 would spread up to a distance of 51 m & 62 m respectively. The 5 & 3 psi blast overpressures travel up to a distance of 88 m & 95 m respectively.

<u>20mm leak at Cold HP Separator overhead:</u> From the consequence analysis of selected failure scenario it can be observed that LFL shall be travelling up to a distance of 29 m. The 5 & 3 psi blast overpressures travel up to a distance of 26 m & 28 m respectively.

<u>20mm leak at Make Up Gas Compressor:</u> From the consequence analysis of selected failure scenario it can be observed that LFL shall be travelling up to a distance of 29 m. The Jet Fire radiation intensity of 37.5 & 12.5 kW/m^2 would spread up to a distance of 19 m & 24 m respectively. The 5 & 3 psi blast overpressures travel up to a distance of 28 m & 31 m respectively.

<u>50mm leak at Stripper Reflux Drum bottom - Toxic:</u> From the consequence results and graphs of the selected credible scenario, it can be concluded that LFL may be extended up to a distance of 236 m. The Jet Fire radiation intensity of 37.5 & 12.5 kW/m^2 would spread up to a distance of 90 m & 111 m respectively. The Pool Fire Radiation Intensity of 37.5 kW/m^2 & 12.5 kW/m^2 can extend up to a distance of 80 m & 118 m respectively. The 5 & 3 psi blast overpressures travel up to a distance of 298 m & 324 m respectively. The IDLH concentration for H_2S can reach up to 484 m from the leak source depending upon the prevailing weather conditions at the time of release.

<u>20mm leak at Stripper Reflux Pumps - Toxic:</u> From the incident outcome analysis of the selected failure scenario it is observed that LFL hazard distance is extended up to 101 m. The Jet Fire

radiation intensity of 37.5 & 12.5 kW/m^2 would spread up to a distance of 43 m & 52 m respectively. The Pool Fire Radiation Intensity of 37.5 kW/m^2 & 12.5 kW/m^2 can extend up to a distance of 34 m & 50 m respectively. The 5 & 3 psi blast wave may spread up to a distance of 125 m & 135 m respectively. The IDLH concentration for H_2S can reach up to 221 m from the leak source depending upon the prevailing weather conditions at the time of release.

20mm leak at Stripper Reflux Drum overhead - Toxic: From the consequence analysis of selected failure scenario it can be observed that LFL shall be travelling up to a distance of 6 m. The IDLH concentration of H_2S may reach up to a distance of 180 m from the leak source depending upon the prevailing weather conditions at the time of release.

50mm leak at Stripper Bottom: From the consequence results and graphs of the selected credible scenario, it can be concluded that LFL may be extended up to a distance of 233 m. The Jet Fire radiation intensity of 37.5 & 12.5 kW/m^2 would spread up to a distance of 83 m & 104 m respectively. The Pool Fire Radiation Intensity of 12.5 kW/m^2 can extend up to a distance of 42 m. The 5 & 3 psi blast overpressures travel up to a distance of 275 m & 293 m respectively.

20mm leak at Heavy Naphtha Pumps: From the consequence analysis results for this failure scenario, it can be realized that LFL may travel up to a distance of 44 m. The Jet Fire radiation intensity of 37.5 & 12.5 kW/m^2 would spread up to a distance of 32 m & 39 m respectively. The Pool Fire Radiation Intensity of 37.5 kW/m^2 & 12.5 kW/m^2 can extend up to a distance of 12 m & 23 m respectively. The 5 & 3 psi blast overpressures travel up to a distance of 57 m & 64 m respectively.

20mm leak at ATF Product Pumps: From the incident outcome analysis of the selected failure scenario it is observed that LFL hazard distance is extended up to 52 m. The Jet Fire radiation intensity of 37.5 & 12.5 kW/m^2 would spread up to a distance of 37 m & 46 m respectively. The Pool Fire Radiation Intensity of 37.5 kW/m^2 & 12.5 kW/m^2 can extend up to a distance of 31 m & 43 m respectively. The 5 & 3 psi blast wave may spread up to a distance of 63 m & 67 m respectively.

20mm leak at Deethanizer Bottom Pumps: From the consequence results and graphs of the selected credible scenario, it can be concluded that LFL may be extended up to a distance of 66 m. The Jet Fire radiation intensity of 37.5 & 12.5 kW/m^2 would spread up to a distance of 42 m & 51 m respectively. The Pool Fire Radiation Intensity of 37.5 kW/m^2 & 12.5 kW/m^2 can extend up to a distance of 11 m & 24 m respectively The 5 & 3 psi blast overpressures travel up to a distance of 86 m & 96 m respectively.

20mm leak at Debutanizer Bottom: From the incident outcome analysis of the selected failure scenario it is observed that LFL hazard distance is extended up to 79 m. The Jet Fire radiation intensity of 37.5 & 12.5 kW/m^2 would spread up to a distance of 40 m & 42 m respectively. The 5 & 3 psi blast wave may spread up to a distance of 87 m & 94 m respectively.

6.5.6 VGO HDT

NOTE: Refer Figures 6.5.6.1 to 6.5.6.7 in Annexure-II

20mm leak at Recycle Gas Compressor: From the consequence analysis of selected failure scenario it can be observed that LFL shall be travelling up to a distance of 29 m. The Jet Fire radiation intensity of 37.5 & 12.5 kW/m^2 would spread up to a distance of 24 m & 32 m respectively. The 5 & 3 psi blast overpressures travel up to a distance of 27 m & 29 m respectively.

20mm leak at Cold HP Separator overhead: From the consequence analysis of selected failure scenario it can be observed that LFL shall be travelling up to a distance of 27 m. The 5 & 3 psi blast overpressures travel up to a distance of 26 m & 28 m respectively.

50mm leak at Stripper Reflux Drum bottom: From the consequence results and graphs of the selected credible scenario, it can be concluded that LFL may be extended up to a distance of 258 m. The Jet Fire radiation intensity of 37.5 & 12.5 kW/m^2 would spread up to a distance of 93 m & 115 m respectively. The Pool Fire Radiation Intensity of 37.5 kW/m^2 & 12.5 kW/m^2 can extend up to a distance of 88 m & 130 m respectively. The 5 & 3 psi blast overpressures travel up to a distance of 318 m & 344 m respectively. The toxic IDLH hazard distances of H_2S may reach up to a distance of 430 m from the leak source depending upon the prevailing weather conditions at the time of release.

20mm leak at Stripper Reflux Pumps - Toxic: From the consequence analysis results for this failure scenario, it can be realized that LFL may travel up to a distance of 108 m. The Jet Fire radiation intensity of 37.5 & 12.5 kW/m^2 would spread up to a distance of 45 m & 55 m respectively. The Pool Fire Radiation Intensity of 37.5 kW/m^2 & 12.5 kW/m^2 can extend up to a distance of 35 m & 51 m respectively. The 5 & 3 psi blast overpressures travel up to a distance of 123 m & 131 m respectively. The toxic IDLH hazard distances of H_2S may reach up to a distance of 202 m from the leak source depending upon the prevailing weather conditions at the time of release.

50mm leak at Debutanizer Receiver Bottom - Toxic: From the incident outcome analysis of the selected failure scenario it is observed that LFL hazard distance is extended up to 127 m. The Jet Fire radiation intensity of 37.5 & 12.5 kW/m^2 would spread up to a distance of 94 m & 112 m respectively. The 5 & 3 psi blast wave may spread up to a distance of 155m & 164 m respectively. The toxic IDLH hazard distances of H_2S may reach up to a distance of 1386 m from the leak source depending upon the prevailing weather conditions at the time of release.

20mm leak at LPG Product Pumps - Toxic: From the consequence analysis results for this failure scenario, it can be realized that LFL may travel up to a distance of 48 m. The Jet Fire radiation intensity of 37.5 & 12.5 kW/m^2 would spread up to a distance of 46 m & 55 m respectively. The 5 & 3 psi blast overpressures travel up to a distance of 51 m & 55 m respectively. The toxic IDLH hazard distances of H_2S may reach up to a distance of 450 m from the leak source depending upon the prevailing weather conditions at the time of release.

20mm leak at Debutanizer Bottom: From the consequence results and graphs of the selected credible scenario, it can be concluded that LFL may be extended up to a distance of 73 m. The Jet Fire radiation intensity of 37.5 & 12.5 kW/m^2 would spread up to a distance of 39 m & 41 m respectively. The 5 & 3 psi blast overpressures travel up to a distance of 86 m & 92 m respectively.

6.5.7 SULPHUR BLOCK

NOTE: Refer Figures 6.5.7.1 to 6.5.7.7 in Annexure-II

20 mm Leak at Regenerator Reflux Drum - Toxic: From the incident outcome analysis of the selected failure scenario it is observed that LFL hazard distance is extended up to 2 m. The IDLH concentration for H_2S can reach up to 85 m from the leak source at a cloud height of 10 m.

20 mm Leak at SWS-I Stripper Overhead - Toxic: From the incident outcome analysis of the selected failure scenario it is observed that LFL hazard distance is extended up to 1 m. The IDLH concentration for H_2S can reach up to 90 m from the leak source at a cloud height of 40 m.

20 mm Leak at SWS-II 1st Stage Stripper Overhead - Toxic: From the incident outcome analysis of the selected failure scenario it is observed that LFL hazard distance is extended up to 3 m. The IDLH concentration of H_2S may reach up to a distance of 220 m from the leak source at a cloud height of 40 m.

20 mm Leak at SWS-II 2nd Stage Stripper Overhead - Toxic: From the consequence results and graphs of the selected credible scenario, it can be concluded that LFL hazard distance is extended up to 1 m. The IDLH concentration for NH3 can reach up to 80 m from the leak source at a cloud height of 40 m.

20 mm Leak at ARU Acid Gas KOD - Toxic: From the incident outcome analysis of the selected failure scenario it is observed that LFL hazard distance is extended up to 2 m. The IDLH concentration of H2S may reach up to a distance of 102 m from the leak source.

20 mm Leak at SWS Sour Gas KOD - Toxic: From the consequence results and graphs of the selected credible scenario, it can be concluded that LFL hazard distance is extended up to 1 m. The IDLH concentration of H2S may reach up to a distance of 113 m from the leak source.

20 mm Leak at SWS NH3 Rich Sour Gas KOD - Toxic: From the incident outcome analysis of the selected failure scenario it is observed that LFL hazard distance is extended up to 1 m. The IDLH concentration for NH3 can reach up to 60 m from the leak source.

6.5.8 PPU

NOTE: Refer Figures 6.5.8.1 to 6.5.8.5 in Annexure-II

20mm leak at Propylene Charge Pump: From the incident outcome analysis of the selected failure scenario it is observed that LFL hazard distance is extended up to 49 m. The Jet Fire radiation intensity of 37.5 & 12.5 kW/m^2 would spread up to a distance of 49 m & 57 m respectively. The 5 & 3 psi blast wave may spread up to a distance of 51 m & 55 m respectively.

20mm leak at C3 LPG Pump: From the consequence analysis results for this failure scenario, it can be realized that LFL may travel up to a distance of 65 m. The Jet Fire radiation intensity of 37.5 & 12.5 kW/m^2 would spread up to a distance of 46 m & 55 m respectively. The Pool Fire Radiation Intensity of 37.5 kW/m^2 & 12.5 kW/m^2 can extend up to a distance of 16 m & 28 m respectively. The 5 & 3 psi blast overpressures travel up to a distance of 85 m & 94 m respectively.

20mm leak at Propylene Recycle Pump: From the consequence results and graphs of the selected credible scenario, it is observed that LFL hazard distance is extended up to 49 m. The Jet Fire radiation intensity of 37.5 & 12.5 kW/m^2 would spread up to a distance of 48 m & 56 m respectively. The 5 & 3 psi blast wave may spread up to a distance of 51 m & 55 m respectively.

6.5.9 DCU

NOTE: Refer Figures 6.5.9.1 to 6.5.9.10 in Annexure-II

20mm leak at Fractionator Reflux Pump: From the consequence analysis results for this failure scenario, it can be realized that LFL may travel up to a distance of 113 m. The Jet Fire radiation intensity of 37.5 & 12.5 kW/m^2 would spread up to a distance of 49 m & 60 m respectively. The 5 & 3 psi blast overpressures travel up to a distance of 135 m & 145 m respectively.

50mm leak at Coker Fractionator Overhead Receiver: From the incident outcome analysis of the selected failure scenario it is observed that LFL hazard distance is extended up to 45 m. The Jet Fire radiation intensity of 37.5 & 12.5 kW/m^2 would spread up to a distance of 21 m & 25 m respectively. The Pool Fire Radiation Intensity of 12.5 kW/m^2 can extend up to a distance of 21 m. The 5 & 3 psi blast wave may spread up to a distance of 59 m & 66 m respectively.

20mm leak at WGC - Toxic: From the consequence results and graphs of the selected credible scenario, it is observed that LFL hazard distance is extended up to 7 m. The toxic IDLH hazard distances of H_2S may reach up to a distance of 388 m from the leak source depending upon the prevailing weather conditions at the time of release.

20mm leak at Stripper charge pump - Toxic: From the incident outcome analysis of the selected failure scenario it is observed that LFL hazard distance is extended up to 91 m. The Jet Fire radiation intensity of 37.5 & 12.5 kW/m^2 would spread up to a distance of 45 m & 55 m respectively. The Pool Fire Radiation Intensity of 37.5 kW/m^2 & 12.5 kW/m^2 can extend up to a distance of 35 m & 51 m respectively. The 5 & 3 psi blast wave may spread up to a distance of 110 m & 118 m respectively. The toxic IDLH hazard distances of H_2S may reach up to a distance of 322 m from the leak source depending upon the prevailing weather conditions at the time of release.

20mm leak at Stripper Bottom pump - Toxic: From the consequence results and graphs of the selected credible scenario, it can be concluded that LFL may be extended up to a distance of 39 m. The Jet Fire radiation intensity of 37.5 & 12.5 kW/m^2 would spread up to a distance of 39 m & 47 m respectively. The 5 & 3 psi blast overpressures travel up to a distance of 39 m & 43 m respectively. The toxic IDLH hazard distances of H_2S may reach up to a distance of 82 m from the leak source depending upon the prevailing weather conditions at the time of release.

50mm leak at Debutanizer Overhead Receiver - Toxic: From the consequence analysis results for this failure scenario, it can be realized that LFL may travel up to a distance of 122 m. The Jet Fire radiation intensity of 37.5 & 12.5 kW/m^2 would spread up to a distance of 91 m & 108 m respectively. The 5 & 3 psi blast overpressures travel up to a distance of 146 m & 156 m respectively. The toxic IDLH hazard distances of H_2S may reach up to a distance of 1427 m from the leak source depending upon the prevailing weather conditions at the time of release.

20mm leak at LPG Product Pump - Toxic: From the consequence results and graphs of the selected credible scenario, it can be concluded that LFL may be extended up to a distance of 48 m. The Jet Fire radiation intensity of 37.5 & 12.5 kW/m^2 would spread up to a distance of 46 m & 54 m respectively. The 5 & 3 psi blast overpressures travel up to a distance of 51 m & 55 m respectively. The toxic IDLH hazard distances of H_2S may reach up to a distance of 480 m from the leak source depending upon the prevailing weather conditions at the time of release.

50mm leak at Debutanizer Bottom: From the incident outcome analysis of the selected failure scenario it is observed that LFL hazard distance is extended up to 32 m. The Jet Fire radiation intensity of 37.5 & 12.5 kW/m^2 would spread up to a distance of 35 m & 43 m respectively. The 5 & 3 psi blast wave may spread up to a distance of 38 m & 41 m respectively.

20mm leak at Coker Light Naphtha Pump: From the consequence results and graphs of the selected credible scenario, it can be concluded that LFL may be extended up to a distance of 84 m. The Jet Fire radiation intensity of 37.5 & 12.5 kW/m^2 would spread up to a distance of 45 m & 54 m respectively. The Pool Fire Radiation Intensity of 37.5 kW/m^2 & 12.5 kW/m^2 can extend up to a distance of 26 m & 40 m respectively. The 5 & 3 psi blast overpressures travel up to a distance of 98 m & 105 m respectively.

6.5.10 INDMAX FCC

NOTE: Refer Figures 6.5.10.1 to 6.5.10.10 in Annexure-II

50mm leak at MF Reflux Drum bottom: From the incident outcome analysis of the selected failure scenario it is observed that LFL hazard distance is extended up to 82 m. The Jet Fire radiation intensity of 37.5 & 12.5 kW/m^2 would spread up to a distance of 52 m & 64 m respectively. The Pool Fire Radiation Intensity of 12.5 kW/m^2 can extend up to a distance of 26 m. The 5 & 3 psi blast wave may spread up to a distance of 114 m & 127 m respectively.

20mm leak at MF Reflux Pump: From the incident outcome analysis of the selected failure scenario it is observed that LFL hazard distance is extended up to 111 m. The Jet Fire radiation intensity of 37.5 & 12.5 kW/m^2 would spread up to a distance of 47 m & 58 m respectively. The 5 & 3 psi blast wave may spread up to a distance of 135 m & 145 m respectively.

20mm leak at Stripper charge pump: From the incident outcome analysis of the selected failure scenario it is observed that LFL hazard distance is extended up to 88 m. The Jet Fire radiation intensity of 37.5 & 12.5 kW/m^2 would spread up to a distance of 48 m & 58 m respectively. The Pool Fire Radiation Intensity of 37.5 kW/m^2 & 12.5 kW/m^2 can extend up to a distance of 30 m & 43 m respectively. The 5 & 3 psi blast wave may spread up to a distance of 98 m & 105 m respectively.

20mm leak at Stripper Bottom: From the consequence results and graphs of the selected credible scenario, it can be concluded that LFL may be extended up to a distance of 49 m. The Jet Fire radiation intensity of 37.5 & 12.5 kW/m^2 would spread up to a distance of 39 m & 47 m respectively. The 5 & 3 psi blast overpressures travel up to a distance of 51 m & 56 m respectively.

50mm leak at Debutanizer Overhead Receiver: From the consequence analysis results for this failure scenario, it can be realized that LFL may travel up to a distance of 122 m. The Jet Fire radiation intensity of 37.5 & 12.5 kW/m^2 would spread up to a distance of 87 m & 103 m respectively. The 5 & 3 psi blast overpressures travel up to a distance of 146 m & 156 m respectively.

20mm leak at LPG Product Pump: From the consequence results and graphs of the selected credible scenario, it can be concluded that LFL may be extended up to a distance of 51 m. The Jet Fire radiation intensity of 37.5 & 12.5 kW/m^2 would spread up to a distance of 47 m & 56 m respectively. The 5 & 3 psi blast overpressures travel up to a distance of 62 m & 67 m respectively.

20mm leak at C3/C4 Splitter Feed Pump: From the consequence results and graphs of the selected credible scenario, it can be concluded that LFL may be extended up to a distance of 52 m. The Jet Fire radiation intensity of 37.5 & 12.5 kW/m^2 would spread up to a distance of 47 m & 56 m respectively. The 5 & 3 psi blast overpressures travel up to a distance of 62 m & 67 m respectively.

50mm leak at C3/C4 Splitter Overhead Receiver: From the consequence analysis results for this failure scenario, it can be realized that LFL may travel up to a distance of 117 m. The Jet Fire radiation intensity of 37.5 & 12.5 kW/m^2 would spread up to a distance of 96 m & 113 m respectively. The 5 & 3 psi blast overpressures travel up to a distance of 135 m & 144 m respectively.

20mm leak at C3/C4 Splitter bottom: From the consequence results and graphs of the selected credible scenario, it can be concluded that LFL may be extended up to a distance of 34 m. The Jet Fire radiation intensity of 37.5 & 12.5 kW/m^2 would spread up to a distance of 41 m & 48 m respectively. The 5 & 3 psi blast overpressures travel up to a distance of 38 m & 41 m respectively.

6.5.11 HGU

NOTE: Refer Figures 6.5.11.1 to 6.5.11.3 in Annexure-II

50 mm Leak at Naphtha Surge Drum bottom: From the consequence modeling of the selected failure scenario, it can be observed that LFL may be spreading upto a distance of 142 m from leak source. The Jet Fire Radiation Intensity of 37.5 kW/m^2 & 12.5 kW/m^2 would extend up to a distance 76m & 94 m respectively. The Pool Fire radiation intensity of 37.5 kW/m^2 is not realized & 12.5 kW/m^2 would spread up to a distance of 37 m. The 5 & 3 psi blast waves for this leakage scenario would be extended upto a distance of 187 m & 204 m respectively.

20 mm Leak at Naphtha Feed Pump: From the consequence results and graphs of the selected credible scenario, it can be concluded that LFL may be extended up to a distance of 92 m. The Jet Fire radiation intensity of 37.5 & 12.5 kW/m^2 would spread up to a distance of 56 m & 68 m respectively. The 5 & 3 psi blast waves for this leakage scenario would be extended upto a distance of 111 m & 119 m respectively.

20 mm Leak at H2 Recycle Compressor: From the incident outcome analysis of the selected failure scenario it is observed that LFL hazard distance is extended up to 22 m. The Jet Fire radiation intensity of 37.5 kW/m^2 is not realized & 12.5 kW/m^2 would spread up to a distance of 16 m. The 5 & 3 psi blast waves may reach up to a distance of 26 m & 29 m respectively.

6.5.12 INDMAX GDS

NOTE: Refer Figures 6.5.12.1 to 6.5.12.13 in Annexure-II

20mm leak at SHU Reactor Feed Pumps - Toxic: From the consequence results and graphs of the selected credible scenario, it can be concluded that LFL may be extended up to a distance of 92 m. The Jet Fire radiation intensity of 37.5 & 12.5 kW/m^2 would spread up to a distance of 52 m & 63 m respectively. The 5 & 3 psi blast overpressures travel up to a distance of 111 m & 119 m respectively. The toxic IDLH hazard distances of benzene may reach up to a distance of 59 m from the leak source depending upon the prevailing weather conditions at the time of release.

50mm leak at SHU Feed Surge Drum - Toxic: From the incident outcome analysis of the selected failure scenario it is observed that LFL hazard distance is extended up to 150 m. The Jet Fire radiation intensity of 37.5 & 12.5 kW/m^2 would spread up to a distance of 76 m & 93 m respectively. The Pool Fire Radiation Intensity of 12.5 kW/m^2 can extend up to a distance of 35 m. The 5 & 3 psi blast wave may spread up to a distance of 187 m & 205 m respectively. The toxic IDLH hazard distances of benzene may reach up to a distance of 129 m from the leak source depending upon the prevailing weather conditions at the time of release.

20mm leak at RGC: From the consequence results and graphs of the selected credible scenario, it is observed that LFL hazard distance is extended up to 19m. The Jet Fire radiation intensity of

12.5 kW/m^2 would spread up to a distance of 12 m. The 5 & 3 psi blast wave may spread up to a distance of 14 m & 15 m respectively.

50mm leak at LCN Splitter Reflux Drum: From the incident outcome analysis of the selected failure scenario it is observed that LFL hazard distance is extended up to 179 m. The Jet Fire radiation intensity of 37.5 & 12.5 kW/m^2 would spread up to a distance of 84 m & 101 m respectively. The Pool Fire Radiation Intensity of 37.5 & 12.5 kW/m^2 can extend up to a distance of 31 m & 31 m respectively. The 5 & 3 psi blast wave may spread up to a distance of 210 m & 225 m respectively.

20mm leak at LCN Splitter Reflux Pump: From the consequence analysis results for this failure scenario, it can be realized that LFL may travel up to a distance of 69 m. The Jet Fire radiation intensity of 37.5 & 12.5 kW/m^2 would spread up to a distance of 44 m & 53 m respectively. The 5 & 3 psi blast overpressures travel up to a distance of 755 m & 81 m respectively.

20mm leak at LCN Product Pump: From the consequence analysis results for this failure scenario, it can be realized that LFL may travel up to a distance of 46 m. The Jet Fire radiation intensity of 37.5 & 12.5 kW/m^2 would spread up to a distance of 42 m & 50 m respectively. The 5 & 3 psi blast overpressures travel up to a distance of 51m & 55 m respectively.

20mm leak at HDS Feed Pumps - Toxic: From the incident outcome analysis of the selected failure scenario it is observed that LFL hazard distance is extended up to 55 m. The Jet Fire radiation intensity of 37.5 & 12.5 kW/m^2 would spread up to a distance of 44 m & 54 m respectively. The 5 & 3 psi blast wave may spread up to a distance of 63 m & 68 m respectively. The toxic IDLH hazard distances of benzene may reach up to a distance of 46 m from the leak source depending upon the prevailing weather conditions at the time of release.

50mm leak at Hot Separator Bottom - Toxic: From the consequence results and graphs of the selected credible scenario, it can be concluded that LFL may be extended up to a distance of 185 m. The Jet Fire radiation intensity of 37.5 & 12.5 kW/m^2 would spread up to a distance of 95 m & 117 m respectively. The Pool Fire Radiation Intensity of 12.5 kW/m^2 can extend up to a distance of 61 m. The 5 & 3 psi blast overpressures travel up to a distance of 213 m & 226 m respectively. The toxic IDLH hazard distances of benzene may reach up to a distance of 65 m from the leak source depending upon the prevailing weather conditions at the time of release.

20mm leak at Stabilizer Bottom Pump - Toxic: From the consequence analysis results for this failure scenario, it can be realized that LFL may travel up to a distance of 41 m. The Jet Fire radiation intensity of 37.5 & 12.5 kW/m^2 would spread up to a distance of 38 m & 47 m respectively. The 5 & 3 psi blast overpressures travel up to a distance of 50 m & 54 m respectively. The toxic IDLH hazard distances of benzene may reach up to a distance of 33 m from the leak source depending upon the prevailing weather conditions at the time of release.

20mm leak at MCN Splitter Bottom Pumps: From the consequence results and graphs of the selected credible scenario, it can be concluded that LFL may be extended up to a distance of 41 m. The Jet Fire radiation intensity of 37.5 & 12.5 kW/m^2 would spread up to a distance of 38 m & 46 m respectively. The 5 & 3 psi blast overpressures travel up to a distance of 50 m & 54 m respectively.

20mm leak at MCN Splitter Reflux Pumps - Toxic: From the incident outcome analysis of the selected failure scenario it is observed that LFL hazard distance is extended up to 45 m. The Jet Fire radiation intensity of 37.5 & 12.5 kW/m^2 would spread up to a distance of 38 m & 45 m respectively. The 5 & 3 psi blast wave may spread up to a distance of 51 m & 55 m respectively. The toxic IDLH hazard distances of benzene may reach up to a distance of 207 m from the leak source depending upon the prevailing weather conditions at the time of release.

50mm leak at MCN Splitter Reflux Drum -Toxic: From the consequence results and graphs of the selected credible scenario, it can be concluded that LFL may be extended up to a distance of 115 m. The Jet Fire radiation intensity of 37.5 & 12.5 kW/m^2 would spread up to a distance of 74 m & 89 m respectively. The 5 & 3 psi blast overpressures travel up to a distance of 135 m & 145 m respectively. The toxic IDLH hazard distances of benzene may reach up to a distance of 479 m from the leak source depending upon the prevailing weather conditions at the time of release.

6mm leak at Benzene Removal Column Bottom Pumps - Toxic: From the incident outcome analysis of the selected failure scenario it is observed that LFL hazard distance is extended up to 16 m. The Jet Fire radiation intensity of 37.5 & 12.5 kW/m^2 would spread up to a distance of 13 m & 16 m respectively. The Pool Fire Radiation Intensity of 37.5 & 12.5 kW/m^2 can extend up to a distance of 8 m & 17 m respectively. The 5 & 3 psi blast wave may spread up to a distance of 14 m & 16 m respectively. The toxic IDLH hazard distances of benzene may reach up to a distance of 53 m from the leak source depending upon the prevailing weather conditions at the time of release.

6.5.13 LPG AMINE TREATING UNIT

NOTE: Refer Figures 6.5.13.1 to 6.5.13.2 in Annexure-II

20 mm Leak at DHDT LPG Feed line - Toxic: From the consequence results and graphs of the selected credible scenario, it can be concluded that LFL may be extended up to a distance of 29 m. The Jet Fire radiation intensity of 37.5 & 12.5 kW/m^2 would spread up to a distance of 20 m & 24 m respectively. The 5 & 3 psi blast waves for this leakage scenario would be extended up to a distance of 30 m & 34 m respectively. The toxic IDLH hazard distances of H_2S may reach up to a distance of 72 m from the leak source depending upon the prevailing weather conditions at the time of release.

20 mm Leak at Amine Settler Drum: From the consequence analysis of selected failure scenario it can be observed that LFL shall be travelling up to a distance of 51 m. The Jet Fire radiation

intensity of 37.5 kW/m^2 & 12.5 kW/m^2 would extend up to a distance of 44 m & 53 m respectively. The 5 & 3 psi blast overpressures travel up to a distance of 62 m & 67 m respectively.

6.5.14 LPG TREATING UNIT (TRAIN-I)

NOTE: Refer Figures 6.5.14.1 to 6.5.14.2 in Annexure-II

20 mm Leak at LPG Feed line: From the consequence results and graphs of the selected credible scenario, it can be concluded that LFL may be extended up to a distance of 51 m. The Jet Fire radiation intensity of 37.5 & 12.5 kW/m^2 would spread up to a distance of 44 m & 52 m respectively. The 5 & 3 psi blast waves for this leakage scenario would be extended up to a distance of 62 m & 66 m respectively.

20 mm Leak at LPG Product line: From the consequence analysis of selected failure scenario it can be observed that LFL shall be travelling up to a distance of 49 m. The Jet Fire radiation intensity of 37.5 kW/m^2 & 12.5 kW/m^2 would extend up to a distance of 43 m & 51 m respectively. The 5 & 3 psi blast overpressures travel up to a distance of 51 m & 55 m respectively.

6.5.15 LPG TREATING UNIT (TRAIN-II)

NOTE: Refer Figures 6.5.15.1 to 6.5.15.2 in Annexure-II

20 mm Leak at LPG Feed line: From the consequence results and graphs of the selected credible scenario, it can be concluded that LFL may be extended up to a distance of 45 m. The Jet Fire radiation intensity of 37.5 & 12.5 kW/m^2 would spread up to a distance of 43 m & 50 m respectively. The 5 & 3 psi blast waves for this leakage scenario would be extended upto a distance of 51 m & 55 m respectively.

20 mm Leak at LPG Product line: From the consequence analysis of selected failure scenario it can be observed that LFL shall be travelling up to a distance of 41 m. The Jet Fire radiation intensity of 37.5 kW/m^2 & 12.5 kW/m^2 would extend up to a distance of 41 m & 48 m respectively. The 5 & 3 psi blast overpressures travel up to a distance of 50 m & 54 m respectively.

6.5.16 FGTU

NOTE: Refer Figure 6.5.16.1 in Annexure-II

20 mm Leak at Sour FG Line - Toxic: From the incident outcome analysis of the selected failure scenario it is observed that IDLH concentration of H_2S may reach up to a distance of 348 m from the leak source.

6.5.17 OCTAMAX

NOTE: Refer Figures 6.5.17.1 to 6.5.17.4 in Annexure-II

20mm leak at Feed Coalescer: From the consequence analysis results for this failure scenario, it can be realized that LFL may travel up to a distance of 58 m. The Jet Fire radiation intensity of 37.5 & 12.5 kW/m^2 would spread up to a distance of 46 m & 55 m respectively. The 5 & 3 psi blast overpressures travel up to a distance of 63 m & 65 m respectively.

20mm leak at C4 Raffinate Pump: From the consequence results and graphs of the selected credible scenario, it can be concluded that LFL may be extended up to a distance of 49 m. The

Jet Fire radiation intensity of 37.5 & 12.5 kW/m^2 would spread up to a distance of 44 m & 52 m respectively. The 5 & 3 psi blast waves for this leakage scenario would be extended upto a distance of 51 m & 56 m respectively.

50mm leak at Product Separator Reflux Drum bottom: From the incident outcome analysis of the selected failure scenario it is observed that LFL hazard distance is extended up to 110 m. The Jet Fire radiation intensity of 37.5 & 12.5 kW/m^2 would spread up to a distance of 77 m & 93 m respectively. The 5 & 3 psi blast wave may spread up to a distance of 131 m & 139 m respectively.

20mm leak at Product Rundown Pump: From the consequence modeling of the selected failure scenario, it can be observed that LFL may be spreading upto a distance of 78 m from leak source. The Jet Fire Radiation Intensity of 37.5 kW/m^2 & 12.5 kW/m^2 would extend up to a distance 39 m & 48 m respectively. The Pool Fire Radiation Intensity of 37.5 kW/m^2 & 12.5 kW/m^2 can extend up to a distance of 23 m & 36 m respectively. The 5 & 3 psi blast waves for this leakage scenario would be extended upto a distance of 86 m & 92 m respectively.

6.5.18 REFINERY OFFSITES

Pump House:

NOTE: Refer Figures 6.5.18.1 to 6.5.18.14 in Annexure-II

20mm leak at OCTAMAX Feed Pumps: From the consequence results and graphs of the selected credible scenario, it can be concluded that LFL may be extended up to a distance of 71 m. The Jet Fire radiation intensity of 37.5 kW/m^2 & 12.5 kW/m^2 would extend up to a distance of 48 m & 58 m respectively. The 5 & 3 psi blast overpressures travel up to a distance of 86 m & 92 m respectively.

20mm leak at Propylene Pumps: From the consequence results and graphs of the selected credible scenario, it can be concluded that LFL may be extended up to a distance of 49 m. The Jet Fire radiation intensity of 37.5 kW/m^2 & 12.5 kW/m^2 would extend up to a distance of 47 m & 55 m respectively.. The 5 & 3 psi blast overpressures travel up to a distance of 51 m & 55 m respectively.

20mm leak at Cracked LPG Pumps: From the incident outcome analysis of the selected failure scenario it is observed that LFL hazard distance is extended up to 54 m. The Jet Fire radiation intensity of 37.5 & 12.5 kW/m^2 would spread up to a distance of 46 m & 54 m respectively. The 5 & 3 psi blast wave may spread up to a distance of 62 m & 67 m respectively.

20mm leak at C3 mix Pumps: From the consequence results and graphs of the selected credible scenario, it can be concluded that LFL may be extended up to a distance of 41 m. The Jet Fire radiation intensity of 37.5 & 12.5 kW/m^2 would spread up to a distance of 42 m & 50 m respectively. The 5 & 3 psi blast overpressures travel up to a distance of 50 m & 53 m respectively.

<u>20mm leak at Crude Oil Pumps:</u> From the consequence results and graphs of the selected credible scenario, it can be concluded that LFL may be extended up to a distance of 78 m. The Jet Fire radiation intensity of 37.5 & 12.5 kW/m^2 would spread up to a distance of 33 m & 41 m respectively. The Pool Fire Radiation Intensity of 37.5 & 12.5 kW/m^2 can extend up to a distance of 19 m & 33 m respectively. The 5 & 3 psi blast overpressures travel up to a distance of 91 m & 100 m respectively.

<u>20mm leak at Diesel Product Recirculation Pumps:</u> From the consequence results and graphs of the selected credible scenario, it can be concluded that LFL may be extended up to a distance of 13m. The Jet Fire radiation intensity of 37.5 & 12.5 kW/m^2 would spread up to a distance of 7 m & 8 m respectively. The Pool Fire Radiation Intensity of 12.5 kW/m^2 can extend up to a distance of 32 m. The 5 & 3 psi blast overpressures travel up to a distance of 11 m & 12 m respectively.

<u>20mm leak at MS-VI Product Recirculation Pumps:</u> From the consequence results and graphs of the selected credible scenario, it can be concluded that LFL may be extended up to a distance of 100 m. The Jet Fire radiation intensity of 37.5 & 12.5 kW/m^2 would spread up to a distance of 43 m & 52 m respectively. The 5 & 3 psi blast overpressures travel up to a distance of 128 m & 139 m respectively.

<u>20mm leak at ATF Product Recirculation Pumps:</u> From the incident outcome analysis of the selected failure scenario it is observed that LFL hazard distance is extended up to 20 m. The Jet Fire radiation intensity of 37.5 & 12.5 kW/m^2 would spread up to a distance of 29 m & 35 m respectively. The Pool Fire Radiation Intensity of 12.5 kW/m^2 can extend up to a distance of 33 m. The 5 & 3 psi blast wave may spread up to a distance of 26 m & 28 m respectively.

<u>20mm leak at NHT Feed Pumps:</u> From the consequence results and graphs of the selected credible scenario, it can be concluded that LFL may be extended up to a distance of 101 m. The Jet Fire radiation intensity of 37.5 & 12.5 kW/m^2 would spread up to a distance of 44 m & 53 m respectively. The 5 & 3 psi blast overpressures travel up to a distance of 128 m & 138 m respectively.

<u>20mm leak at ISOM Feed Pump:</u> From the consequence results and graphs of the selected credible scenario, it can be concluded that LFL may be extended up to a distance of 112 m. The Jet Fire radiation intensity of 37.5 & 12.5 kW/m^2 would spread up to a distance of 50 m & 60 m respectively.. The 5 & 3 psi blast overpressures travel up to a distance of 135 m & 145 m respectively.

<u>20mm leak at CCR Feed Pump:</u> From the incident outcome analysis of the selected failure scenario it is observed that LFL hazard distance is extended up to 108 m. The Jet Fire radiation intensity of 37.5 & 12.5 kW/m^2 would spread up to a distance of 49 m & 60 m respectively. The

Pool Fire Radiation Intensity of 37.5 & 12.5 kW/m^2 can extend up to a distance of 35 m & 45 m respectively. The 5 & 3 psi blast wave may spread up to a distance of 124 m & 133 m respectively.

20mm leak at Isomerate Pumps: From the consequence results and graphs of the selected credible scenario, it can be concluded that LFL may be extended up to a distance of 99 m. The Jet Fire radiation intensity of 37.5 & 12.5 kW/m^2 would spread up to a distance of 44 m & 53 m respectively. The 5 & 3 psi blast overpressures travel up to a distance of 117 m & 127 m respectively.

20mm leak at Reformate Pumps: From the incident outcome analysis of the selected failure scenario it is observed that LFL hazard distance is extended up to 100 m. The Jet Fire radiation intensity of 37.5 & 12.5 kW/m^2 would spread up to a distance of 43 m & 53 m respectively. The 5 & 3 psi blast wave may spread up to a distance of 128 m & 138 m respectively.

20mm leak at DHDT Feed Pumps: From the consequence results and graphs of the selected credible scenario, it can be concluded that LFL may be extended up to a distance of 100 m. The Jet Fire radiation intensity of 37.5 & 12.5 kW/m^2 would spread up to a distance of 39 m & 49 m respectively. The 5 & 3 psi blast overpressures travel up to a distance of 117 m & 128 m respectively.

Tank on Fire:

NOTE: Refer Figures 6.5.18.15 to 6.5.18.21 in Annexure-II

Crude Tank on Fire: From the consequence analysis of selected failure scenario it can be observed that Pool Fire radiation intensity of 32kW/m^2 is not realized & 8kW/m^2 would extend up to a distance of 51 m.

NHT Feed Tank on Fire: From the consequence modeling of the selected failure scenario, it can be observed that Pool Fire radiation intensity of 32kW/m^2 is not realized & 8kW/m^2 would extend up to a distance of 37 m.

Diesel Tank on Fire: From the incident outcome analysis of the selected failure scenario it is observed that Pool Fire radiation intensity of 32kW/m2 is not realized & 8kW/m^2 would extend up to a distance of 40 m.

MS Tank on Fire: From the event outcome of the selected failure scenario it can be observed that Pool Fire radiation intensity of 32kW/m^2 is not realized & 8kW/m^2 would extend up to a distance of 35 m.

DHDT Feed Tank on Fire: From the consequence analysis of selected failure scenario it can be observed that Pool Fire radiation intensity of 32kW/m^2 is not realized & 8kW/m^2 would extend up to a distance of 32 m.

INDMAX GDS Feed Tank on Fire: From the consequence results and graphs of the selected credible scenario, it can be concluded that Pool Fire radiation intensity of 32kW/m^2 is not realized & 8kW/m^2 would extend up to a distance of 31 m.

Isomerate Tank on Fire: From the consequence analysis of selected failure scenario it can be observed that Pool Fire radiation intensity of 32kW/m^2 is not realized & 8kW/m^2 would extend up to a distance of 28 m.

6.5.19 PIPELINE TERMINAL

1

NOTE: Refer Figures 6.5.19.1 to 6.5.19.9 in Annexure-II

20 mm leak at LPG Pipeline Transfer Pumps: From the consequence results and graphs of the selected credible scenario, it can be concluded that LFL may be extended up to a distance of 59 m. The Jet Fire radiation intensity of 37.5 & 12.5 kW/m^2 would spread up to a distance of 45 m & 54 m respectively. The 5 & 3 psi blast overpressures travel up to a distance of 63 m & 68 m respectively.

20 mm leak at MS (Regular/ Premium) Pipeline Transfer Pumps: From the consequence results and graphs of the selected credible scenario, it can be concluded that LFL may be extended up to a distance of 102 m. The Jet Fire radiation intensity of 37.5 & 12.5 kW/m^2 would spread up to a distance of 43 m & 53 m respectively. The 5 & 3 psi blast overpressures travel up to a distance of 128 m & 139 m respectively.

20 mm leak at ATF Pipeline Transfer Pumps: From the incident outcome analysis of the selected failure scenario it is observed that LFL hazard distance is extended up to 46 m. The Jet Fire radiation intensity of 37.5 & 12.5 kW/m^2 would spread up to a distance of 42 m & 52 m respectively. The Pool Fire Radiation Intensity of 12.5 kW/m^2 can extend up to a distance of 40 m. The 5 & 3 psi blast wave may spread up to a distance of 51 m & 55 m respectively.

20 mm leak at Diesel Pipeline Transfer Pumps: From the consequence results and graphs of the selected credible scenario, it can be concluded that LFL may be extended up to a distance of 27 m. The Jet Fire radiation intensity of 37.5 & 12.5 kW/m^2 would spread up to a distance of 13 m & 16 m respectively. The Pool Fire Radiation Intensity of 12.5 kW/m^2 can extend up to a distance of 52 m. The 5 & 3 psi blast overpressures travel up to a distance of 23 m & 25 m respectively.

20 mm leak at Naphtha Pipeline Transfer Pumps: From the consequence results and graphs of the selected credible scenario, it can be concluded that LFL may be extended up to a distance of 97 m. The Jet Fire radiation intensity of 37.5 & 12.5 kW/m^2 would spread up to a distance of 43 m & 53 m respectively. The 5 & 3 psi blast overpressures travel up to a distance of 117 m & 127 m respectively.

20 mm leak at Propylene Jetty Transfer Pumps: From the consequence results and graphs of the selected credible scenario, it can be concluded that LFL may be extended up to a distance of 48 m. The Jet Fire radiation intensity of 37.5 & 12.5 kW/m^2 would spread up to a distance of 46 m &

54 m respectively.. The 5 & 3 psi blast overpressures travel up to a distance of 51 m & 55 m respectively.

50 mm leak at MS metering area: From the consequence results and graphs of the selected credible scenario, it can be concluded that LFL may be extended up to a distance of 251 m. The Jet Fire radiation intensity of 37.5 & 12.5 kW/m^2 would spread up to a distance of 97 m & 120 m respectively. The Pool Fire Radiation Intensity of 12.5 kW/m^2 can extend up to a distance of 57 m. The 5 & 3 psi blast overpressures travel up to a distance of 303 m & 327 m respectively.

20 mm leak at Crude Pipeline Receipt: From the consequence results and graphs of the selected credible scenario, it can be concluded that LFL may be extended up to a distance of 85 m. The Jet Fire radiation intensity of 37.5 & 12.5 kW/m^2 would spread up to a distance of 34 m & 43 m respectively. The Pool Fire Radiation Intensity of 37.5 & 12.5 kW/m^2 can extend up to a distance of 19 m & 30 m respectively. The 5 & 3 psi blast overpressures travel up to a distance of 105 m & 115 m respectively.

50 mm leak at Crude Pipeline Receipt: From the consequence results and graphs of the selected credible scenario, it can be concluded that LFL may be extended up to a distance of 212 m. The Jet Fire radiation intensity of 37.5 & 12.5 kW/m^2 would spread up to a distance of 76 m & 96 m respectively. The Pool Fire Radiation Intensity of 12.5 kW/m^2 can extend up to a distance of 42 m. The 5 & 3 psi blast overpressures travel up to a distance of 266 m & 291 m respectively.

6.5.20 PIPELINE

1

NOTE: Refer Figures 6.5.20.1 to 6.5.20.6 in Annexure-II

20 mm leak at LPG Pipeline: From the consequence results and graphs of the selected credible scenario, it can be observed that LFL may be extended up to a distance of 30 m. The Jet Fire radiation intensity of 37.5 & 12.5 kW/m^2 would spread up to a distance of 23 m & 40 m respectively. The 5 & 3 psi blast overpressures travel up to a distance of 32 m & 37 m respectively.

50 mm leak at LPG Pipeline: From the incident outcome analysis of the selected failure scenario it is observed that LFL hazard distance is extended up to 134 m. The Jet Fire radiation intensity of 37.5 & 12.5 kW/m^2 would spread up to a distance of 59 m & 94 m respectively. The 5 & 3 psi blast wave may spread up to a distance of 168 m & 183 m respectively.

20 mm leak at MS (Regular/ Premium) Pipeline: From the consequence results and graphs of the selected credible scenario, it can be observed that LFL may be extended up to a distance of 95 m. The Jet Fire radiation intensity of 37.5 & 12.5 kW/m^2 would spread up to a distance of 22 m & 37 m respectively. The 5 & 3 psi blast overpressures travel up to a distance of 121 m & 133 m respectively.

50 mm leak at MS (Regular/ Premium) Pipeline: From the consequence modeling of the selected failure scenario, it can be observed that LFL may be spreading up to a distance of 205 m from

leak source. The Jet Fire Radiation Intensity of 37.5 kW/m^2 & 12.5 kW/m^2 would extend up to a distance 53 m & 86 m respectively. The Pool Fire Radiation Intensity of 37.5 kW/m^2 & 12.5 kW/m^2 can extend up to a distance of 30 m & 52 m respectively. The 5 & 3 psi blast waves for this leakage scenario would be extended upto a distance of 269 m & 295 m respectively.

20 mm leak at Crude Pipeline: From the consequence results and graphs of the selected credible scenario, it can be concluded that LFL may be extended up to a distance of 89 m. The Jet Fire radiation intensity of 37.5 & 12.5 kW/m^2 would spread up to a distance of 21 m & 34 m respectively. The 5 & 3 psi blast overpressures travel up to a distance of 112 m & 124 m respectively.

50 mm leak at Crude Pipeline: From the consequence results and graphs of the selected credible scenario, it can be concluded that LFL may be extended up to a distance of 220 m. The Jet Fire radiation intensity of 37.5 & 12.5 kW/m^2 would spread up to a distance of 51 m & 79 m respectively. The Pool Fire Radiation Intensity of 12.5 kW/m^2 can extend up to a distance of 34 m. The 5 & 3 psi blast overpressures travel up to a distance of 292 m & 322 m respectively.

6.5.21 LFP

NOTE: Refer Figures 6.5.21.1 to 6.5.21.2 in Annexure-II 1

20 mm leak at Crude Booster Pumps: From the consequence results and graphs of the selected credible scenario, it can be concluded that LFL may be extended up to a distance of 94 m. The Jet Fire radiation intensity of 37.5 & 12.5 kW/m^2 would spread up to a distance of 36 m & 45 m respectively. The 5 & 3 psi blast overpressures travel up to a distance of 117 m & 128 m respectively.

50 mm leak at Crude Booster Pumps: From the consequence results and graphs of the selected credible scenario, it can be concluded that LFL may be extended up to a distance of 250 m. The Jet Fire radiation intensity of 37.5 & 12.5 kW/m^2 would spread up to a distance of 80 m & 101 m respectively. The 5 & 3 psi blast overpressures travel up to a distance of 319 m & 350 m respectively.

6.5.22 KARAIKAL PORT TERMINAL

NOTE: Refer Figures 6.5.22.1 to 6.5.22.4 in Annexure-II 1

20 mm leak at LPG Pipeline: From the consequence results and graphs of the selected credible scenario, it can be observed that LFL may be extended up to a distance of 57 m. The Jet Fire radiation intensity of 37.5 & 12.5 kW/m^2 would spread up to a distance of 43 m & 52 m respectively. The 5 & 3 psi blast overpressures travel up to a distance of 63 m & 68 m respectively.

50 mm leak at LPG Pipeline: From the incident outcome analysis of the selected failure scenario it is observed that LFL hazard distance is extended up to 134 m. The Jet Fire radiation intensity of

37.5 & 12.5 kW/m^2 would spread up to a distance of 59 m & 94 m respectively. The 5 & 3 psi blast wave may spread up to a distance of 201 m & 213 m respectively.

<u>20 mm leak at MS (Regular/ Premium) Pipeline:</u> From the consequence results and graphs of the selected credible scenario, it can be observed that LFL may be extended up to a distance of 83 m. The Jet Fire radiation intensity of 37.5 & 12.5 kW/m^2 would spread up to a distance of 39 m & 47 m respectively. The Pool Fire Radiation Intensity of 37.5 kW/m^2 & 12.5 kW/m^2 can extend up to a distance of 21 m & 32 m respectively. The 5 & 3 psi blast overpressures travel up to a distance of 104 m & 113 m respectively.

<u>50 mm leak at MS (Regular/ Premium) Pipeline:</u> From the consequence modeling of the selected failure scenario, it can be observed that LFL may be spreading up to a distance of 184 m from leak source. The Jet Fire Radiation Intensity of 37.5 kW/m^2 & 12.5 kW/m^2 would extend up to a distance 86 m & 106 m respectively. The Pool Fire Radiation Intensity of 12.5 kW/m^2 can extend up to a distance of 49 m. The 5 & 3 psi blast waves for this leakage scenario would be extended upto a distance of 237 m & 259 m respectively.

7 MAJOR FINDINGS& RECOMMENDATIONS

The detailed consequence analysis of release of hydrocarbon in case of major credible scenarios are modeled in terms of release rate, dispersion, flammability and toxic characteristics, which have been discussed in detail in the report. The major findings and recommendations arising out of the Rapid Risk analysis study are summarized below:

- Consequence modeling of various credible scenarios for CDU/VDU Block is carried out and it is observed that the Cooling Towers present on the eastern side of the unit & adjacent MS Block unit may get affected from Radiation & Explosion effects emanating from the unit, depending upon the prevalent wind conditions & ignition source encountered at the time of release.

  It is recommended to install Fire & Gas detectors at suitable location within the unit. Utilize Low frequency failure scenarios such as 50 mm leak scenarios for preparation of Emergency Response & Disaster Management Plan.

- Flammable & Toxic failure scenarios are modeled for NHT, CCR & ISOM and their Explosion, Radiation & Toxic effects are studied. It is observed that the adjacent Tank Farm, CDU/VDU, SRR-2 and S/S-2 may get affected on account of leakage scenarios (Explosion & Radiation effects) from these units, depending upon the equipment location in the unit and prevalent weather conditions at the time of release. Moreover, H_2S, Benzene & Toluene IDLH concentration from toxic failure scenarios may also affect operators present in these plants and may extend up to CDU/VDU, Offsite area, SRR-2, S/S-2, SRR-1, S/S-1 and S/S-11. In the event of 20 mm leak from NHT stripper reflux pump, the IDLH concentration of H_2S may reach up to 217 m leak source and it may cross Refinery compound wall towards North West side depending upon the prevalent weather conditions at the time of release and equipment locations within unit.

  It is recommended to maintain at least 217 m distance between NHT Stripper Reflux Pump and Refinery Compound Wall while finalizing equipment layout during detailed engineering stage.

  It is recommended to make SRR-2 & SRR-1 positive pressurized with HC, H_2S detectors at inlet of HVAC duct which shall close inlet damper on actuation of HC/H_2S detector.

  It is also recommended to install Fire & Gas (Flammable & Toxic) detectors at strategic locations within these units along with remotely operated isolation valves for inventory isolation in the event of any leakage. Utilize low frequency failure scenarios such as 50 mm leak *scenarios for preparation of Emergency Response & Disaster Management Plan.*

- Flammable & Toxic failure scenarios are modeled for the DHDT Unit, it is observed that affect zones arising out of the high & low frequency credible scenarios for HP & Toxic sections of the DHDT shall cross the unit B/Ls and may affect the nearby VGO HDT, INDMAX GDS, LPG Treating Unit (Train II), Offsite area, OMS Control Room 6, SRR-4, S/S-4, SRR-5 and S/S-5 depending upon the prevalent weather conditions at the time of release and equipment locations within unit.

It is recommended to make OMS Control Room 6, SRR-4 and SRR-5 positive pressurized with HC & H_2S detectors at inlet of HVAC duct which shall close inlet damper on actuation of HC/H_2S detector

It is recommended to install Fire & Gas (Flammable & Toxic) detectors at strategic locations within unit along with remotely operated isolation valves for inventory isolation in the event of any leakage. Utilize low frequency failure scenarios such as 50 mm leak scenarios for preparation of Emergency Response & Disaster Management Plan.

- Various credible leak scenarios are modeled for the VGO-HDT unit and it is observed that Radiation, Explosion & Toxic effect zones may cross the B/Ls of the unit. H_2S IDLH concentration in the event of 20 mm Leak at LPG Product Pump discharge circuit may affect nearby DHDT, INDMAX GDS, INDMAX, OCTAMAX, CDU/VDU, MS Block, LPG Treating Unit (Train II), Offsite area , OMS Control Room 6, OMS Control Room 5, SRR-1, S/S-1, SRR-4, S/S-4, SRR-3, S/S-3, SRR-5, S/S-5, SRR-2 & S/S-2 and it may cross Refinery compound wall depending upon the equipment location & prevalent weather conditions at the time of the release.

  It is recommended to maintain at least 450 m distance between LPG product pump and Refinery Compound Wall while finalizing equipment layout during detailed engineering stage.

  It is recommended to make OMS Control Room 6, OMS Control Room 5, SRR-1, SRR-2, SRR-3, SRR-4 and SRR-5 positive pressurized with HC & H_2S detectors at inlet of HVAC duct which shall close inlet damper on actuation of HC/H_2S detector.

  It is recommended to install Fire & Gas (Flammable & Toxic) detectors at strategic locations within the unit along with remotely operated isolation valves for inventory isolation in the event of any leakage. Utilize low frequency failure scenarios such as 50 mm leak scenarios for preparation of Emergency Response & Disaster Management Plan.

- Toxic Scenarios are modeled for the SRU / ARU(1 & 2)/ SWS (1&2) and it is observed that the H2S IDLH concentration may cross the unit's B/Ls and affect the nearby facilities and personnel present, depending upon the prevalent weather conditions at the time of the release.

  Hence, it is recommended to install Toxic gas detectors at strategic locations within the unit along with remotely operated isolation valves for inventory isolation in the event of any leakage. The outcomes of these scenarios to be also utilized for preparation of Emergency Response & Disaster Management Plan.

- Flammable scenarios are modeled for PPU and it is observed that the hazard effect zone may cross the unit's B/L and may affect the nearby facilities depending upon the prevalent weather conditions at the time of the release.

  Hence it is recommended to install HC gas detectors at strategic locations within the unit.

- Various credible Flammable & Toxic failure scenarios are modeled for the DCU and it is observed that Radiation & Explosion effect zones may cross the unit's B/L and may affect Control Room-8 (Circulating Fluidized Bed Combustion Boiler), Control Room-3 (Air & N2 Plant) and SRR-6 (DCU & PPU). H_2S IDLH concentration in the event of 20 mm Leak at WGC discharge, Stripper Charge Pump and LPG Product Pump discharge circuit may affect HGU, CFBC, PPU, Polymer Lab, PP Ware House, Cooling Tower, Air & N2 Plant, SRR-1, S/S-6, SRR-8, S/S-7, S/S-16, SRR-6, Control Room-3 (Air & N2 Plant), Control Room-8 (CFBC) and it may cross the Refinery Compound Wall, depending upon the operating conditions, prevalent weather conditions at the time of release.

  Hence it is recommended to relocate DCU unit or toxic handling section of DCU in such a way that the IDLH contours of H_2S are contained within the facility.

  Hence it is recommended to relocate the Control Room-8 (CFBC), Control Room-3 (Air & N2 Plant) to alternate safe location to safeguard the persons. Ensure that SRR--6 (DCU & PPU) shall be made blast resistant.

  It is recommended to make Control Room-8 (CFBC), Control Room-3 (Air & N2 Plant), Polymer Lab, SRR-1, SRR-8 and SRR-6 (DCU & PPU) positive pressurized with HC & H_2S detectors at inlet of HVAC duct which shall close inlet damper on actuation of HC/H_2S detector.

  It is also recommended to install Fire & Gas (Flammable & Toxic) detectors at strategic locations within the unit along with remotely operated isolation valves for inventory isolation in the event of any leakage. Utilize low frequency failure scenarios such as 50 mm leak scenarios for preparation of Emergency Response & Disaster Management Plan.

- Credible Failure scenarios are modeled for the INDMAX FCC unit and it is observed that affect zones (Flammable & Explosion) arising out of the high & low frequency credible scenarios may cross the unit B/Ls and may affect the nearby units, depending upon the prevalent weather conditions at the time of release and equipment locations within unit.

  It is recommended to install Fire & Gas detectors at suitable location within the unit. Utilize Low frequency failure scenarios such as 50 mm leak scenarios for preparation of Emergency Response & Disaster Management Plan.

- Flammable scenarios are modeled for Hydrogen Generation Unit (HGU), it is observed that the consequence outcomes for the Naphtha handling section of the unit may cross the unit's B/L and affect the nearby offsite area and CFBC, depending upon equipment location & prevalent weather conditions at the time of the release.

It is recommended to install Fire & Gas detectors at suitable location within the unit. Utilize Low frequency failure scenarios such as 50 mm leak scenarios for preparation of Emergency Response & Disaster Management Plan.

- Various credible leak scenarios are modeled for the INDMAX GDS unit and it is observed that Radiation, Explosion & Toxic effect zones may cross the B/Ls of the unit. Benzene IDLH concentration in the event of 20 mm Leak at MCN Splitter Reflux Pump discharge circuit may affect nearby DHDT, VGO HDT, LPG Treating Unit (Train II), Offsite area, OMS Control Room 5, SRR-4, SRR-5, S/S-5, SRR-2 depending upon the equipment location & prevalent weather conditions at the time of the release.

  It is recommended to make OMS Control Room 5, SRR-2, SRR-4 and SRR-5 positive pressurized with HC detectors at inlet of HVAC duct which shall close inlet damper on actuation of HC/H_2S detector.

  It is recommended to install Fire & Gas detectors at strategic locations within the unit along with remotely operated isolation valves for inventory isolation in the event of any leakage. Utilize low frequency failure scenarios such as 50 mm leak scenarios for preparation of Emergency Response & Disaster Management Plan.

- Credible Flammable & Toxic scenarios are modeled for the LPG Amine Treating Unit and it is observed that the hazard effect zone may cross the unit's B/L and may affect the nearby facilities depending upon the prevalent weather conditions at the time of the release.

  Hence it is recommended to install HC/H_2S gas detectors at strategic locations within the unit.

- Flammable scenarios are modeled for the LPG Treating Unit (Train I & II) and it is observed that the hazard effect zone may cross the unit's B/L and may affect the nearby facilities depending upon the prevalent weather conditions at the time of the release.

  Hence it is recommended to install HC gas detectors at strategic locations within the unit.

- Toxic scenarios are modeled for the FGTU unit and it is observed that the H_2S IDLH concentration may cross the unit's B/L and affect the nearby CDU/VDU, MS block, CWTP, Offsite area, S/S-2, S/S-1, SRR-1, MCR-1, S/S-8 and SRR-9 depending upon the prevalent weather conditions at the time of the release.

  It is recommended to make SRR-1, MCR-1, and SRR-9 positive pressurized with HC & H_2S detectors at inlet of HVAC duct which shall close inlet damper on actuation of HC/H_2S detector.

It is also recommended to install Toxic gas detectors at strategic locations within the unit.

- Credible Failure scenarios are modeled for the OCTAMAX unit and it is observed that affect zones (Flammable & Explosion) arising out of the high & low frequency credible scenarios may cross the unit B/Ls and may affect the nearby units, depending upon the prevalent weather conditions at the time of release and equipment locations within unit.

  It is recommended to install Fire & Gas detectors at suitable location within the unit. Utilize Low frequency failure scenarios such as 50 mm leak scenarios for preparation of Emergency Response & Disaster Management Plan.

- Flammable failure scenarios are modeled for the hydrocarbon Pumps in the Offsite and it is observed that Radiation & Explosion effects may affect the nearby Storage Tanks.

  Hence it is recommended to provide the Fire & Gas detectors at strategic locations in the Offsite pump houses with adequate fire protection system for tankages & pump houses.

- Tank on fire case modeled for storage tanks and it is observed that the Radiation effects may affect the nearby storage tanks and flare trestle. In case of tank on fire in TF-16, TF-18, TF-20, TF-9, and TF-12, 8 kW/m2 radiations from one tank may affect next immediate Tank located in the same tank TF and, possibly resulting in their failure.

  Hence it is recommended to increase the distance between TF-8 dyke wall and supports of Flare trestle further by 15m to prevent damage of flare trestle supports due to any accidental pool fire in TF-8 dyke.

  It is recommended to increase the inter distance between the tanks located TF-16, TF-18, TF-20, TF-9, and TF-12 or provide adequate fire fighting protective devices to prevent further escalation.

- Credible Failure scenarios are modeled for Pipeline Terminal and it is observed that affect zones (Flammable & Explosion) arising out of the high & low frequency credible scenarios may affect SRR-16, S/S-20, depending upon the prevalent weather conditions at the time of release and equipment locations within unit. 1

  Hence it is recommended to make SRR-16 blast resistant building.

  It is recommended to install Fire & Gas detectors at suitable location within the terminal. Utilize Low frequency failure scenarios such as 50 mm leak scenarios for preparation of Emergency Response & Disaster Management Plan.

- Credible Failure scenarios are modeled for LFP and it is observed that affect zones (Flammable & Explosion) arising out of the high & low frequency credible scenarios may cross the facility B/Ls and may affect the nearby population and temple, depending upon the prevalent weather conditions at the time of release and equipment locations within unit. 1

Hence it is recommended to locate the Booster Pump discharge & associated facility such that hazard distance of 128 m is not reaching to the populated area in the village and nearby temple.

It is recommended to install Fire & Gas detectors at suitable location within the facility with provision for isolating inventory in case of detection of any leakage. Utilize Low frequency failure scenarios such as 50 mm leak scenarios for preparation of Emergency Response & Disaster Management Plan.

- In case of 20 mm leak of MS from pipeline, it is observed that LFL may reach up to a distance of 95 m from leak source. However, this appears to have a very low likelihood of occurrence as far as the pipeline under study is considered, since it will run underground all over its length. The major contribution of pipeline leaks can be attributed to third-party interference – digging, ploughing or tampering. 1

  It is advisable to maintain at least 95 m distance from any nearby habitation / village / any other manned facility along the pipeline route.

  In view of this; it is therefore recommended that regular inspections be undertaken in the vicinity of the pipeline, along its length, so that all third party activity in the area may be obviated or curtailed before harm ensues from the same.

  The major contribution of pipeline ruptures or large holes (50mm) can be attributed to third-party interference – digging, ploughing or tampering. Though the possibility of rupture of a pipeline is remote, but the consequence distances are high. Regular inspection of the pipeline is the sole way to forestall such a problem. And also it is recommended to include the scenario of pipeline rupture/ large hole scenarios in disaster management plan.

- Various credible scenarios are modeled for Karaikal Port Terminal and it is observed that the hazard effect zone may cross the terminal B/L and may affect the nearby facilities depending upon the prevalent weather conditions at the time of the release. In case of 20 mm leak from MS pipeline, it is observed that the 5 & 3 psi blast wave may reach up to a distance of 104 m and 113 m respectively from leak source. 1

  Hence it is recommended to maintain a buffer zone of 113 from Terminal pipeline and associated equipments. Safety distances to be reverified based upon finalized plot plan during detail engineering.

  It is recommended to install Fire & Gas detectors at suitable location within the facility with provision for isolating inventory in case of detection of any leakage. Utilize Low frequency failure scenarios such as 50 mm leak scenarios for preparation of Emergency Response & Disaster Management Plan.

General Recommendations

- ✓ Detailed Quantitative Risk Analysis needs to be carried out for entire facility for overall risk assessment.
- ✓ No Operator Cabin to be located inside battery limits of units. Detailed QRA required to be carried out prior to fixing the location of any Operator Cabin in the close vicinity of Process units.
- ✓ For positively pressurized building, both Hydrocarbon & Toxic detectors need to be placed at suction duct of HVAC. HVAC to be tripped automatically in event of the detection of any Hydrocarbon / toxic material by detector.
- ✓ In order to prevent secondary incident arising from any failure scenario, it is recommended that sprinklers and other protective devices provided on the tanks to be regularly checked to ensure that they are functional.
- ✓ Proper checking of contract people for Smoking or Inflammable materials to be ensured at entry gates to avoid presence of any unidentified source of ignition.
- ✓ It shall be ensured that all the vehicles entering the plant shall be provided with spark arrestors at the exhaust.
- ✓ The critical operating steps shall be displayed on the board near the location where applicable.
- ✓ Mock drills to be organized at organization level to ensure preparation of the personnel's working in premises for handling any hazardous situation.
- ✓ Active fire protection system shall be provided throughout the plant for preventing escalation of fire.
- ✓ Recommended to use portable HC/H_2S detector during sampling and maintenance etc.
- ✓ It is recommended for usage of safer oxidizing agents (Chlorine free) in Cooling Water circuit.
- ✓ Cognizance must be taken of the fact that the area bordering the pipeline will have to be kept free of habitation, and means to discourage the growth of such must be incorporated in the offsite disaster management plan.
- ✓ Since most incidents on buried pipelines are caused by external interference (digging, ploughing or drilling in the vicinity of the pipeline, it is recommended that frequent patrolling and pipeline inspection be instituted to enable early detection and cession of all such activities near the pipeline. 1
- ✓ Ensuring that the public in vicinity of the pipeline is made aware of the hazards and also the hazards of unplanned and irregular third party activities- this may be done through frequent safety awareness programmes, warning signage, explicit display of Do's and Don'ts etc.
- ✓ Line patrolling: Line patrolling is a visual inspection of the pipeline along the whole of its length. It involves verification of:

- General condition of the pipeline.
- Any breaches and soil erosion along the route of the pipeline, especially earth washed out at road and channel crossings.
- Growth of vegetation, which needs to be curtailed to ensure the free movement of vehicles to attend to any incident.
- All digging, ploughing and dredging in the vicinity of the pipeline, which may damage the pipeline.
- General condition of the cathodic protection at various locations.

Mitigating Measures

Mitigating measures are those measures in place to minimize the loss of containment event and, hazards arising out of Loss of containment. These include:

- ✓ Early detection of an undesirable event (HC/ toxic leak, Flame etc.) and development of subsequent quick isolation mechanism.
- ✓ Measures for controlling / minimization of Ignition sources inside the operating area.
- ✓ Active and Passive Fire Protection for critical equipment's and major structures
- ✓ Effective Emergency Response plans to be in place

Ignition Control

- ✓ Ignition control will reduce the likelihood of fire events. This is the key for reducing the risk within facilities processing flammable materials. As part of mitigation measure it is strongly recommended to consider minimization of the traffic movement in the vicinity of operating area.

Escape Routes

- ✓ Ensure sufficient escape routes from the site are available to allow redundancy in escape from all areas.
- ✓ Ensure sufficient number of windsocks throughout the site to ensure visibility from all locations. This will enable people to escape upwind or crosswind from flammable / toxic releases.
- ✓ Provide sign boards marking emergency/safe roads to be taken during any exigencies.

Preventive Maintenance for Critical Equipment

- ✓ In order to reduce the failure frequency of critical equipment, the following are recommended:
  a. High head pumps and Compressors, which are in flammable/ toxic services, are needed to be identified.
     i. Their seals, instruments and accessories are to be monitored closely
     ii. A detailed preventive maintenance plan to be prepared and followed.

b. High inventory vessels whose rupture may lead to massive consequences are needed to be identified and following to be ensured:
    i. Monitoring of vessel internals during shut down.
    ii. A detailed preventive maintenance plan to be prepared and followed.
    iii. Emergency inventory isolation valves shall be provided for vessel/column having large inventory and containing flammable/ toxic compound

8 GLOSSARY

CASUALTY	Someone who suffers serious injury or worse i.e. including fatal injuries. As a rough guide fatalities are likely to be half the total casualties. But this may vary depending on the nature of the event.
HAZARD	A chemical or physical condition with the potential of causing damage.
FLAMMABILITY LIMITS	In fuel-air systems, a range of compositions exists inside which a (UFL – LFL) flame will propagate substantial distance from an ignition source. The limiting fuel concentrations are termed as Upper flammability or explosives limit (Fuel concentrations exceeding this are too rich) and Lower flammability or explosives limit (Fuel concentrations below this are too lean).
FLASH FIRE	The burning of a vapor cloud at very low flame propagation speed. Combustion products are generated at a rate low enough for expansion to take place easily without significant overpressure ahead or behind the flame front. The hazard is therefore only due to thermal effects.
OVERPRESSURE	Maximum pressure above atmosphere pressure experiences during the passage of a blast wave from an explosion expressed in this report as pounds per square inch (psi).
EXPLOSION	A rapid release of energy, which causes a pressure discontinuity or shock wave moving away from the source. An explosion can be produced by detonation of a high explosive or by the rapid burning of a flammable gas cloud. The resulting overpressure is sufficient to cause damage inside and outside the cloud as the shock wave propagation into the atmosphere beyond the cloud. Some authors use the term deflagration for this type of explosion
DOMINO EFFECT	The effect that loss of containment of one installation leads to loss of containment of other installations
EVENT TREE	A logic diagram of success and failure combinations of events used to identify accident sequences leading to all possible consequences of a given initiating event.
TLV	"Threshold limit value" is defined as the concentration of the substance in air that can be breathed for five consecutive 8 hours work day (40 hours work week) by most people without side effect.
STEL	"Short Term Exposure Limit" is the maximum permissible average exposure for the time period specified (15 minutes).

IDLH	"Immediate Dangerous to Life and Health" is the maximum concentration level from which one could escape within 30 minutes without any escape impairing symptoms.
PASQUILL CLASS	Classification to qualify the stability of the atmosphere, indicated by a letter ranging from A, for very unstable, to F, for stable.
FREQUENCY	The number of times an outcome is expected to occur in a given period of time.

9 REFERENCES

1. Classification of hazardous locations, A. W. Cox, F. P. Lees and M. L. Ang, Published by the Institute of Chemical engineers, U. K.
2. The reference manual, Volume-II, Creemer & Warner Ltd. U. K. (Presently Entec).
3. Risk analysis of six potentially hazardous industrial objects in the Rijnmond area; A pilot study. A report to the Rijnmond Public Authority. D. Riedel publishing company, U. K.
4. Loss prevention in the process industries, Hazard identification, Assessment and Control, Frank. P. Lees (Vol. I, II & III), Published by Butterworth-Heinemann, U. K.
5. AICHE, CCPS, Chemical process Quantitative Risk Analysis
6. Guideline for Quantitative Risk assessment, ‘Purple book’.

ANNEXURE-I

CONSEQUENCE ANALYSIS

HAZARD DISTANCES

Consequence Analysis Hazard Distances

Unit	Sl. No.	Equipment	Failure Case	Operating Conditions		Leak Rate (Kg/s)	State Liquid /Gas	Weather Condition	LFL (m)	Jet Fire (m)			Pool Fire (m)			Over Pressure (m)			IDLH Hazard Distance (m)
				Temp. (^{O}C)	Press. (Kg/cm^2g)					4 kW/m^2	12.5 kW/m^2	37.5 kW/m^2	4 kW/m^2	12.5 kW/m^2	37.5 kW/m^2	2 psi	3 psi	5 psi	
CDU/VDU	1	Crude Charge Pump	Instrument Tapping Failure (20mm)	30	28	13.8	Liq	2F	94	74	55	44	-	-	-	132	121	113	-
								3.5B/C	85	67	50	39	-	-	-	111	103	97	-
	2	Naphtha Stabilizer Reflux Drum bottom	Large Hole (50mm)	40	8.0	34.7	Liq	2F	124	127	99	83	-	-	-	171	158	148	-
								3.5B/C	129	120	92	75	-	-	-	164	153	144	-
	3	LPG Product Pump	Instrument Tapping Failure (20mm)	40	25.0	9.8	Liq	2F	56	71	55	46	-	-	-	74	68	63	-
								3.5B/C	50	67	51	42	-	-	-	71	65	61	-
	4	Stabilizer feed Pump	Instrument Tapping Failure (20mm)	40	15.0	8.3	Liq	2F	104	72	55	46	47	31	21	143	132	123	-
								3.5B/C	73	69	51	41	47	34	22	97	90	85	-
	5	Naphtha Splitter Bottom Pump	Instrument Tapping Failure (20mm)	140	18.0	9.0	Liq	2F	60	68	53	43	-	-	-	75	69	64	-
								3.5B/C	53	65	49	39	-	-	-	71	66	62	-
	6	Lt. Naphtha Product Pump	Instrument Tapping Failure (20mm)	66	15.0	8.4	Liq	2F	97	74	57	47	58	34	26	127	118	110	-
								3.5B/C	71	70	53	43	61	38	27	97	90	85	-
	7	Hy. Naphtha Product Pump	Instrument Tapping Failure (20mm)	189	20.0	9.4	Liq	2F	53	66	51	42	-	-	-	73	67	63	-
								3.5B/C	49	63	47	38	-	-	-	59	55	51	-
NHT	1	NHT Feed Pump	Instrument Tapping Failure (20mm)	56	43	14.8	Liq	2F	93	87	67	55	-	-	-	129	119	111	-
								3.5B/C	89	83	62	50	-	-	-	111	103	97	-
	2	RGC	Instrument Tapping Failure (20mm)	69	34	0.8	Gas	2F	21	19	13	-	-	-	-	30	27	25	-
								3.5B/C	17	19	13	-	-	-	-	17	15	14	-
	3	Stripper Receiver Bottom- Toxic	Large Hole (50mm)	40	18	54.8	Liq	2F	282	160	121	98	122	84	56	395	367	343	H2S - 525
								3.5B/C	203	153	113	90	120	84	60	276	257	241	H2S - 362
	4	Stripper Reflux pump - Toxic	Instrument Tapping Failure (20mm)	40	23.5	10.0	Liq	2F	93	73	56	46	38	30	22	129	119	111	H2S - 217
								3.5B/C	77	70	52	42	37	30	23	97	91	85	H2S - 165
	5	Stripper Bottom - Toxic (benzene)	Instrument Tapping Failure (20mm)	207	19.2	8.0	Liq	2F	72	47	37	29	-	-	-	99	92	86	-
								3.5B/C	63	46	42	39	-	-	-	84	78	73	-
	6	HDT Separator Bottom - Toxic (benzene)	Instrument Tapping Failure (20mm)	40	24	11.1	Liq	2F	106	77	59	48	-	-	-	143	132	124	-
								3.5B/C	83	74	55	44	-	-	-	110	103	96	-
	7	Light Naphtha Pump - Toxic (benzene)	Instrument Tapping Failure (20mm)	55	11	7.2	Liq	2F	92	70	54	45	56	31	-	130	120	112	Benzene - 30
								3.5B/C	66	67	50	41	60	35	24	84	78	73	Benzene - 20
	8	Heavy Naphtha Pump	Instrument Tapping Failure (20mm)	148	13.5	7.9	Liq	2F	58	66	51	42	61	42	33	74	68	63	-
								3.5B/C	51	63	47	38	66	49	37	71	66	61	-
ISOM	1	ISOM Charge Pump	Instrument Tapping Failure (20mm)	40	43	14.4	Liq	2F	94	88	68	57	-	-	-	129	119	111	-
								3.5B/C	89	84	63	51	-	-	-	111	103	97	-
	2	MUG	Instrument Tapping Failure (20mm)	80	42	0.9	Gas	2F	24	22	17	8	-	-	-	31	28	26	-
								3.5B/C	22	22	18	11	-	-	-	30	28	25	-
	3	Stabilizer Receiver Bottom	Large Hole (50mm)	40	14.5	48.9	Liq	2F	202	158	122	101	-	-	-	285	264	246	-
								3.5B/C	191	151	114	92	-	-	-	257	240	226	-
	4	Stabilizer Reflux Pump	Instrument Tapping Failure (20mm)	40	20	9.2	Liq	2F	75	74	57	48	-	-	-	102	94	87	-
								3.5B/C	68	70	53	43	-	-	-	84	78	73	-

Consequence Analysis Hazard Distances

Unit	Sl. No.	Equipment	Failure Case	Operating Conditions		Leak Rate (Kg/s)	State Liquid /Gas	Weather Condition	LFL (m)	Jet Fire (m)			Pool Fire (m)			Over Pressure (m)			IDLH Hazard Distance (m)
				Temp. (^{O}C)	Press. (Kg/cm^2g)					4 kW/m^2	12.5 kW/m^2	37.5 kW/m^2	4 kW/m^2	12.5 kW/m^2	37.5 kW/m^2	2 psi	3 psi	5 psi	
	5	Stabilizer Bottom	Large Hole (50mm)	167	15.3	48.4	Liq	2F	103	129	100	83	-	-	-	142	131	123	-
								3.5B/C	100	119	91	74	-	-	-	138	128	120	-
	6	Stabilizer Bottom (Isomerate)	Instrument Tapping Failure (20mm)	167	15.3	7.7	Liq	2F	32	56	44	36	-	-	-	45	41	38	-
								3.5B/C	30	53	40	33	-	-	-	32	29	27	-
CCR	1	Separator Bottom Pumps -Toxic	Instrument Tapping Failure (20mm)	44	33	13.3	Liq	2F	94	87	67	55	-	-	-	131	120	112	Toulene - 298
								3.5B/C	85	83	62	50	-	-	-	110	103	97	Toulene - 224
	2	H2 Rich Gas Compressor	Instrument Tapping Failure (20mm)	107	30	0.9	Gas	2F	16	17	12	-	-	-	-	16	15	13	-
								3.5B/C	14	17	12	-	-	-	-	16	14	13	-
	3	Stabilizer Reflux Pump	Instrument Tapping Failure (20mm)	44	32	10.4	Liq	2F	48	69	55	46	-	-	-	61	56	51	-
								3.5B/C	44	66	50	41	-	-	-	59	54	50	-
	4	Stabilizer Overhead Receiver Bottom	Large Hole (50mm)	44	15	44.5	Liq	2F	120	136	106	88	-	-	-	169	157	147	-
								3.5B/C	122	129	98	80	-	-	-	163	153	144	-
	5	Stabilizer Bottom	Instrument Tapping Failure (20mm)	239	16	8.0	Liq	2F	71	47	38	30	-	-	-	99	92	86	-
								3.5B/C	66	46	42	40	-	-	-	84	78	73	-
DHDT	1	Feed Pumps	Instrument Tapping Failure (20mm)	173	87.5	21.3	Liq	2F	77	82	62	51	-	-	-	103	95	88	-
								3.5B/C	73	74	55	45	-	-	-	99	92	86	-
	2	HP Cold Separator Vap - Toxic	Instrument Tapping Failure (20mm)	55	68	1.6	Gas	2F	29	21	n/a	n/a	-	-	-	31	28	26	H2S - NR
								3.5B/C	25	22	n/a	n/a	-	-	-	30	28	26	H2S - NR
	3	MUG discharge	Instrument Tapping Failure (20mm)	125	82.6	1.2	Gas	2F	29	30	22	16	-	-	-	35	31	28	-
								3.5B/C	24	30	24	19	-	-	-	34	30	27	-
	4	Stripper Reflux Drum - Toxic	Large Hole (50mm)	40	8	39.8	Liq	2F	236	146	111	90	181	118	75	355	324	298	H2S - 484
								3.5B/C	164	139	103	82	175	117	80	227	210	197	H2S - 350
	5	Stripper Reflux Pump - Toxic	Instrument Tapping Failure (20mm)	40	12	7.8	Liq	2F	101	69	52	43	72	50	32	147	135	125	H2S - 221
								3.5B/C	70	65	49	39	69	49	34	98	91	85	H2S - 175
	6	Stripper Reflux Drum Overhead - Toxic (Elevation - 9m)	Instrument Tapping Failure (20mm)	40	8	0.5	Gas	2F	6	-	-	-	-	-	-	-	-	-	H2S - 180
								3.5B/C	6	-	-	-	-	-	-	-	-	-	H2S - NR
	7	Stripper bottom	Large Hole (50mm)	246	8.6	40.1	Liq	2F	233	139	104	83	67	39	n/a	314	293	275	-
								3.5B/C	193	132	97	76	73	42	n/a	254	238	225	-
	8	Heavy Naptha Pump	Instrument Tapping Failure (20mm)	164	8.3	2.9	Liq	2F	44	50	39	32	40	20	12	72	64	57	-
								3.5B/C	36	46	35	29	42	23	12	49	44	40	-
	9	ATF Product Pump	Instrument Tapping Failure (20mm)	208	9.3	6.6	Liq	2F	52	60	46	37	55	38	28	73	67	63	-
								3.5B/C	45	57	43	34	59	43	31	59	54	50	-
	10	Deethanizer Bottom pump	Instrument Tapping Failure (20mm)	145	16	5.2	Liq	2F	66	66	51	42	41	20	11	108	96	86	-
								3.5B/C	52	61	47	38	40	24	10	78	71	65	-
	11	Debutanizer bottom	Instrument Tapping Failure (20mm)	202	12.8	7.2	Liq	2F	79	45	37	32	-	-	-	101	94	87	-
								3.5B/C	64	46	42	40	-	-	-	84	78	73	-

Consequence Analysis Hazard Distances

Unit	Sl. No.	Equipment	Failure Case	Operating Conditions		Leak Rate (Kg/s)	State Liquid /Gas	Weather Condition	LFL (m)	Jet Fire (m)			Pool Fire (m)			Over Pressure (m)			IDLH Hazard Distance (m)
				Temp. (^{O}C)	Press. (Kg/cm^2g)					**4** kW/m^2	**12.5** kW/m^2	**37.5** kW/m^2	**4** kW/m^2	**12.5** kW/m^2	**37.5** kW/m^2	**2** psi	**3** psi	**5** psi	
VGO HDT	1	RGC	Instrument Tapping Failure (20mm)	117	95	2.2	Gas	**2F**	29	31	23	-	-	-	-	32	29	27	-
								3.5B/C	23	32	24	-	-	-	-	31	28	26	-
	2	Cold HP Separator Overhead - Toxic	Instrument Tapping Failure (20mm)	55	65	1.8	Gas	**2F**	27	-	-	-	-	-	-	30	28	26	H2S - NR
								3.5B/C	24	-	-	-	-	-	-	30	27	25	H2S - NR
	3	Stripper Reflux drum btm - Toxic	Large Hole (50mm)	40	10	45.4	Liq	**2F**	258	152	115	93	198	130	84	376	344	318	H2S - 430
								3.5B/C	179	145	107	84	189	127	88	241	223	209	H2S - 320
	4	Stripper Reflux pump - Toxic	Instrument Tapping Failure (20mm)	40	16	9.2	Liq	**2F**	108	72	55	45	71	51	34	142	131	123	H2S - 202
								3.5B/C	77	69	51	41	66	49	35	98	91	85	H2S - 161
	5	Debutanizer Receiver bottom - Toxic	Large Hole (50mm)	40	15	48.7	Liq	**2F**	127	142	112	94	-	-	-	171	158	148	H2S - 1386
								3.5B/C	131	134	103	84	-	-	-	175	164	155	H2S - 594
	6	LPG Product Pump -Toxic	Instrument Tapping Failure (20mm)	40	25	10.1	Liq	**2F**	48	69	55	46	-	-	-	61	55	51	H2S - 450
								3.5B/C	45	65	50	41	-	-	-	58	54	50	H2S - 303
	7	Debutanizer Botom	Instrument Tapping Failure (20mm)	212	15.5	7.2	Liq	**2F**	73	45	37	30	-	-	-	100	92	86	-
								3.5B/C	62	45	41	39	-	-	-	84	78	73	-
SWS-I/SWS-II/ARU/SRU	1	Amine Regenerator Reflux Drum Overhead - Toxic	Instrument Tapping Failure (20mm)	40	0.8	0.1	Gas	**2F**	2	-	-	-	-	-	-	-	-	-	H2S - NR
								3.5B/C	2	-	-	-	-	-	-	-	-	-	H2S - NR
	2	SWS-I Stripper Overhead - Toxic	Catastrophic Rupture	90	1	0.1	Gas	**2F**	1	-	-	-	-	-	-	-	-	-	H2S - NR
								3.5B/C	1	-	-	-	-	-	-	-	-	-	H2S - NR
	3	SWS-II Stage 1 Stripper Overhead - Toxic	Instrument Tapping Failure (20mm)	90	7	0.5	Gas	**2F**	3	-	-	-	-	-	-	-	-	-	H2S - NR
								3.5B/C	3	-	-	-	-	-	-	-	-	-	H2S - NR
	4	SWS-II Stage 2Stripper Overhead - Toxic	Catastrophic Rupture	90	1	0.1	Gas	**2F**	1	-	-	-	-	-	-	-	-	-	H2S - NR
								3.5B/C	1	-	-	-	-	-	-	-	-	-	H2S - NR
	5	ARU Acid Gas KOD Inlet - Toxic	Instrument Tapping Failure (20mm)	40	0.8	0.1	Gas	**2F**	2	-	-	-	-	-	-	-	-	-	H2S - 102
								3.5B/C	2	-	-	-	-	-	-	-	-	-	H2S - 39
	6	SWS Sour Gas KOD Inlet - Toxic	Catastrophic Rupture	90	0.8	0.1	Gas	**2F**	1	-	-	-	-	-	-	-	-	-	H2S - 113
								3.5B/C	1	-	-	-	-	-	-	-	-	-	H2S - 36
	7	SWS NH3 Rich Sour Gas KOD Inlet - Toxic	Instrument Tapping Failure (20mm)	90	0.8	0.1	Gas	**2F**	1	-	-	-	-	-	-	-	-	-	H2S - 60
								3.5B/C	1	-	-	-	-	-	-	-	-	-	H2S - 31
PPU	1	Propylene Charge Pump	Instrument Tapping Failure (20mm)	45	38	11.9	Liq	**2F**	49	71	57	49	-	-	-	60	55	51	-
								3.5B/C	46	67	52	44	-	-	-	58	54	50	-
	2	C3 LPG Pump	Instrument Tapping Failure (20mm)	45	23	4.9	Liq	**2F**	65	69	55	46	43	28	16	106	94	85	-
								3.5B/C	53	63	50	42	17	12	7	78	71	65	-
	3	Propylene Recycle Pump	Instrument Tapping Failure (20mm)	40	35	11.4	Liq	**2F**	49	71	56	48	-	-	-	60	55	51	-
								3.5B/C	46	66	52	43	-	-	-	58	54	50	-
	4	Hydrogen Compressor	Instrument Tapping Failure (20mm)	40	38	0.6	Gas	**2F**	24	22	16	-	-	-	-	32	29	27	-
								3.5B/C	21	22	18	9	-	-	-	31	28	26	-
	5	RG Compressor	Instrument Tapping Failure (20mm)	64	34	2.4	Gas	**2F**	14	-	-	-	-	-	-	16	14	13	-
								3.5B/C	13	-	-	-	-	-	-	16	14	13	-

Consequence Analysis Hazard Distances

Unit	Sl. No.	Equipment	Failure Case	Operating Conditions		Leak Rate (Kg/s)	State Liquid /Gas	Weather Condition	LFL (m)	Jet Fire (m)			Pool Fire (m)			Over Pressure (m)			IDLH Hazard Distance (m)
				Temp. (^{O}C)	Press. (Kg/cm^2g)					4 kW/m^2	12.5 kW/m^2	37.5 kW/m^2	4 kW/m^2	12.5 kW/m^2	37.5 kW/m^2	2 psi	3 psi	5 psi	
DCU	1	Fractionator Reflux Pump	Instrument Tapping Failure (20mm)	40	21.5	10.6	Liq	2F	113	78	60	49	-	-	-	156	145	135	-
								3.5B/C	84	74	56	45	-	-	-	110	103	97	-
	2	Coker Fractionator Overhead Receiver	Large Hole (50mm)	40	0.14	5.4	Liq	2F	45	32	25	21	51	20	-	75	66	59	-
								3.5B/C	31	31	24	20	56	21	-	50	45	41	-
	3	Wet Gas Compressor - Toxic	Instrument Tapping Failure (20mm)	122	14.3	0.9	Gas	2F	7	14	-	-	-	-	-	-	-	-	H2S - 388
								3.5B/C	6	14	-	-	-	-	-	-	-	-	H2S - 163
	4	Stripper charge pump - Toxic	Instrument Tapping Failure (20mm)	40	20	9.3	Liq	2F	91	72	55	45	73	50	33	127	118	110	H2S - 322
								3.5B/C	72	69	51	41	72	51	35	97	90	84	H2S - 221
	5	Stripper Bottom pump - Toxic	Instrument Tapping Failure (20mm)	154	20	8.7	Liq	2F	39	60	47	39	-	-	-	47	43	39	H2S - 82
								3.5B/C	36	57	43	35	-	-	-	45	42	38	H2S - 76
	6	Debutanizer Overhead Receiver - Toxic	Large Hole (50mm)	40	13.7	46.2	Liq	2F	121	136	108	91	-	-	-	168	156	146	H2S - 1427
								3.5B/C	122	128	99	82	-	-	-	162	152	143	H2S - 614
	7	LPG Product Pump - Toxic	Instrument Tapping Failure (20mm)	40	26	10.2	Liq	2F	48	68	54	46	-	-	-	60	55	51	H2S - 480
								3.5B/C	44	64	50	41	-	-	-	58	53	50	H2S - 329
	8	Debutanizer Bottom	Large Hole (50mm)	189	14.3	7.4	Liq	2F	32	55	43	35	-	-	-	45	41	38	-
								3.5B/C	29	52	39	32	-	-	-	32	29	27	-
	9	Coker Light Naphtha Pump	Instrument Tapping Failure (20mm)	79	13	7.7	Liq	2F	84	70	54	45	54	35	25	114	105	98	-
								3.5B/C	66	66	50	40	54	40	26	84	78	73	-
	10	Coker heavy naptha pump	Seal Failure (6mm)	156	14.2	0.7	Liq	2F	10	22	17	14	-	-	-	15	14	13	-
								3.5B/C	8	20	15	12	-	-	-	-	-	-	-
INDMAX FCC	1	MF Reflux Drum bottom	Large Hole (50mm)	60	0.68	11.7	Liq	2F	82	83	64	52	61	26	-	143	127	114	-
								3.5B/C	60	79	60	48	67	26	-	95	86	79	-
	2	MF Reflux Pumps	Instrument Tapping Failure (20mm)	60	19	9.9	Liq	2F	111	76	58	47	-	-	-	156	145	135	-
								3.5B/C	81	72	54	43	-	-	-	110	102	96	-
	3	WGC	Instrument Tapping Failure (20mm)	112	17	1.2	Gas	2F	8	17	12	-	-	-	-	-	-	-	-
								3.5B/C	8	17	12	-	-	-	-	-	-	-	-
	4	Stripper Charge Pumps	Instrument Tapping Failure (20mm)	40	25	9.8	Liq	2F	88	75	58	48	59	42	29	114	105	98	-
								3.5B/C	76	71	54	43	57	43	30	96	89	84	-
	5	Stripper bottom	Instrument Tapping Failure (20mm)	110	17.3	7.5	Liq	2F	49	61	47	39	-	-	-	61	56	51	-
								3.5B/C	43	58	44	35	-	-	-	58	54	50	-
	6	Debutanizer Overhead Receiver bottom	Large Hole (50mm)	40	11	40.6	Liq	2F	120	131	103	87	-	-	-	168	156	146	-
								3.5B/C	122	124	95	78	-	-	-	162	152	143	-
	7	LPG Product Pumps	Instrument Tapping Failure (20mm)	41	29	10.5	Liq	2F	51	70	56	47	-	-	-	72	67	62	-
								3.5B/C	48	66	51	42	-	-	-	59	54	50	-
	8	C3/C4 Splitter Feed Pump	Instrument Tapping Failure (20mm)	40	29	10.5	Liq	2F	52	70	56	47	-	-	-	72	67	62	-
								3.5B/C	48	66	51	42	-	-	-	59	54	50	-

Consequence Analysis Hazard Distances

Unit	Sl. No.	Equipment	Failure Case	Operating Conditions		Leak Rate (Kg/s)	State Liquid /Gas	Weather Condition	LFL (m)	Jet Fire (m)			Pool Fire (m)			Over Pressure (m)			IDLH Hazard Distance (m)
				Temp. (^{O}C)	Press. (Kg/cm^2g)					**4** kW/m^2	**12.5** kW/m^2	**37.5** kW/m^2	**4** kW/m^2	**12.5** kW/m^2	**37.5** kW/m^2	**2** psi	**3** psi	**5** psi	
	9	C3/C4 Splitter Overhead Receiver	Large Hole (50mm)	55	22	56.4	Liq	**2F**	117	142	113	96	-	-	-	156	144	135	-
								3.5B/C	115	133	103	86	-	-	-	151	141	133	-
	10	C3/C4 Splitter Bottom	Instrument Tapping Failure (20mm)	116	22.66	9.3	Liq	**2F**	34	61	48	41	-	-	-	45	41	38	-
								3.5B/C	31	58	44	37	-	-	-	44	40	38	-
HGU	1	Naphtha Surge Drum	Large Hole (50mm)	40	2.5	22.1	Liq	**2F**	142	122	94	76	75	36	-	226	204	187	-
								3.5B/C	109	114	86	69	81	37	-	147	135	126	-
	2	Naphtha Feed Pump	Instrument Tapping Failure (20mm)	40	45	15.0	Liq	**2F**	92	88	68	56	-	-	-	129	119	111	-
								3.5B/C	89	84	63	51	-	-	-	111	103	97	-
	3	H2 Recycle Gas Compressor	Instrument Tapping Failure (20mm)	99	38	0.6	Gas	**2F**	22	21	16	-	-	-	-	32	29	26	-
								3.5B/C	19	22	17	-	-	-	-	18	16	15	-
INDMAX GDS	1	SHU Reactor Feed Pumps - Toxic	Instrument Tapping Failure (20mm)	72	35	13.4	Liq	**2F**	92	82	63	52	-	-	-	129	119	111	Benzene - 59
								3.5B/C	86	79	59	47	-	-	-	110	103	96	Benzene -52
	2	SHU Feed Surge Drum - Toxic	Large Hole (50mm)	72	3	24.6	Liq	**2F**	150	123	93	76	74	35	-	227	205	187	Benzene -129
								3.5B/C	111	116	86	69	81	35	-	163	150	139	Benzene -92
	3	RGC	Instrument Tapping Failure (20mm)	88	25	0.6	Gas	**2F**	19	16	12	n/a	-	-	-	17	15	14	-
								3.5B/C	17	16	13	n/a	-	-	-	16	15	14	-
	4	LCN Splitter Reflux Drum	Large Hole (50mm)	55	5.6	31.0	Liq	**2F**	179	131	101	84	32	31	31	243	225	210	-
								3.5B/C	151	124	94	76	-	-	-	204	191	179	-
	5	LCN Splitter Reflux Pump	Instrument Tapping Failure (20mm)	55	13	7.5	Liq	**2F**	69	68	53	44	-	-	-	88	81	75	-
								3.5B/C	59	65	49	40	-	-	-	72	67	62	-
	6	LCN Product Pump	Instrument Tapping Failure (20mm)	102	16	8.2	Liq	**2F**	46	64	50	42	-	-	-	60	55	51	-
								3.5B/C	41	61	46	38	-	-	-	58	53	50	-
	7	HDS Feed Pumps - Toxic	Instrument Tapping Failure (20mm)	202	30	11.5	Liq	**2F**	55	70	54	44	-	-	-	74	68	63	Benzene -46
								3.5B/C	52	67	50	40	-	-	-	71	66	61	Benzene -39
	8	Hot Separator Bottom - Toxic	Large Hole (50mm)	190	16.1	54.3	Liq	**2F**	177	154	117	95	88	56	-	241	224	209	Benzene -65
								3.5B/C	185	144	107	85	98	61	-	242	226	213	Benzene -62
	9	Stabilizer Bottom Pump - Toxic	Instrument Tapping Failure (20mm)	224	20	9.1	Liq	**2F**	41	61	47	38	-	-	-	59	54	50	Benzene -33
								3.5B/C	38	58	43	35	-	-	-	46	42	39	Benzene -28
	10	MCN Splitter Bottom Pumps	Instrument Tapping Failure (20mm)	228	17	8.6	Liq	**2F**	41	60	46	38	-	-	-	59	54	50	-
								3.5B/C	38	57	43	34	-	-	-	46	42	39	-
	11	MCN Splitter Reflux Pumps - Toxic	Instrument Tapping Failure (20mm)	128	9	6.4	Liq	**2F**	45	58	45	38	-	-	-	60	55	51	Benzene -207
								3.5B/C	39	55	42	34	-	-	-	46	42	39	Benzene -157
	12	MCN Splitter Reflux Drum -Toxic	Large Hole (50mm)	128	4.5	28.5	Liq	**2F**	115	115	89	74	-	-	-	157	145	135	Benzene -479
								3.5B/C	117	109	83	67	-	-	-	150	140	132	Benzene -308
	13	Benzene Removal Column Bottom Pumps - Toxic	Seal Failure (6mm)	112	11.6	0.3	Liq	**2F**	16	20	16	13	25	16	7	18	16	14	Benzene - 52
								3.5B/C	9	18	14	12	25	17	8	-	-	-	Benzene - 33

Consequence Analysis Hazard Distances

Unit	Sl. No.	Equipment	Failure Case	Operating Conditions		Leak Rate (Kg/s)	State Liquid /Gas	Weather Condition	LFL (m)	Jet Fire (m)			Pool Fire (m)			Over Pressure (m)			IDLH Hazard Distance (m)
				Temp. (^{O}C)	Press. (Kg/cm^2g)					**4** kW/m^2	**12.5** kW/m^2	**37.5** kW/m^2	**4** kW/m^2	**12.5** kW/m^2	**37.5** kW/m^2	**2** psi	**3** psi	**5** psi	
LPG AMINE TREATING UNIT	1	DHDT LPG - Toxic	Instrument Tapping Failure (20mm)	40	23	0.8	Liq	**2F**	29	30	24	20	10	7	4	38	34	30	H2S- 72
								3.5B/C	21	28	22	18	-	-	-	32	29	26	H2S- 61
	2	Amine Settler Drum	Instrument Tapping Failure (20mm)	45	20	8.8	Liq	**2F**	51	67	53	44	-	-	-	72	67	62	-
								3.5B/C	46	64	49	40	-	-	-	59	54	50	-
LPG TREATING UNIT (TRAIN-I)	1	LPG Feed at B/L	Instrument Tapping Failure (20mm)	45	19	8.6	Liq	**2F**	51	67	52	44	-	-	-	72	66	62	-
								3.5B/C	46	63	48	40	-	-	-	59	54	50	-
	2	LPG Product	Instrument Tapping Failure (20mm)	45	16.5	8.1	Liq	**2F**	49	65	51	43	-	-	-	61	55	51	-
								3.5B/C	44	61	47	38	-	-	-	58	54	50	-
LPG TREATING UNIT (TRAIN-II)	1	LPG Feed at B/L	Instrument Tapping Failure (20mm)	40	18	8.3	Liq	**2F**	45	64	50	43		-	-	59	55	51	-
								3.5B/C	41	60	46	38	-	-	-	57	53	49	-
	2	LPG Product	Instrument Tapping Failure (20mm)	45	15.5	7.7	Liq	**2F**	41	61	48	41	-	-	-	58	54	50	-
								3.5B/C	37	57	44	37	-	-	-	45	41	38	-
FGTU	1	DHDT Sour Fuel Gas	Instrument Tapping Failure (20mm)	45	6.5	0.4	Gas	**2F**	5	9	7	-	-	-	-	-	-	-	H2S - 348
								3.5B/C	4	9	-	-	-	-	-	-	-	-	H2S - 205
OCTAMAX	1	C4 Mix Feed	Instrument Tapping Failure (20mm)	40	20	8.7	Liq	**2F**	58	70	55	46	-	-	-	74	68	63	-
								3.5B/C	51	66	51	41	-	-	-	71	65	61	-
	2	C4 Raffinate Pump	Instrument Tapping Failure (20mm)	51	17	8.4	Liq	**2F**	49	67	52	44	-	-	-	61	56	51	-
								3.5B/C	44	63	48	40	-	-	-	58	54	50	-
	3	Product Separator Reflux Drum	Large Hole (50mm)	51	5.1	29.0	Liq	**2F**	109	118	93	77	-	-	-	145	134	124	-
								3.5B/C	110	112	86	70	-	-	-	149	139	131	-
	4	Product Rundown Pump	Instrument Tapping Failure (20mm)	155	9	6.4	Liq	**2F**	78	62	48	39	51	32	22	100	92	86	-
								3.5B/C	58	59	44	35	53	36	23	72	66	62	-

Consequence Analysis Hazard Distances

Unit	Sl. No.	Equipment	Failure Case	Operating Conditions		Leak Rate (Kg/s)	State Liquid /Gas	Weather Condition	LFL (m)	Jet Fire (m)			Pool Fire (m)			Over Pressure (m)			IDLH Hazard Distance (m)	Remarks
				Temp. (^{O}C)	Press. (Kg/cm^2g)					4 kW/m^2	12.5 kW/m^2	37.5 kW/m^2	4 kW/m^2	12.5 kW/m^2	37.5 kW/m^2	2 psi	3 psi	5 psi		
OFFSITES	1	OCTMAX Feed Pumps	Instrument Tapping Failure (20mm)	Amb	19.3	9.0	Liq	2F	71	74	58	48	-	-	-	100	92	86		
								3.5B/C	63	70	53	43	-	-	-	84	78	73		
	2	Propylene Pumps	Instrument Tapping Failure (20mm)	Amb	28	10.3	Liq	2F	49	69	55	47	-	-	-	60	55	51		
								3.5B/C	46	65	50	42	-	-	-	58	54	50		
	3	Cracked LPG Pumps	Instrument Tapping Failure (20mm)	Amb	21.7	9.2	Liq	2F	54	69	54	46	-	-	-	73	67	62		
								3.5B/C	49	65	50	41	-	-	-	59	54	50		
	4	C3 mix Pumps	Instrument Tapping Failure (20mm)	40	19.4	8.5	Liq	2F	41	62	50	42	-	-	-	58	53	50		
								3.5B/C	38	58	45	38	-	-	-	45	41	38		
	5	Crude Oil Pumps	Instrument Tapping Failure (20mm)	Amb	4.1	5.3	Liq	2F	78	55	41	33	48	29	19	109	100	91		
								3.5B/C	57	53	38	30	47	33	19	73	67	63		
	6	Diesel Product Recirculation Pumps	Instrument Tapping Failure (20mm)	Amb	4	5.2	Liq	2F	12	11	8	7	58	30	-	12	12	11		
								3.5B/C	13	11	8	7	64	32	-	13	12	11		
	7	MS-VI Product Recirculation Pumps	Instrument Tapping Failure (20mm)	Amb	9.2	7.1	Liq	2F	100	68	52	43	-	-	-	151	139	128		
								3.5B/C	71	65	49	39	-	-	-	99	91	86		
	8	ATF Product Recirculation Pumps	Instrument Tapping Failure (20mm)	Amb	4.6	5.3	Liq	2F	20	46	35	29	60	31	-	30	28	26		
								3.5B/C	20	48	35	28	66	33	-	30	28	26		
	9	NHT Feed Pumps	Instrument Tapping Failure (20mm)	Amb	10.1	7.3	Liq	2F	101	69	53	44	-	-	-	151	138	128		
								3.5B/C	72	66	49	40	-	-	-	99	91	86		
	10	ISOM Feed Pump	Instrument Tapping Failure (20mm)	Amb	19.4	9.8	Liq	2F	112	78	60	50	-	-	-	157	145	135		
								3.5B/C	81	74	56	45	-	-	-	110	102	96		
	11	CCR Feed Pump	Instrument Tapping Failure (20mm)	Amb	19.3	10.3	Liq	2F	108	78	60	49	62	45	35	144	133	124		
								3.5B/C	83	74	56	45	-	-	-	111	103	97		
	12	Isomerate Pumps	Instrument Tapping Failure (20mm)	Amb	9.6	6.9	Liq	2F	99	69	53	44	-	-	-	139	127	117		
								3.5B/C	70	66	49	40	-	-	-	98	91	85		
	13	Reformate Pumps	Instrument Tapping Failure (20mm)	Amb	9.4	7.2	Liq	2F	100	69	53	43	-	-	-	151	138	128		
								3.5B/C	71	65	49	39	-	-	-	98	91	85		
	14	DHDT Feed Pumps	Instrument Tapping Failure (20mm)	Amb	9	7.7	Liq	2F	100	65	49	39	-	-	-	140	128	117		
								3.5B/C	70	62	45	36	-	-	-	99	91	86		

Consequence Analysis Hazard Distances

Unit	Sl. No.	Equipment	Failure Case	Operating Conditions		Leak Rate (Kg/s)	Weather Condition	LFL (m)	Jet Fire (m)			Pool Fire (m)				Over Pressure (m)			IDLH Hazard Distance (m)	Remarks
				Temp. (^{O}C)	Press. (Kg/cm^2g)				4 kW/m^2	8 kW/m^2	32 kW/m^2	4 kW/m^2	8 kW/m^2	12.5 kW/m2	32 kW/m^2	2 psi	3 psi	5 psi		
OFFSITES (TANK ON FIRE)	1	Crude Tank	Tank on Fire	Amb	Atm	-	2F	-	-	-	-	94	63	48	NR	-	-	-	-	
							3.5B/C	-	-	-	-	103	69	51	NR	-	-	-	-	
	2	NHT Feed Tank	Tank on Fire	Amb	Atm	-	2F	-	-	-	-	72	49	36	NR	-	-	-	-	
							3.5B/C	-	-	-	-	80	55	40	NR	-	-	-	-	
	3	Diesel Tank	Tank on Fire	Amb	Atm	-	2F	-	-	-	-	67	50	38	NR	-	-	-	-	
							3.5B/C	-	-	-	-	71	55	42	NR	-	-	-	-	
	4	MS Tank	Tank on Fire	40	Atm	-	2F	-	-	-	-	67	46	34	NR	-	-	-	-	
							3.5B/C	-	-	-	-	74	52	38	NR	-	-	-	-	
	5	DHDT Feed Tank	Tank on Fire	Amb	Atm	-	2F	-	-	-	-	59	43	32	NR	-	-	-	-	
							3.5B/C	-	-	-	-	64	49	36	NR	-	-	-	-	
	6	INDMAX Gasoline HDT Feed Tank	Tank on Fire	Amb	Atm	-	2F	-	-	-	-	59	41	31	NR	-	-	-	-	
							3.5B/C	-	-	-	-	64	47	35	NR	-	-	-	-	
	7	Isomerate Tank	Tank on Fire	Amb	Atm	-	2F	-	-	-	-	57	40	29	NR	-	-	-	-	
							3.5B/C	-	-	-	-	63	45	33	NR	-	-	-	-	

Consequence Analysis Hazard Distances

Unit	Sl. No.	Equipment	Failure Case	Operating Conditions		Leak Rate (Kg/s)	State Liquid /Gas	Weather Condition	LFL (m)	Jet Fire (m)			Pool Fire (m)			Over Pressure (m)			IDLH Hazard Distance (m)	Remarks
				Temp. (^{O}C)	Press. (Kg/cm^2g)					4 kW/m^2	12.5 kW/m^2	37.5 kW/m^2	4 kW/m^2	12.5 kW/m^2	37.5 kW/m^2	2 psi	3 psi	5 psi		
PIPELINE TERMINAL	1	LPG Pipeline Transfer Pumps	20mm Leak	Amb	19	8.7	Liq	2F	59	69	54	45	-	-	-	75	68	63	-	
								3.5B/C	52	65	50	41	-	-	-	71	66	61	-	
	2	MS (Regular/ Premium) PipelineTransfer Pumps	20mm Leak	Amb	10	7.4	Liq	2F	102	69	53	43	-	-	-	152	139	128	-	
								3.5B/C	72	66	49	39	-	-	-	99	92	86	-	
	3	ATF Pipeline Transfer Pumps	20mm Leak	Amb	10	7.8	Liq	2F	40	69	52	42	70	40	-	48	44	40	-	
								3.5B/C	46	65	49	39	78	46	-	60	55	51	-	
	4	Diesel Pipeline Transfer Pumps	20mm Leak	Amb	11	8.7	Liq	2F	22	20	15	12	77	45	-	26	25	23	-	
								3.5B/C	27	22	16	13	89	52	-	26	24	23	-	
	5	Naphtha Pipeline Transfer Pumps	20mm Leak	Amb	9	6.8	Liq	2F	97	68	53	43	-	-	-	139	127	117	-	
								3.5B/C	69	65	49	39	-	-	-	87	80	75	-	
	6	Propylene Pipeline Transfer Pumps	20mm Leak	Amb	26	9.9	Liq	2F	48	68	54	46	-	-	-	60	55	51	-	
								3.5B/C	45	64	50	41	-	-	-	58	54	50	-	
	7	MS Metering Station	50mm Leak	Amb	10	46.1	Liq	2F	251	157	120	97	97	56	-	357	327	303	-	
								3.5B/C	185	150	112	89	91	57	-	254	236	220	-	
	8	Crude Pipeline Receipt	20mm Leak	Amb	5	5.8	Liq	2F	85	57	43	34	41	30	19	126	115	105	-	
								3.5B/C	61	55	40	31	21	20	18	86	80	74	-	
	9	Crude Pipeline Receipt	50mm Leak	Amb	5	36.4	Liq	2F	212	131	96	76	72	39	-	321	291	266	-	
								3.5B/C	152	119	86	67	76	42	-	218	201	187	-	
Pipeline	1	LPG Pipeline	20mm Leak	Amb	19	8.7	Liq	2F	30	64	40	15	-	-	-	42	37	32	-	
								3.5B/C	23	63	38	23	-	-	-	40	35	31	-	
	2	LPG Pipeline	50mm Leak	Amb	19	54.5	Liq	2F	134	152	94	54	-	-	-	201	183	168	-	
								3.5B/C	52	148	90	59	-	-	-	99	87	77	-	
	3	MS Pipeline	20mm Leak	Amb	10	7.3	Liq	2F	95	60	37	18	-	-	-	147	133	121	-	
								3.5B/C	44	59	35	22	-	-	-	65	59	53	-	
	4	MS Pipeline	50mm Leak	Amb	10	45.9	Liq	2F	205	140	86	53	100	52	-	327	295	269	-	
								3.5B/C	159	137	84	55	63	41	30	234	213	196	-	
	5	Crude Pipeline	20mm Leak	Amb	7	6.9	Liq	2F	89	56	34	21	-	-	-	138	124	112	-	
								3.5B/C	47	53	33	21	-	-	-	66	60	54	-	
	6	Crude Pipeline	50mm Leak	Amb	7	43.1	Liq	2F	220	128	79	51	67	34	-	360	322	292	-	
								3.5B/C	149	108	66	42	-	-	-	224	203	186	-	
LFP	1	Crude Booster Pumps @ LFP	20mm Leak	Amb	7	6.9	Liq	2F	94	61	45	36	-	-	-	140	128	117	-	
								3.5B/C	66	58	42	33	-	-	-	87	81	75	-	
	2	Crude Booster Pumps @ LFP	50mm Leak	Amb	7	43.1	Liq	2F	250	137	101	80	-	-	-	386	350	319	-	
								3.5B/C	172	124	90	71	-	-	-	246	227	211	-	
Karaikal Port Terminal	1	LPG Pipeline	20mm Leak	Amb	15	7.8	Liq	2F	57	66	52	43	-	-	-	74	68	63	-	
								3.5B/C	49	63	48	39	-	-	-	60	55	51	-	
	2	LPG Pipeline	50mm Leak	Amb	15	48.5	Liq	2F	160	151	118	98	-	-	-	227	210	197	-	
								3.5B/C	173	143	109	89	-	-	-	227	213	201	-	
	3	MS Pipeline	20mm Leak	Amb	5	5.2	Liq	2F	83	61	47	39	49	32	21	124	113	104	-	
								3.5B/C	61	58	43	35	-	-	-	86	79	74	-	
	4	MS Pipeline	50mm Leak	Amb	5	32.4	Liq	2F	184	139	106	86	91	49	-	286	259	237	-	
								3.5B/C	140	132	98	78	96	49	-	186	172	161	-	