CHAPTER 7

RISK ANALYSIS STUDY

7.0 RISK ASSESSMENT

7.1 INTRODUCTION

The Risk Analysis study conducted at HPCL Hisar includes a description of the process, screening of dangerous goods, qualitative assessment and where required, subsequent quantitative risk assessment that reviews.

- Input/output materials receipt, storage and handling;
- Primary items of the process;
- To demonstrate the risks identified in the process area and to determine they are acceptable in relation to the surrounding land use
- That any residual risk will be appropriately managed and
- To advise risk reduction strategies where unacceptable risks are identified.

The primary objectives of a RA are to:-

- Identify potential hazards associated with the proposal;
- Analyze the consequences of significant hazards on people and the environment, and the likelihood or frequency of these hazards occurring;
- Estimate the resultant risk to the surrounding land uses and environment and
- Analyze the safeguards to ensure they are adequate, and therefore demonstrate that the operation can operate within acceptable risk levels to its surroundings.

7.2 METHODOLOGY

A Risk Analysis is to provide sufficient information and assessment of risks to show that a project satisfies the risk management requirements of the proponent company and the relevant public authorities. Within this brief, the main objective of the PHA is to show that the residual risk levels are acceptable in relation to the surrounding land use, and that risk will be appropriately managed. This is done by systematically:

- Identifying intrinsic hazards and abnormal operating conditions that could give rise to hazards

- Identifying the range of safeguards
- Assessing the risks by determining the probability (likelihood) and consequence (effects) of hazardous events for people, the surrounding land uses and environment and
- Identifying approaches to reduce the risks by elimination, minimization and/or incorporation of additional protective measures.

With proper application, this method should demonstrate that the plant can operate within acceptable risk levels in relation to its surroundings.

The RA needs to be carefully and clearly documented with the assumptions and uncertainties of final design and operation defined. The salient features of Risk Assessment study is summarized below:

Risk assessment is defined as a mathematical function of the probability and consequence of an incident. The target of risk assessment is to identify potential accidents, analyses the causation and evaluate the effects of the risk reduction measures. The following Table shows the various tools used as qualitative as well as quantitative in process safety design studies.

QUALITATIVE AND QUANTITATIVE TOOLS

Qualitative	Quantitative
Checklist	Fault tree analysis
Site survey	Event tree analysis
Site inspection	Probabilistic risk assessment
Safety audit	Quantitative risk assessment
Site observation	
HAZID	
HAZOP	

7.2.1 HAZARD IDENTIFICATION:

Hazard identification is the first key step in risk assessment study. Hazards are identified in the HPCL Hisar POL Depot, its inventories such as quantity used and its composition, operating temperature and pressure of the process, storage condition etc. Based on the nature of hazard and consequence, the significant scenarios are identified to carry out Risk Assessment study. The hazards identified for the RA is based on the previous QRA risk assessment.

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

The hazard assessment was based on the following methodologies

A) Inventory guidelines based on The Manufacture, Storage & Import of Hazardous Chemicals (Amendment) Rules, 2000 of the Environment (Protection) Act, 1986;
B) Past accident analysis;
C) Fire & Explosion indexing based on Dow's Hazard Classification Guide (7th edition)

7.2.2 SOURCE CHARACTERISTICS - HAZARD CLASSIFICATION BASED ON INHERENT HAZARDS

There are a number of properties that identify the hazard potential of a petroleum product. The properties show that while MS and ethanol are easily ignitable and will burn rapidly. However all petroleum products require interaction with air or oxygen and an ignition source for the hazard to be realized. Based on the properties and the definitions given in the MSIHC Schedule 1, Part 1(b), the hydrocarbons can be classified as follows.

- Motor Spirit as 'Extremely Flammable Liquid'
- High Speed Diesel 'Flamable Liquid'
- Ethanol as 'Very Highly Flammable Liquid'
- Super Kerosene Oil 'Flamable Liquid'

Table below summarizes the hazardous properties of products in storage.

Property	MS	Ethanol	HSD	SKO
Boiling Point (°C)	30-215	78	110 - 375	135 - 300
Flash Point (°C)	< - 10	16.6	>35	>35
Auto ignition Temperature (°C)	250-280	363	230-250	210
Lower Flammable Limit (%)	1.5	3.3	0.6	0.7
Upper Flammable Limit (%)	7.6	19	6	0.5

HPCL Hisar: Depot

Figure 7.1 - Ariel view of the Project Site

7.2.3 CREDIBLE ACCIDENT SOURCES/WORST CASE SCENARIOS - PAST ACCIDENT ANALYSIS.

The possibility of fire and/or explosion in hydrocarbon tank farms has been largely confirmed from accounts of past incidents. The lessons learnt from the major events will help in improving the standards of tank farm safety.

7.2.4 ANALYSIS OF TANK FIRES

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

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

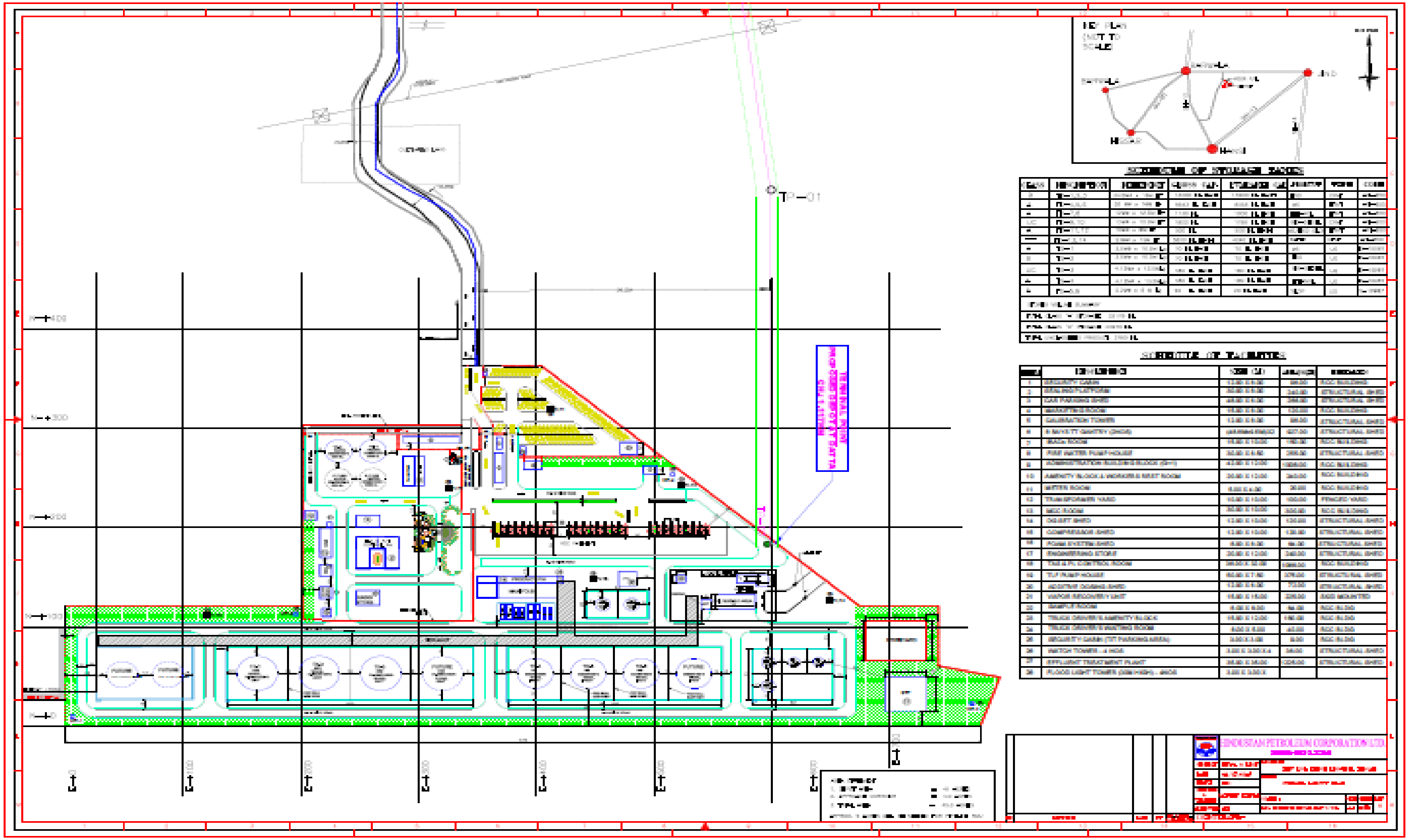


Figure 7.2: Proposed tank location at HPCL – Hisar

The details of storage tank facility:

The proposed tanks in this Depot are given in **Table 7.1**. The capacities of tanks, number of tanks and type of tanks areas given by Hindustan Corporation Limited and tanks are designed as per international codes:

Table7.1: HPCL – Hisar Tank Details

Class	Description	Gross Capacity	Product	Type
B	TK-,1,2,3	14,400 KL each	HSD	CRVT
A	TK-4,5,6	9,543 KL each	MS	IFRVT
A	TK- 7,8	1,130 KL	Ethanol	IFRVT
UC	TK-9, 10	1,800 KL	Bio Diesel	CRVT
A	TK- 11,12	500 KL	MS/HSD Slop	IFRVT
--	TK-13,14	5,800 KL each	Water	OTVT
A	TS-1	70 KL each	MS	UG
B	TS-2	70 KL each	HSD	UG
UC	TS-3	180 KL each	Bio Diesel	UG
A	TS-4	180 KL each	Ethanol	UG
A	TS-5,6	20 KL each	Slop	UG
Stored Volume Summary:				
Total Class A: **32,179KL**				
Total Class B: **43,270 KL**				
Total unclassified product: **3,780 KL**				

7.3 INPUT DATA

7.3.1 MATERIAL INVENTORY

Material required for the QRA study is provided by the client. The static and dynamic inventory is calculated based on the flow rate and equipment dimension provided by the client. The inventory details with respect to vessel and pipelines is given at Table7.1: HPCL – Hisar Tank **Details**.

Static Inventory:

Static inventory is the holdup volume within the isolatable section. The static inventory for piping, vessels and columns is calculated based on following formula.

a) Piping

The formula used for calculating the volume of material in the piping is [(πD2L)/4] m^3.

Where D is diameter in meter and L is length in meter.

Piping length is assumed based on Plot Plan of the respective facility with 10% margin.

b) Vessels:

The formula used for calculating the volume of vessels is [(πD2H)/4] m^3.

Where D is diameter of vessel/column and H is the height of vessel.

Separate Liquid and Gas hold up volume shall be calculated for the vessels as applicable based on equipment datasheets.

7.3.2 PROCESS CONDITIONS

The initial step is the identification of fuel sources and their location. This is then followed by assessing information relating to the fuel itself, and the inventories stored or processed, together with the process conditions.

7.3.3 MATERIAL COMPOSITION

Material required for the QRA study is taken from the data provided by the client for most of the cases.

7.3.4 WEATHER

Meteorological data are required at two stages of the QRA. First, various parts of the consequence modelling require specification of wind speed and atmospheric stability.

Second, the impact (risk) calculations require wind-rose frequencies for each combination of wind speed and stability class used.

Data on the wind speed and stability category have been obtained from the client and this will be used for this particular QRA study. There are two different weather classes for

Day and Night which are listed below:

Day Weather Class

- D3 : D stability (neutral) and 3 m/s wind speed.
- B2 : B stability (neutral) and 2 m/s wind speed.

Night Weather Class

- D3 : D stability (neutral) and 3 m/s wind speed.
- F2 : F stability (very stable) and 2 m/s wind speed.

This distribution is combined with the wind rose information to generate likelihood for the wind to be from a particular direction and of a specified speed and stability. Referring to the same study, the following meteorological parameters will be applied:

An average ambient condition as follow is used in the study:

- Atmospheric temperature : 25-35°C
- Surface temperature : 25-35°C
- Humidity : 70%
- Solar radiation flux : 0.5kw/m^2 for day and 0kw/m^2 for night

7.3.5 IGNITION SOURCES

In order to calculate the risk from flammable materials, information on the ignition sources (which are present in the area over which a flammable cloud may drift) is required.

In order to calculate the risk from flammable materials, information on the ignition sources (which are present in the area over which a flammable cloud may drift) is required. For each ignition source considered, the following factors need to be specified:

- Presence Factor
- This is the probability that an ignition source is active at a particular location.
- Ignition Factor

- This defines the "strength" of an ignition source. It is derived from the probability that a source will ignite a cloud if the cloud is present over the source for a particular length of time.
- Location

The location of each ignition source must be specified on the site layout. This allows the position of the source relative to the location of each release to be calculated. The results of the dispersion calculations for each flammable release are then used to determine the size and mass of the cloud when it reaches the source of ignition.

If these factors are known for each source of ignition considered, then the probability of a flammable cloud being ignited as it moves downwind over the sources can be calculated. Ignition sources in a QRA study may be of 3 types:

- Point sources: Known specific sources such as flares, workshops, etc.
- Line sources: Roads, railways, electrical transmission lines.
- Area sources: Population, industrial sites where location of specific ignition sources is unknown.

As per the Assumption, the following was considered for the storage tanks

Table 7.2: Release Sizes: Tanks

Release Category	Hole Size (mm)
Small	5
Medium	25
Large	100
Catastrophic Rupture	-

7.3.6 RELEASE HEIGHT

In order to determine the impact distance of released fluid, the height of release from the isolatable section is considered as 1 m.

7.3.7 RELEASE DIRECTION

The direction of fluid release from the isolatable section is considered as horizontal.

7.3.8 RELEASE DURATION

In this study, the maximum release duration is considered as 30 minutes (1800 seconds); however, the release duration shall primarily be governed by the inventory of the isolatable section.

7.3.9 FREQUENCY ANALYSIS

The frequency of occurrence of an event is based on the probability of the scenario and the presence of constraints that influence the development of the event.

In this chapter the frequency of occurrence for each isolatable scenario is derived. Ignition characteristic and ignition probabilities are also discussed.

7.3.10 MODES OF FAILURE

In case of leakage/ rupture in the process equipment or piping, flammable or toxic substances may be released into the atmosphere. This can occur in the form of a small gasket failure in a flanged joint, a bleeding valve or inadvertently left open valves, failure of a piping, corrosion, or any other external factors.

7.3.11 FAILURE FREQUENCY

The frequency of occurrence of an event is based on the probability of an LOC scenario and the presence of constraints that influence the development of the event (e.g. sources of ignition). Failure frequency and hole size probability for all the scenarios was derived from the OGP risk assessment data base.

7.3.12 BASE FAILURE FREQUENCY

The failure frequencies as a function of release sizes for the scenarios are derived from the international database such as International Association of Oil & Gas Producers (IOGP).

Failure frequency databases describe the generic frequencies at which a leak from equipment can happen. Frequencies for different sizes of leak can be obtained from the database. Risk can be calculated by combining the leak frequency information obtained from international databases given below with the consequence.

Full Release:

Release is consistent with flow through the defined hole, beginning at the normal operating pressure, and continuing until controlled by emergency shut-down and blow down (if present and operable) or inventory exhaustion.

7.3.13 TOTAL FAILURE FREQUENCY

The total failure frequencies for isolatable sections are calculated by combining the total number of piping components and equipment obtained from the parts count approach and the base failure frequency.

7.3.14IGNITION PROBABILITY

The probability of ignition is also very dependent on the release rate. A small vapor release into open air is unlikely to ignite since it would be readily dispersed and diluted to below its Lower Flammability Limit (LFL). It will only ignite if there is an ignition source within the flammable region local to the release, which is unlikely in a hazardous area which has appropriately rated electrical equipment. Conversely, larger releases can rapidly form large flammable vapor clouds, which can envelope ignition sources remote from the leak source.

The probability of immediate ignition is an important input parameter within the QRA study. Immediate ignition of the released vapor cloud results in a jet fire / flash fire. The calculation is based on the strength, location and presence factor of all ignition sources specified, and the extent and duration of dispersing vapor clouds being exposed to those sources. Delayed ignition sources can be modeled as point sources (e.g. ground flares), line sources (power lines) or area sources (e.g. to cater for “background” sources posed by a variety of human activity).

The total ignition probability is portioned equally to immediate and delayed ignition. Immediate ignition probabilities are derived from the Guideline to Quantitative risk assessment (PGS 3) and OGP Risk Assessment Directory (434-6).

7.3.14POPULATION

A representative estimate of the exposed populations is sufficient to determine the acceptability of societal risks by determining the order of magnitude of potential fatalities within a population group. The basis of the population assigned to the facility will be based on the data given by HPCL Hisar Terminal. Further analysis of the population will be conducted in order to define various factors associated with the population presence, e.g. day/night variation, fraction of time spent indoor etc.

7.4 MODELLING SCENARIOS

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

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

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

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

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

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

1. Jet Fire
2. Pool Fire
3. Flash Fire

7.4.1 JET FIRE

A jet fire is a turbulent diffusion flame resulting from the combustion of material continuously released with some significant momentum. Jet fires can arise from releases of gases, flashing liquids (two phase) and pure liquid inventories. The high heat fluxes generated can impinge or engulf, and lead to structural failure or pipe work failure and possible further escalation.

7.4.2 FLASH FIRE

If the flammable material released from an isolatable section is not ignited, it may evaporate. The released vapor spreads out in the direction of the wind. If the cloud is released in an open space in absence of significant confinement or obstruction and ignites before being dispersed below the lower flammability limit (LFL) of the flammable material, a flash fire is likely to occur. It is assumed that all persons present in an ignited flammable cloud are lethally injured. Outside the flash fire envelope, no fatal injuries are to be expected.

7.4.3 VAPOUR CLOUD EXPLOSION

A vapour cloud explosion results from the ignition of a flammable mixture of vapour in which flame accelerates to sufficiently high velocities to produce significant overpressure. An explosion may occur when a large amount of flammable material is released in a space with significant confinement or obstruction and is ignited before being dispersed below the lower flammability limit (LFL). The blast wave following these incidents can be fatal.

The main types of explosions are:

- Confined explosions where the cloud is largely confined;
- Unconfined explosions where the cloud is largely unconfined.

For this study, TNT explosion method is applied for conducting the explosion modelling.

Below figure gives a graphic representation of the development of the various potential consequences, subsequent to release.

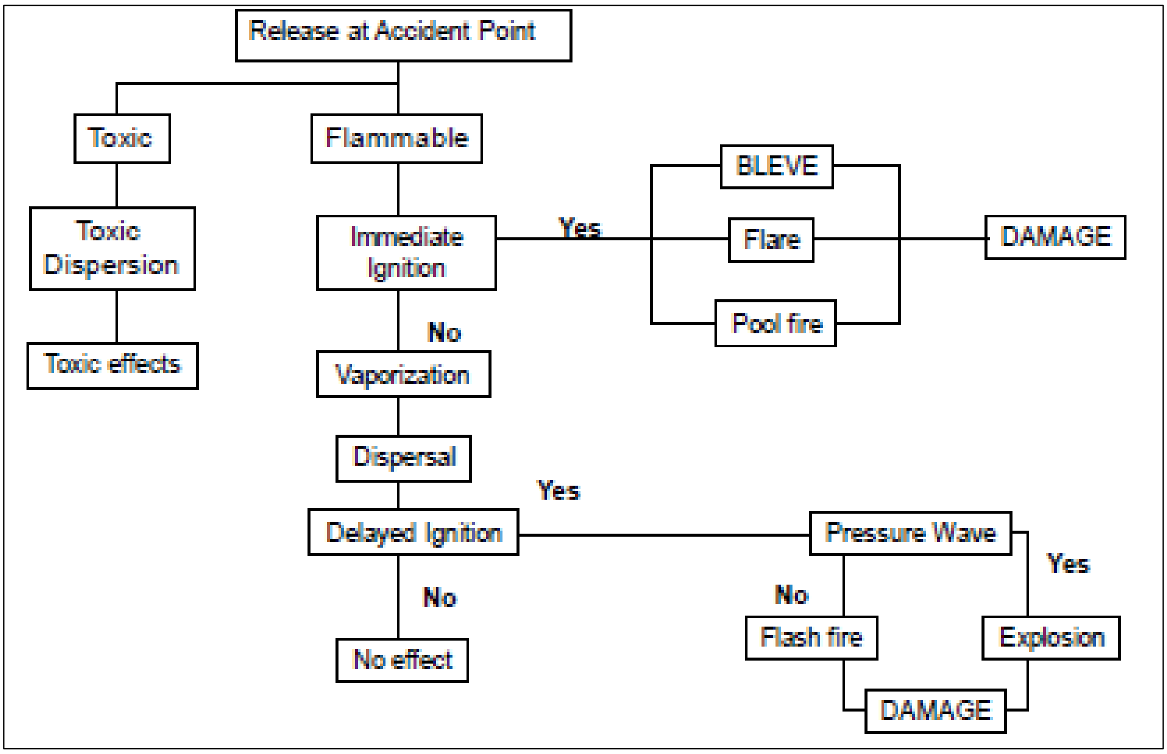


Figure 7.3 : Evolution of Effects following release of Hazardous Material

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

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

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

Dense dispersion model was used to calculate the extent of dispersion up to lower flammable limits (LFL). The amount in the flammable limits was considered for calculation of pressure effects. Fire damage estimates are based upon correlation with recorded incident radiation flux and damage levels.

7.4.4 DAMAGE CRITERIA FOR HEAT RADIATION EFFECTS

The damage criteria give the relation between extent of the physical effects (exposure) and the percentage of the people that are killed or injured due to those effects. Thermal radiation effects are used as damage criteria for fires. Damage criteria are given and explained for heat radiation

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

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

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

Table7.3: Effects due to Incident Radiation Intensity

Incident Radiation (kW/m^2)	Type of Damage
0.7	Equivalent to Solar Radiation
1.6	No discomfort for long exposure
4.0	Sufficient to cause pain within 20 secs. Blistering of skin (first degree burns are likely) Minimum distance for fire man to operate
9.5	Pain threshold reached after 8 sec, second degree burns after 20 sec.

12.5	Minimum energy required for piloted ignition of wood, melting of plastic tubing, etc.,1% fatality for exposure above 60 secs
37.5	Sufficient to cause damage to process equipment99% fatality for exposure above 60 secs

7.4.5 DAMAGE CRITERIA FOR OVERPRESSURE EFFECTS

Explosion damage is estimated based on recorded peak overpressures and corresponding potential damage effects. A Vapour Cloud Explosion [VCE] is a deflagration accompanied by a blast effect that occurs in the open air as a consequence of the ignition of a cloud containing flammable vapour. The estimate of the likely maximum value of overpressure that may be generated in a VCE is of considerable importance for the consequence analysis. If no immediate ignition of a released material occurs, it can disperse into the atmosphere. Following ignition, the vapour cloud will start to burn. It is assumed that fatality will be 100% in the projected area of the vapour cloud.

The factors that affect VCEs are:

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

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

Table7.4: The Damage Criteria Used To Assess Explosion Scenario

Over pressure (bar)	Type of damage
0.30	Heavy; 50% fatality
0.20 to 0.27	Rupture of Oil storage tanks
0.20	Steel frame constructions distorted and pulled away from foundations; Serious injuries are common, fatalities may

	occur
0.10	Repairable; People injured by flying glass and debris
0.03	Large & small windows usually shattered
0.02	10% window glass broken
0.01	Crack of windows

7.5 CONSEQUENCE RESULTS

The consequence results which show the extent of flammable/ toxic gas dispersion, jet fire/ pool fire radiation and explosion overpressure for weather conditions of 2F and 5D are provided. Quantification provides an estimate of the damage potential for each individual scenario. The damage is expressed in terms of the area involved.

7.6 RISK ASSESSMENT

Risk analysis was performed by summing the results of the frequency analysis and consequence analysis with the defined occupancy and derived ignition source in the PHAST software. The risk evaluation was carried out using the available population information and the major hazard events identified. PHAST determines the vulnerability to people inside and outside buildings by combining an equivalent injury / fatality for the consequence results defined with the calculated leak frequencies.

The outcome of the risk analysis is presented as

- Location Specific Individual risk (LSIR)
- Societal Risk (F-N curve)

7.6.1 VULNERABILITY CRITERIA

Vulnerability is the relative probability of fatality in the event of exposure to a hazardous substance. The following indoor / outdoor vulnerabilities are considered for this Risk Assessment study

Table 7.5: Indoor / Outdoor **Vulnerabilities** represents the Indoor / Outdoor vulnerabilities shall be used:

Table 7.5: Indoor / Outdoor Vulnerabilities

Hazard	Impact Level	Vulnerability	
		Outdoor	Indoor
Jet Fire	Radiation (>37.5 kW/m^2)	0.9	0.1
Flash Fire	100 % LEL	0.9	0.05
Fire Ball	Radiation (>37.5 kW/m^2)	0.9	0.1
Over Pressure	Light Explosion (< 250 mbar)	0	0.1
	Heavy Explosion (> 250 mbar)	0.3	1
Toxic	Exposure	0.9	0.1

7.7 LOCATION SPECIFIC INDIVIDUAL RISK (LSIR)

Location Specific Individual Risk (LSIR) is a commonly used risk assessment tool and is defined as the frequency per year at which an individual, who stays unprotected for 24 hours per day and 365 days per year at specific location, is expected to sustain fatal harm due to exposure to hazards induced by the project facility. This makes the LSIR a measure of the geographic distribution of risk, independent of the distribution of people at that location or in the surrounding area. The LSIR is presented as iso-risk contours on a map of the location of interest.

Risk criteria are required to promote consistency in evaluating the results of relevant studies and to formulate a proactive approach to incident prevention. It helps to decide whether risk associated with the project / activity / facility is low enough to proceed. It provides standards to translate the numerical values of risk from a QRA study into value judgement such as “negligible risk “in decision making process.

LSIR (Location Specific Individual Risk) = ∑ Frequency x Occupancy x Vulnerability

- Total Risk = The sum of contributions from all the hazards exposed to.
- Occupancy = The proportion of time exposed to hazards.
- Vulnerability = The probability that exposure to the hazard will result in fatality

Risk criteria for Individual Risk for on-site are as follows:

- Individual risk levels above 1 x 10-3 per year will be considered unacceptable and will be reduced, irrespective of cost
- Individual risk levels below 1 x 10-6 per year will be broadly acceptable
- Risk levels between 1 x 10-3 and 1 x 10-6 per year will be reduced to levels as low as reasonably practicable (ALARP). That is the risk within this region is tolerable only of further risk reduction is considered impracticable because the cost required to reduce the risk is grossly disproportionate to the improved gained.

7.8 SOCIETAL RISK

When considering the risk associated with a major hazard facility, the risk to an individual is not always an adequate measure of total risks; the number of the individuals at risk is also important. Catastrophic incidents with the potential multiple fatalities have a little influence on the level of risk but have a disproportionate effect on the response of society and impact of company reputation.

The concept of societal risk is much more than that for individual risk. A number of factors are involved which make it difficult to determine single value criteria for application to a number of different situations. These factors include;

- The hazard, the consequential risks and the consequential benefits
- The nature of assessment
- Factors of importance to the company, government, regulators and authorities, public attitudes and perception and aversion to major accident

Societal risk is the relationship between frequency of an event and the number of people affected. Societal risk from a major hazard facility can thus be expressed as the relationship between the number of potential fatalities N following a major accident and frequency F at which N fatalities are predicated to occur. The relationship between F and N, and the corresponding relationship involving F, the cumulative frequency of events causing N or more fatalities, are usually presented graphically on log-log axis.

In conjunction with the previous studies performed for the plant has used following societal risk criteria. Societal risk should not be confused as being the risk to society or the risk as being perceived by society. The word “societal” is merely used to indicate a group of people and societal risk refers to the frequency of multiple fatality incidents, which includes workers and the public. Societal risk is usually represented by an FN (Frequency – Number of Fatality) curve.

Societal risk is generally used to describe multiple injury accidents/fatalities, or to describe risks to “unnamed‘ individuals, which could include the public and is usually described by F-N Curves (Frequency vs. Fatalities listed in increasing order of magnitude where F denotes the Frequency of N fatalities or more per year; and N denotes the Number of fatalities).

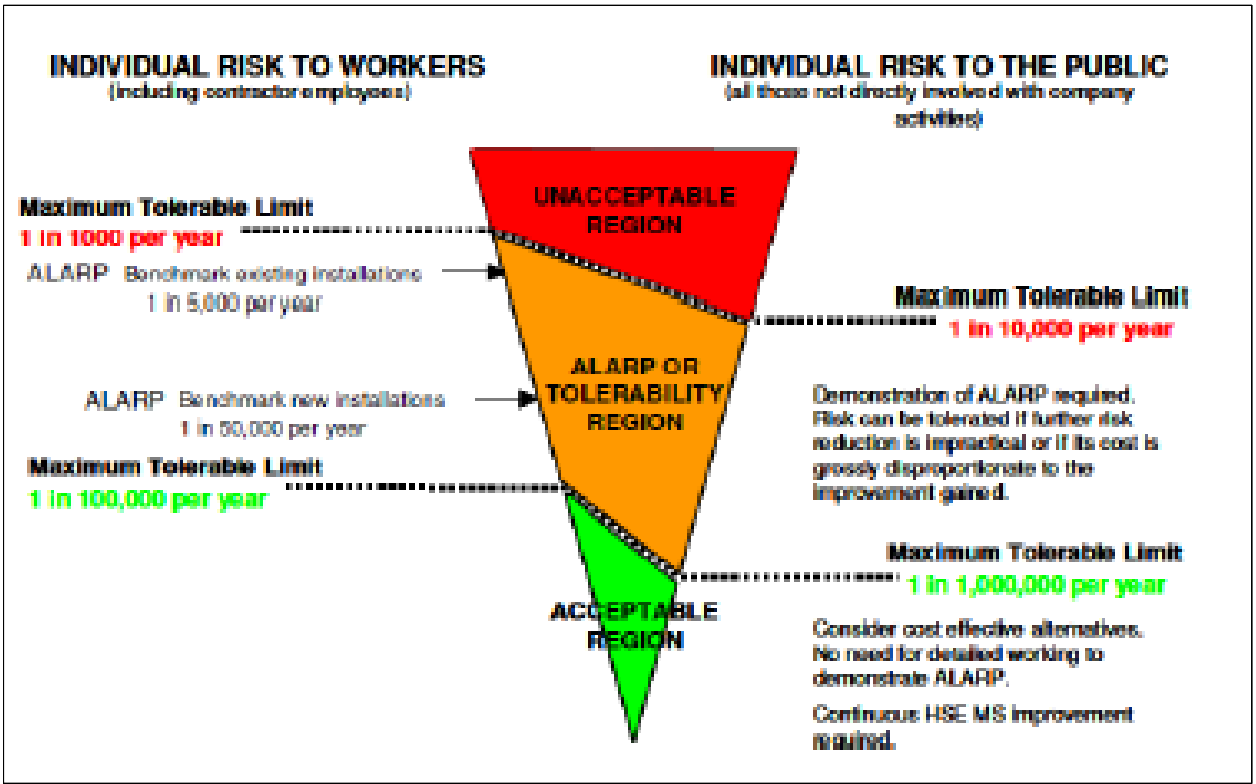


Figure 7.4: Risk Tolerability Criteria for Individual Risk to Workers and Public

Societal Risk:

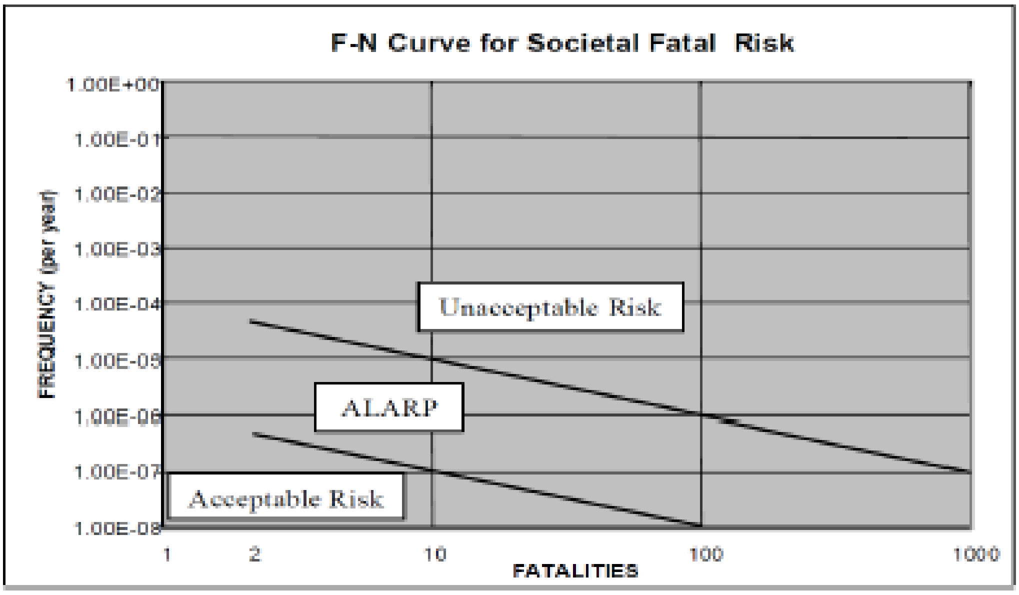


Figure 7.5: F-N Curve for societal risk

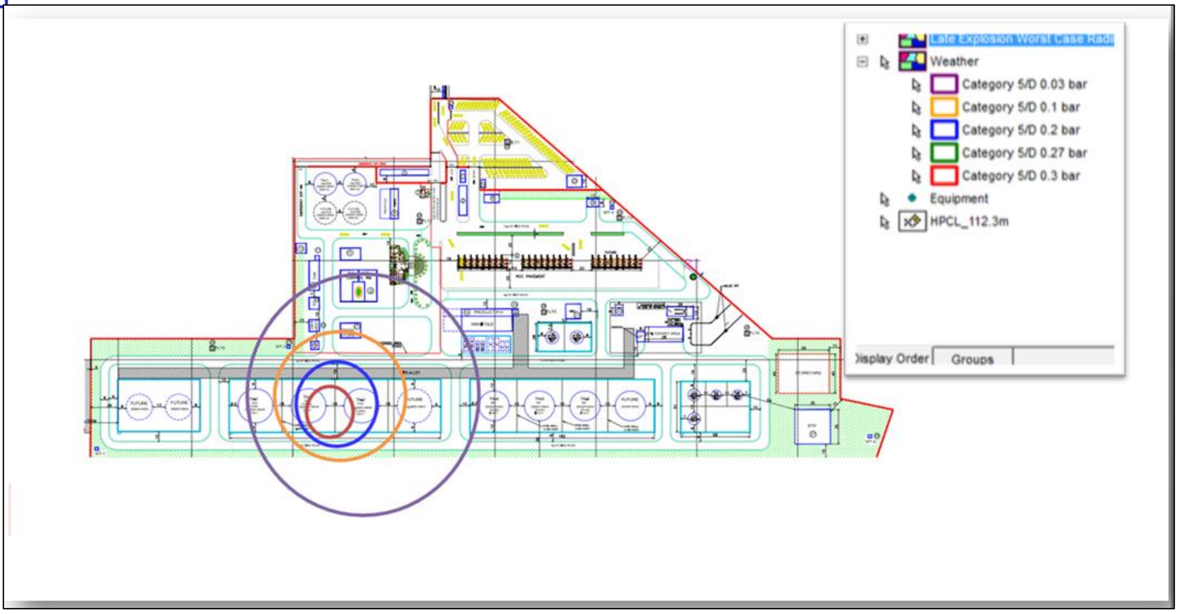
Table7.6: Societal Risk Criteria – Onsite

Maximum Tolerable Intercept With N=1	Negligible Intercept With N=1
10^{-2}	10^{-4}

Table7.7: Societal Risk Criteria – Offsite

Maximum Tolerable Intercept With N=1	Negligible Intercept With N=1
10^{-3}	10^{-5}

The damage locations plotted have been shown below



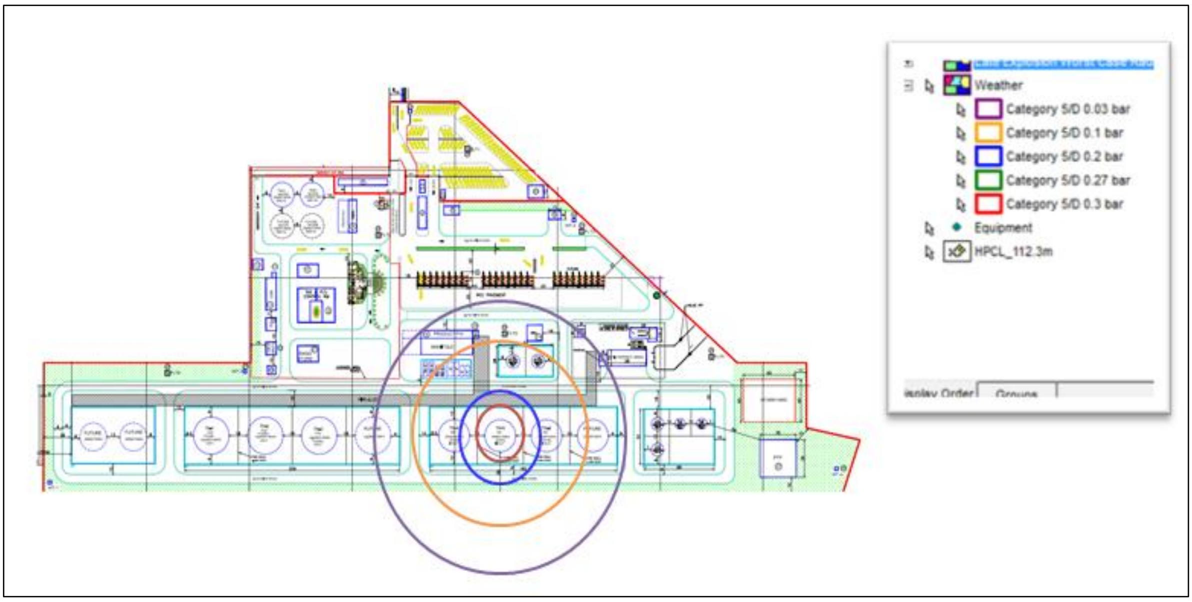


Figure7.6: Pressure Contour of the worst case criteria of an explosion

7.9 RISK RESULTS

Location Specific Individual Risk (LSIR) is a commonly used risk assessment tool and is defined as the frequency per year at which an individual, who stays unprotected for 24 hours per day and 365 days per year at specific location, is expected to sustain fatal harm due to exposure to hazards induced by the project facility. From the LSIR value, the

Individual Risk Per Annum (IRPA) to the personnel based on their exposure within the project facility

The following risk acceptance criteria shall be used

Individual Risk (IR)

- Broadly acceptable risk 10-6 per year
- Upper region of tolerability 10-3 per year for workers
- ALARP region 10-3 to 10-6 per year (for workers)

7.9.1 INDIVIDUAL RISK

The LSIR represents the risk at a specific location without taking into account the distribution of people into account, whereas the Individual Risk (IR) value, sometimes referred to as the "person-specific individual risk", incorporates the movement of a given individual.

In summary, the following criteria for Individual Risk per Annum are used in this RISK ASSESSMENT:

- Broadly acceptable risk 10-6 per year
- Upper region of tolerability 10-3 per year
- ALARP region 10-3 to10-6 per year

7.9.2 HPCL HISAR FACILITY LSIR AND SOCIETAL RISK

The risk assessment model has been considered for Tank Farm area, Drivers rest room, office building security room, Based the Risk Assessment both in plant and societal risk are under acceptable zone and no significant risk is expected to the Datta village.

7.10 POTENTIAL FOR SECONDARY/ CASCADE EVENTS

The potential for occurrence of secondary or cascade effects was also identified. Secondary events that were identified within the depot. The occurrence of the worst case scenario of explosion within the depot is less likely to occur and if it were to occur the damages is likely to be localized within the facility.

7.11 RISK REDUCTION MEASURES

Risk Assessment study provides a quantitative technique for assessing the significance of the impact of any facility on its external environment, highlights key areas for greater attention and provides a tool for comparing alternative options. Though, it cannot substitute for close attention to the fundamentals of safety throughout the design process or for design reviews.

For risk reduction, attempts should be made to either reduce inventories that could get released in the event of loss of containment or failure likelihood or both as far as feasible. Risk Assessment identifies the dominant risk contributors, which enables prioritisation of plants/section that deserve special attention in terms of inspection and maintenance in particular and over all safety management as a whole.

7.12 RISK MITIGATION MEASURES

The proposed project activity comes under Manufacture, Storage, Import of Hazardous Chemicals. Rule, 1989 and subsequent amendments. During design, construction and operation of the proposed facilities, numbers of safety provisions and risk reduction measures will need to be implemented and followed meticulously in compliance with applicable acts, rules, regulations, codes, standards, guidelines and best industry practices. This also includes provisions of not only state-of-the-art equipment, control and instrumentation to enhance safety but also high level induction and refresher safety trainings from senior management to contractual workers levels at the facilities.

Risk mitigation measures for the proposed installation of HPCL POL Depot are described below:

The underground storage tanks has proved to be safer as compared to above ground storage vessels since it provides intrinsically passive and safe environment and eliminates the possibility of Boiling Liquid Expanding Vapour Explosion (BLEVE). The cover of the sand protects the vessel from fire engulfment, radiation from a fire in close proximity and acts of sabotage or vandalism.

i. Any change in the system will be marked on P&ID. The system of "Management of Changes" may be developed as per "Guidelines on Management of Change" (OISD GDN 178).

ii. Any repairs or modifications should be undertaken after statutory approval from applicable authority.

iii. Each storage Tank shall have minimum two different types of level indicators.

iv. Audio-visual indication shall be at local panel and control room.

v. Automatic fire detection and /or protection (Fixed) system based on heat detection through thermal fuses/ quartz bulbs shall be employed. Sensors shall be installed at all critical places.

vi. Hydrant and monitor coverage shall also be provided on all four sides of the Tank Farm for adequate coverage of unprotected portions exposed to thermal radiation including for top of the Tank and for piping, in the immediate vicinity of the Tank.

vii. Hydrant /monitors shall be located at a safe place around the Tank Farm. In any case fire hydrant and/or monitors shall not be installed within 15 meters from the facilities/equipment to be protected.

7.12.1 MAINTENANCE SCHEDULES

The proper preventive maintenance schedule should be prepared to facilitate the maintenance service to be rendered in a planned manner covering the necessary work to be done, mentioning the periodicity *i.e.* daily, weekly, monthly, half yearly and yearly schedules.

7.12.2 ELECTRICAL HAZARDS

Some Important measures to minimise electrical hazards are as given below:

- Inspection of electrical equipment shall be carried out as per OISD Standards 137.
- All electrical equipment's shall be provided with proper earthing.
- Earth pits shall be periodically tested and maintained in good condition.
- Emergency lighting shall be available at all critical locations including fire pump room, control room, etc.
- All electrical equipment shall be free from carbon dust, oil deposits, and grease.
- All electrical cable will be tagged for easy identification and cable routing shall be planned away from heat sources, water, oil, drain piping and air conditioning ducts.
- Provisions shall be made for approved insulated tools, rubber mats, shock proof gloves and boots, tester, fuse tongs, discharge rod, hand lamp, insulated ladder.
- Flame and shock detectors and central fire announcement system for fire safety shall be provided in MCC control panel room.
- Temperature sensitive alarm and protective relays to make alert and disconnect equipment before overheating shall be provided.
- Danger from excess current due to overload or short circuit should be prevented by providing fuses, circuit breakers, thermal protection, etc.
- Only carbon dioxide and dry chemical fire extinguishers shall be used for electrical fires.

7.12.3 FIRE FIGHTING FACILITIES

Fire protection system shall be designed in accordance with the requirements of OISD, NFPA standards, design requirements and safe engineering practices. Fire-fighting facilities should have full capability for early detection and suppression of fire. The fire-fighting system will primarily consist of:

- Hydrant system
- Foam protection system

- Sprinkler system
- Portable fire extinguisher
- Fire detection and alarm system

Presently, fire-fighting facilities are available at HPCL Depot. After commissioning of proposed tank, fire-fighting facilities should be augmented as per relevant OISD/NFPA/TAC Standards. Fire water requirement and fire water storage shall be evaluated for two fires for 4 hours at any point of time in the terminal.

The following facilities will be made available in the plant:

- Water storage capacity = 5800 KL x 2 Nos
- Fire water pumps = 6Nos (main 4x 650 kl/hr& standby 2 x 650 kl /hr)
- Jockey pumps - 3 Nos (main 2x 65 kl/hr& standby 1 x 65 kl /hr)
- Hydrant Points (Double Head), Water Monitors, Sprinklers are installed for the proposed project.

Medium Velocity Water Sprinkler System:

The system has been provided on all product tanks and other operating areas, wherever required as per OISD regulations, and considered to be a very effective cooling system for preventing spread of fire.

Proposed Public Addressing System

This is an intrinsically safe, internal communication system which facilitates internal communication as well as public address.

Intercom

This Intercom connected to P & T line can be used for communication internally and externally at Main Office.

OCCUPATIONAL HEALTH, SAFETY & ENVIRONMENTAL FEATURES IN THE PROJECT

Process Safety & Safety Features

Process Safety focuses on the prevention of fires, explosions and accidental chemical releases at HPCL Depot.

Proposed Safety Management Systems

The Safety Officer in co-ordination with Shift-in-Charge review all plant operations to identify potential unsafe conditions and / or potential problems which may lead to health or safety exposures.

Plant personnel shall work with the Safety Officer to identify potential problems and to identify proper operational procedures and the operational areas of the plant. Actions to be taken include equipment or procedural changes, development of exposure monitoring strategies, and inclusion of warning statements in procedures.

Hazard Analysis by the Team

QRA studies are conducted at plant before commissioning and also applied to the proposed installation and modification of buildings, equipment, mechanical and electrical systems, utilities, fire protection system, grounds etc. Plans or specifications on designated projects shall be submitted to an acceptance committee consisting of Operations Manager, Engineering. Manager, Safety Manager for review prior to project implementation. Recommendations will be submitted with the final plans and specifications to the Departmental head for review. If the departmental head finds that plans and specifications are not meeting the recommendations of the acceptance committee, he shall return the final plans to the originator for modifications or a justification of deviations.

Inspections

The officer in charge of each function is responsible for ensuring the timely completion of periodic inspections and correction of problems.

The frequency of specific inspections is as follows:

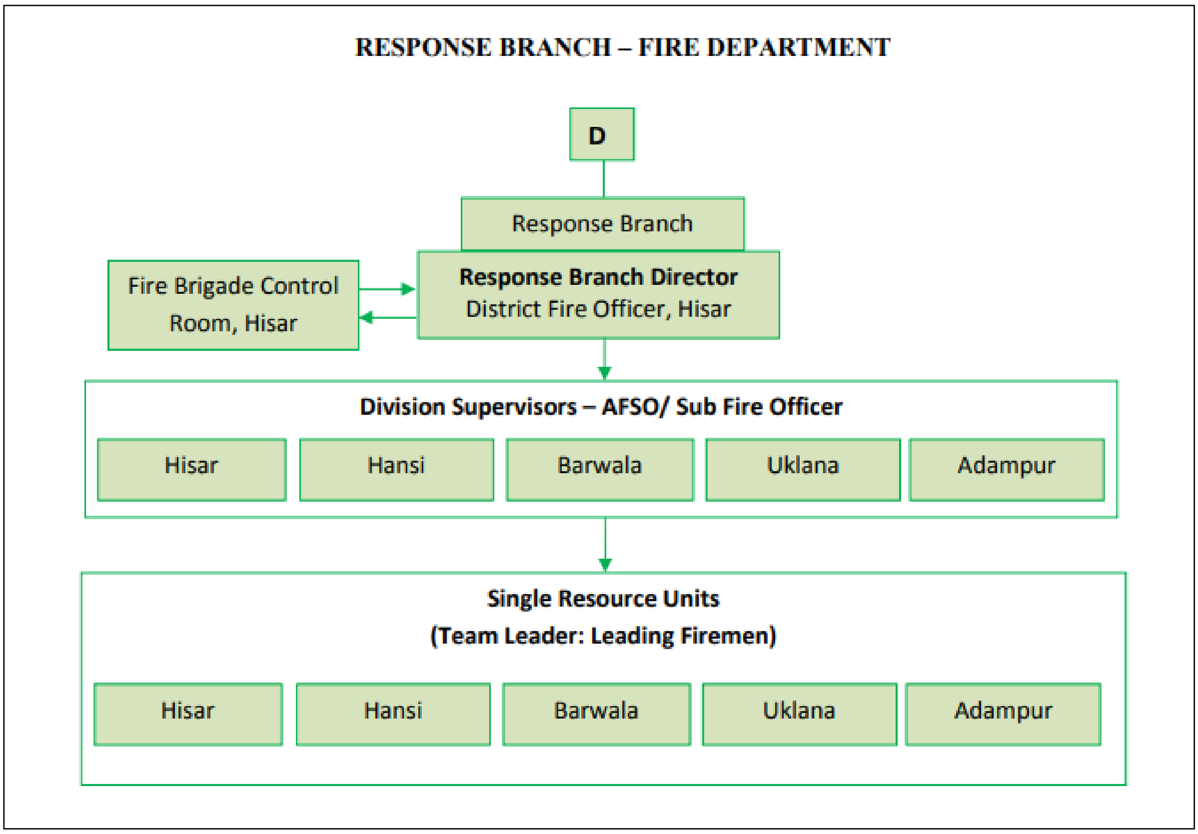
Safety Facilities in the Plant

- HC detection, prevention
- Elimination of source of ignition
- Fire prevention / fighting
- Communication, First aid, Rescue and Personnel protection equipment.

The facilities are detailed in the ERDMP Report.

7.12.4 EMERGENCY RESPONSE PLAN

Anticipating and planning for various contingencies is crucial for ensuring the success of any emergency response actions in an actual Emergency Situation. On-site Emergency response plan shall be prepared for HPCL Hisar, to take the action in an unlikely event of emergency due to accidents. Emergency Response Plan should be updated based on findings of mock drills.



7.12.5 MOCK DRILL EXERCISES

Mock drill should be conducted once in six months. Exercises or drills have two basic functions, namely training and testing. While exercises do provide an effective means of training in response procedures, their primary purpose is to test the adequacy of the emergency management system and to ensure that all response elements are fully capable of managing an unlikely emergency situation.

Mock drills are best means of accomplishing the following goals and objectives:

- To reveal weaknesses in the plans and procedures before emergencies occur.
- To identify deficiencies in resources (both in manpower and equipment).
- To improve the level of co-ordination among various response personnel, departments and agencies.
- To clarify each individual's role and areas of responsibility.

7.13 CONCLUSIONS AND RECOMMENDATIONS

Based on the QRA study for the Hisar Depot, the following conclusions and recommendations can be drawn:

- The workers within the HPCL – Hisar facility experience Individual Risk of per Annum below the ALARP Region of 1.99E-04 per year which comes under ALARP region.
- Risk level of 1x10-6 is found to be inside or close to facility boundary and impact on the village of Datta is found to be in ALARP region.
- Even though the Individual and societal risk levels of the Hisar IRD has been found to be in ALARP or in Acceptable region in assessing with HSE UK risk criteria, In order to maintain the level of risk at this level, it is recommended that all safety measures shall be taken and checked through for its effectiveness.

7.13.1 RECOMMENDATION

- Following fire protection facilities tobe provided in the installation:-
  - ✓ Fire Water System -storage tanks / pumps / distribution piping network along with hydrant and monitors with at least 15 m distance from tank shell.
  - ✓ Fixed Spray System to be provided for class A and class B petroleum product Tank no's. 1, 2,3,4,5,6,7,8, 11, and 12 for cooling and prevention of fire on the surrounding tanks in line OISD 244.
  - ✓ Foam System to be provided for tank no's 1, 2,3,4,5 and 6 in line OISD 244.

- ✓ Jet Nozzle to be provided in each hose boxes in tank farm area.
- ✓ Trolley mounted/Mobile Fire Fighting Equipment to be readily available at the location and positioned to have easy access to it during emergency situation.
- ✓ Carbon Dioxide Extinguishers to be provided for all panels, computers, console, UPS, charger in MCC room, DG Room and control room in line with OISD 117.
- ✓ Dry Chemical Extinguishers to be placed at designated location as per OISD 117 such as tank farm, gantry, buildings, pump house, ware house.
- ✓ Alarm systems to be provided for emergency in TAS control room.

Fire-fighting equipment to be inspected and tested as per OISD-STD-142 and record maintained.

- Medium expansion foam generators to be provided for dyke area to arrest vapour cloud formation from spilled volatile hydrocarbons as per OISD 244. Installation of medium expansion foam generator shall be as per following criteria:
  - ✓ Class A tanks: 2 Nos. Fixed type foam generators (mini) for each tank dyke.
  - ✓ Class B tanks: 2 Nos. Portable foam generator (minimum) for each location.
- High volume long range (HVLR) water cum foam monitors (Manual / Remote) of required capacity to fight tank fires to be provided which shall be of variable flow (with flow adjustable manually in the field) as per OISD 244.
- The hazardous areas to be protected by a well laid combination of hydrants & monitors.
- Fixed water spray system to be provided for Class A petroleum product above ground tanks and for Class 'B' above ground Petroleum storage tanks (fixed roof or floating roof) of diameter larger than 30 m.
- Fixed foam system or Semi-fixed foam system to be provided on all tanks (floating roof or fixed roof) exceeding 18 m diameter storing Class A or Class B petroleum as per OISD 244.
- Hydro Carbon detectors to be installed near all potential leak sources of class A petroleum products i.e tank dykes, tank manifolds and pump house manifold. These

detectors shall be placed in a way that entire possible source of leaks and collection of products is continuously detected. Hydrocarbon detector of proper type shall be selected and also shall be proof tested and shall be maintained in good condition.

- Portable explosive meters / gas tester to be made available and maintained for periodically checking the presence of hydrocarbon in hazardous area.
- Smoke detectors to be installed in control room as per provision made in OISD 244.
- Adequate number of portable fire extinguishers to be placed at designated location as per OISD 117 and are readily accessible and clearly visible at all times. The no. of extinguishers at various locations to be provided as per OISD STD-117.
- Fire extinguishers to be placed near the tank trucks during operations in a designated marked place. Provision of 2 nos. of Fire Extinguishers of ISI mark (1 no. X 10/9 kg DCP and 1 no. 1 kg CO2 /DCP /equivalent approved fire extinguisher).
- Electrical fittings as well as electrical equipment to be of flame-proof type in hazardous area.

- The following general recommendations are based on the finding of individual risk of worker group:

  - ✓ Reduce the maintenance personnel exposure duration in the process area's task activities in tank farm
  - ✓ Reduce the field operator's exposure duration in the process area's task activities within the depot.
  - ✓ Necessary provision to have emergency stop of critical equipment from control room in the event of major leak and flash fire.
  - ✓ There should be an SOP establish for clarity of actions to be taken in case of fire and leak emergency.
  - ✓ The vehicles entering the Depot should be fitted with spark arrestors.
  - ✓ Windsocks to be considered in the plant to ensure visibility from all directions. This will assist people to escape in upwind or cross wind direction from flammable releases.
  - ✓ The active protection devices like fire water sprinklers and other protective devices shall be tested at regular intervals.

- ✓ There should be an SOP established for clarity of actions to be taken in case of fire/leak emergency.
- ✓ Ensure Standard Operating Procedure (SOP) and Standard Maintenance Procedure (SMP) is followed.
- ✓ It is recommended to provide adequate grounding and earthing arrangements in the loading/unloading area. This will avoid static charge generation.
- ✓ It is suggested to have regular patrolling and planned inspection in order to prevent incidents.
- ✓ It is recommended to develop procedures to verify the testing & inspection records of the Tankers at the entry gate

7.14 SUMMARY

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

7.15 PUBLIC CONSULTATION

“Public Consultation" refers to the process by which the concerns of local affected and others who have plausible stake in the environmental impacts of the project are ascertained with a view to taking into account all the material concerns in the project design as appropriate.

The Public Hearing for the proposed New POL Depot.,By Hindusthan Petroleum corporation limited at Datta village, Hansi Tehsil, Hisar district, Haryana has been