CHAPTER 7: RISK ASSESSMENT & DISASTER MANAGEMENT PLAN

7.1 INTRODUCTION

Industrial plants deal with materials, which are generally hazardous in nature by virtue of their intrinsic chemical properties or their temperature or pressure of operation or a combination of these. Fire, explosion, hazardous release or a combination of these are the hazards associated with industrial plants. These have resulted in the development of more comprehensive, systematic and sophisticated methods of safety engineering such as hazard analysis and risk assessment to improve upon the integrity, reliability and safety of industrial plants.

The primary emphasis in safety engineering is to reduce risk to human life and environment. The broad tools attempt to minimize the chances of accidents occurring. Yet, there always exists, no matter how remote, that small probability of a major accident occurring. If the accident involves highly hazardous materials in sufficient large quantities, the consequences may be serious to the plant, to surrounding areas and the populations therein.

BPCL intends to enhance the storage capacity of LPG. Therefore, 3 no.s of Mounded Storage Vessels (MSVs) of 300 MT capacity each is proposed to be installed at Raiganj LPG Bottling plant. Total storage capacities after implementation of the project will be 1350 MT. LPG Bottling Plant operated strictly as a storage & Bottling facility for LPG into 5 kg, 14.2 kg, 19 kg, 35 kg & 47.5 kg cylinders. The LPG cylinders will be distributed in entire Uttar Dianjpur and surrounding Region.

7.2 RISK ASSESSMENT AND HAZARD IDENTIFICATION

Risk is defined as the unwanted consequences of a particular activity in relation to the likelihood that this may occur. Risk Assessment thus comprises of two variables, magnitude of consequences and the probability of occurrence of accident.

The first step in risk assessment is identification of hazards. Hazard is defined as a physical or chemical condition with the potential of accident which can cause damage to people, property or the environment. Hazards are identified by careful review of plant operation and nature of materials used. The various scenarios by which an accident can occur are then determined, concurrently study of both probability and the consequences of an accident is carried out and finally risk assessment is made. If this risk is acceptable then the study is complete. If the risk is unacceptable then the system must be modified and the procedure is restarted.

7.2.1 OBJECTIVE

The objectives of the study are to provide:

- Preliminary identification of hazards and hazardous scenarios that could produce an undesirable consequence arising from the proposed LPG bottling plant.
- Assessment of consequences of leak LPG from bottling plant within the facility in terms of radiation, blast waves or dispersion.
- Determination of the magnitude of all major accidents arising due to the proposed expansion of Raiganj LPG bottling plant that have the potential to cause damage to life, property and environment including:
  - ✓ Effects on are as where personnel may be located within the proposed expansion of Raiganj LPG bottling plant
  - ✓ Effects on are as external to the LPG plant
- Estimation of frequency of occurrence of the hazards.
- Review of safety features (organizational systems & safety equipment)
- Recommendations for prevention, control and mitigation measures for any identified risk

The over all aim of the study is to provide a degree of predictability on the risk of the operation as a result of the proposed expansion of Raiganj LPG bottling plant.

7.2.2 METHODOLOGY & APPROACH EMPLOYED

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

Hazard is present in any system, plant or unit that handles or stores flammable materials. The mere existence of hazards, however, does not automatically imply the existence of risk. Screening & ranking methodologies based on Preliminary Hazard Analysis (PHA) techniques have to be adopted for risk to be evaluated.

The approach and methodology by ABC Techno Labs followed for the RA study are described hereunder:

- ❑ **System Description**

The first step of the RA is the definition of the project limits, where the potential hazards are associated with the transportation, unloading, storage and LPG bottling facilities. Information about design details, process and operating conditions will be described under system description required for the risk analysis. It includes site location, environs, weather data, P&ID, layout drawing, operating and maintenance procedures, and thermo physical property data, etc.

- **Identification of Hazards Analysis**

Various possible hazards will be identified during transportation, unloading, storage and LPG bottling facilities including associated pump houses, etc. The release sources and potential accidents scenarios associated with each hazards will be listed. For each selected release sources, several scenarios may be possible depending upon the failure mode causing loss of containment. The criteria used for selection of scenarios for the consequence analysis will be the Maximum Credible Accidental (MCA) scenarios.

- **Hazards & Operability (HAZOP) Analysis**

The basic philosophy behind the HAZOP is that if a process operates within the intended design parameter, hazards will not occur, and by identifying how a process can deviate from the intended parameters and preventing these deviations process hazards can be minimized. The emphasis of the HAZOP technique is on identifying potential process hazards, not on finding solutions to reduce or eliminate them. The HAZOP study is carried out using the traditional HAZOP guide word method, which utilizes set of guide words that will be applied on each line of process diagram.

- **Effects & Consequence Estimation**

Effects & consequence distance estimation will be performed to determine the potential for damage or injury from the selected scenarios. The incident outcomes will be analyzed using release rates, dispersion, combustion, heat radiation and explosion models from fire and explosion. Damage distance computation will be based on jet fire, flash fire, and vapour cloud explosion (VCE) and boiling liquid expanding vapour explosion (BLEVE) scenarios, as applicable.

- **Failure Frequency Analysis**

Failure frequency analysis will be done for mounded bullets, pumps, valve, flange and piping, etc. Standard international database will be referred for estimation of probabilities.

Failure rate data is essentially derived from internationally well known generic databases. The generic failure data base selected for calculating the failure frequencies and the values in the database are used to reflect the mechanical and process design of the transfer pipeline and process facilities.

- **Risk Summation**

Risk quantification and summation will be based on probabilities from standard international database. The risk to personnel will be expressed in terms of Individual Risk (IR) represented by Iso Risk Contours and Group Risk/Societal risk represented by F-N Curves based on risk tolerability criteria.

- **Risk Mitigation Measures**

Based on consequence analysis and risk summation findings, risk mitigation measures will be suggested in view of applicable standards, guidelines and best practices to reduce risk and enhance safety at the proposed transportation, unloading, storage and LPG bottling facilities.

7.3 LIQUIFIED PETROLEUM GAS (LPG)

Liquefied Petroleum Gas (LPG) is a colourless and odourless gas. It is highly flammable at normal temperature and pressure (flammability limits 2.2% to 9.6 % in air), therefore there should be no ignition sources in close proximity to areas where LPG is stored and handled. On release it may give rise to both fire and explosion hazards. LPG is a blend of Propane and Butane, readily liquefied under moderate pressure. LPG is 1.5 to 2.0 times heavier than air, therefore, difficult to disperse. It should never be used or stored below ground, as this could result in asphyxiation when released in a confined space. Since LPG has only a faint scent, a mercaptan odorant is added to help in detection of its leakage especially when used as a domestic fuel. In the event of a LPG leak, the vapourisation of liquid cools the surrounding atmospheric air and condenses the water vapour contained in it to form a whitish fog, which is easy to observe. LPG in fairly large concentrations displaces oxygen leading to a nauseous or suffocating feeling.

Physical and chemical properties of LPG are as given below:

Boiling Point	:	-42 ºC - 0ºC
Vapour Pressure	:	300 – 1400 kPa @ 40ºC
Solubility in Water @ 20ºC	:	<200ppm
Physical State	:	Liquid (gas at ambient pressure)

Colour	:	Colourless
Specific Gravity	:	Liquid 0.51 – 0.58 (water = 1)
		Vapour 1.52 – 2.01 (air = 1)
Autoignition Temperature	:	466.1 ºC
Flammable Limits LEL		
Lower Flammability Limit (LFL)	:	2.2% (in air v/v)
Flammable Limits UEL		
Upper Flammability Limit (UFL)	:	9.6% (in air v/v)

As part of LPG bottling of cylinders for local distribution, currently LPG is stored in 3 above ground bullets and in case of external flame impinging on the shell of a bullets above the liquid level, it will weakening the container and lead to sudden shell rupture called Boiling Liquid Expanding Vapour Explosion (BLEVE).

BPCL now proposed to install three mounded vessels (3x300MT) for storage of LPG. Hence in this case, there is no possibility of Boiling Liquid Expanding Vapour Explosion (BLEVE) as in the event of early fire, flame impingement or heating of vessels will not be possible on mounded vessels. Therefore, from mounded bullets, release of LPG is possible only from leakage in piping, valves or flanges, etc.

Table 7.1: Details of LPG Storage Capacities

Sl. No.	Product	Capacity	Status
1.	LPG Above Ground Bullets (3x150 MT)	450 MT	Existing
2.	LPG Mounded Storage Vessels (3x300 MT)	900 MT	Proposed
	Total	**1350 MT**	

7.4 HAZARDS FROM LPG STORAGE AND HANDLING

7.4.1 BOILING LIQUID EXPANDING VAPOUR EXPLOSION

A Boiling Liquid Expanding Vapour Explosion (BLEVE) occurs when there is a sudden loss of containment of a pressure vessel containing a superheated liquid or liquefied gas from above ground pressure vessels filled with LPG. The primary cause is usually an external flame impinging on the shell of a vessel above the liquid level, weakening the container and leading to sudden shell rupture. A pressure relief valve does not protect against this mode of failure. It should be noted, however, that a BLEVE can occur due to any mechanism that results in the sudden failure of containment allowing a superheated liquid to flash, typically increasing its volume over 200 times. This is sufficient to generate a pressure wave and fragments. It is resulted as fireball.

7.4.2 Jet Fire

If released LPG from hole/opening is ignited immediately, jet fire may take place. The extent of injury to people depends on the heat flux and duration of exposure to heat.

7.4.3 Vapour Cloud Explosion

If released LPG is not ignited immediately, the cloud of vapour LPG will spread in the surrounding area. LPG vapours are heavier than air and tend to settle down at lower level. As long as the LPG concentration is between the lower and higher flammability limits, the LPG vapour cloud may be set on fire by an ignition source. For generation of over pressure effect, some degree of confinement of the flammable cloud is required.

7.4.4 Flash Fire

When released quantities of LPG are not ignited immediately, vapour cloud of LPG spreads towards wind direction in the surrounding area, some portion of LPG vapour cloud will have LPG concentration between the lower and upper flammable limits, the LPG vapour cloud may be set on fire by an ignition source in entire length of flammable LPG vapour cloud resulting flash fire. In the event of flash fire, essentially, no over pressure effect is possible.

7.5 Hazardous Conditions Due To Release of LPG

As a result of release of LPG followed by immediate or delayed ignition, the following hazardous conditions may be encountered:

7.5.1 Thermal Effects

In case of jet fire, thermal effect is likely to cause injury or damage to people and damage to objects. A substantial body of experimental data exists and forms the basis for thermal effect estimation. The consequence caused by exposure to heat radiation is a function of:

- ✓ Radiation energy onto the human body [kW/m^2];
- ✓ Exposure duration [sec];
- ✓ Protection of the skin tissue (clothed or naked body).

The following damage distances for thermal radiation are used in the risk analysis:

37.5 kW/m^2	:	Damage to process equipment. 100% fatality in 60 s exposure. 1% fatality in 10 s exposure.
12.5 kW/m^2	:	First degree burn in 10 s exposure

4.0 kW/m^2	:	First degree burn in 30 s exposure

7.5.2 DELAYED IGNITION AND EXPLOSION

In case of delayed ignition of LPG cloud, two physical effects may occur in following ways:

- Flash fire over the whole or part of the LPG vapour cloud;
- Vapour cloud explosion that results in blast wave with typical peak overpressures in circle around the ignition source. Vapour cloud explosion to occur some degree of confinement is essential.

TNO Multi-energy method is used to calculate the blast overpressure. Table 7.2 gives extent of damage with respect to the peak overpressure resulting from a blast wave:

Table 7.2: Damage Effects Due to Overpressure

Peak Overpressure	Extent of Type
0.830 bar	Total Destruction
0.350 bar	Heavy Damage
0.170 bar	Moderate Damage
0.100 bar	Minor Damage

(Source: TNO)

Table 7.3 given provides an illustrative listing of damage effects caused by peak overpressure.

Table 7.3: Illustrative Damage Effects due to Overpressures

Peak Overpressure (Bar)	Failure
0.005	5 % Window Shattering
0.02	50 % Window Shattering
0.07	Collapse of a roof of a tank
0.07-0.14	Connection failure of panelling
0.08-0.1	Minor Damage to Steel Framework
0.15-0.2	Concrete block wall shattered
0.2	Collapse of Steel Framework
0.2-0.3	Collapse of self framing Steel panel building
0.2-0.3	Ripping of empty oil tanks
0.2-0.3	Deformation of a pipe bridge

Peak Overpressure (Bar)	Failure
0.2-0.4	Big trees topple over
0.3	Panelling torn off
0.35-0.4	Piping failure
0.35-0.8	Damage to Distillation Column
0.4-0.85	Collapse of pipe bridge
0.5	Loaded Train Wagon overturned
0.5	Brick walls shattered
0.5-1.0	Movement of round tank, failure of connecting piping

(Source: TNO)

7.6 Identification of Hazard for LPG Unloading, Storage and Bottling Facilities

7.6.1 Categories of Hazards

For identification of hazards during unloading, storage and bottling of LPG, it is essential to identify categories of hazard. Hazard categories, which may be responsible for accidental release of LPG from Raiganj bottling plant are listed in Table 7.4.

Table 7.4: Hazard Categories

Extreme Weather and Natural Disasters • High winds; • Squalls; • Lightning; • Earthquake; etc	Human Factors • Occupational accidents; • Improper and Inadequate training; • Non availability of SOPs; etc
Process Upsets • Pressure deviations; • Temperature deviations; • Flow deviations; • Level deviations; etc	Structural Failures • Subsidence; • Seismic; • Corrosion; • Fatigue; etc
Loss of Containment • Corrosion; • Change in fluid properties; • Deviation in Design / Operating Conditions; • Unloading activities;	Inspection and Maintenance • Confined Space; • Non Accessibility; • Reduced visibility; • Non availability of maintenance and inspection schedules; etc

• Maintenance activities; • Human errors during: -operations maintenance; -Instrumentation; etc • Ignition sources: - Electrical; - Hot surface; etc	

Source: ABC Techno Labs India Pvt. Ltd.

7.6.2 HAZARD IDENTIFICATION (HAZID)

Hazard identification (HAZID) for the proposed LPG unloading, storage and bottling facilities has been carried out for likely hazardous events which may cause major accident hazards. A systematic investigation has been carried with special focus on external events that could potentially impact the operation and safety of LPG unloading, storage and bottling facilities. Table 7.5 gives for various potential consequence and safeguards for likely hazardous events for the facility.

Table 7.5: Hazids for LPG Unloading, Storage and Bottling Facilities at Raiganj

Sl.No	Hazardous Event	Potential Consequences	Safeguards
1.	Collision of LPG by bullet mounted truck during transportation of LPG to LPG bottling plant.	♦ Release of LPG ♦ Fire and Explosion	♦ Training of drivers for safe driving ♦ Transport Emergency (TREM) Card
2.	Rupture or hole in Transfer piping from Unloading to storage facility at LPG Bottling Plant.	♦ Release of LPG ♦ Fire and Explosion	♦ SOPs to be followed. ♦ Supervision by trained operator ♦ Regular inspection and maintenance of piping
3.	Rupture or hole in bottom line of mounded bullets	♦ LPG release ♦ Fire and Explosion	♦ Ensure corrosion protection ♦ Ensure mechanical integrity time to time ♦ Regular inspection and preventive maintenance of piping.
3.	Pump Failure	♦ LPG release ♦ Fire and	♦ Ensure proper operating procedures ♦ Preventive maintenance

Sl.No	Hazardous Event	Potential Consequences	Safeguards
		Explosion	to follow
4.	Failure of Valve	♦ LPG release ♦ Fire and explosion	♦ Ensure proper operating procedures ♦ Preventive maintenance of pump
5.	Rupture in piping from Mounded Bullets to Bulk Loading Facility.	♦ LPG release ♦ Fire and explosion	♦ Ensure corrosion protection ♦ Ensure mechanical integrity time to time ♦ Preventive maintenance to follow
6.	Leakage from Bullet Truck	♦ BLEVE ♦ Fire and explosion	♦ Proper connection of flanges ♦ Ensure proper operating procedures during loading of bullet truck
7.	Natural Disaster such as high winds, earthquake, etc	♦ Damage to piping ♦ LPG release ♦ Fire and explosion	♦ Follow relevant design standards to withstand natural disasters

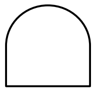
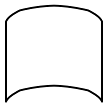
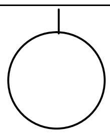
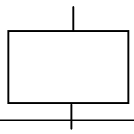
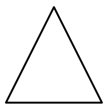
Source: ABC Techno Labs India Pvt. Ltd.

7.6.3 Release and Outcome Scenarios

Based on LPG unloading, storage and bottling facilities at the BPCL's proposed expansion of Raiganj LPG bottling plant, maximum credible LPG release and outcome scenarios which may result during LPG unloading, storage and bottling facilities are given above in Table 7.1.

7.7 Fault Tree Analysis

Fault Tree Analysis (FTA) is a popular and productive hazard identification tool. FTA is top to bottom approach. It provides a standardized discipline to evaluate and control hazards using Boolean logic to combine a series of lower-level events. The Boolean logic function symbols used in FTA are grouped as events, gates, and transfer symbols as described below:

	AND Gate	The output occurs only if all inputs occur (inputs are independent)
	OR Gate	The output occurs if any input occurs
	Basic Gate	Failure or error in a system component or element (example: switch stuck in open position)
	Intermediate Event	An intermediate event gate can be used immediately above a primary event to provide more room to type the event description.
	Transfer symbol	Transfer symbols are used to connect the inputs and outputs of related fault trees, such as the fault tree of a subsystem to its system.

7.8 DOW FIRE & EXPLOSION INDEX FOR RAIGANJ LPG BOTTLING PLANT

For hazards identification, Dow Fire & Explosion (F&E) Index is most commonly used, which is a formal systematized approach using a rating form. This final rating number provides a relative ranking of the hazard at a hazardous installation like LPG Bottling Plant.

The Dow F&E Index is designed for rating the relative hazards with the storage handling and processing of explosive and flammable materials like LPG. The main idea of this procedure is to provide a purely systematic approach, mostly independent of judgemental factors, for determining the relative magnitude of the hazards in a facility.

The Dow F&E Index provides a direct and easy method for quickly estimating the risks in a storage, handling and process facilities dealing with hazardous substances. The method assigns penalties and credits based on storage/plant features. Penalties are assigned to hazardous materials and conditions that can contribute to an accident/hazardous situation. Credits are assigned to plant safety features that can mitigate the effects of an accident. These penalties and credits are combined to derive an index that is a relative ranking of the facility risk.

The procedure begins with a material factor, which is a function only of the type of chemicals stored, handled or processed. This factor is adjusted for general and special process hazards. These adjustments or penalties are based on conditions such as storage above the flash and boiling point, endothermic or exothermic reactions etc.

Dow fire and explosion index ranges, with regards degree of hazards is shown in following Table.

Dow F&E Index Range	Degree of Hazards
1 – 60	Light
61 – 96	Moderate
97 – 127	Intermediate
128 – 158	Heavy
159 – Up	Severe

7.8.1 Dow F&E Index for Raiganj LPG Bottling Plant

The Raiganj LPG Bottling Plant is engaged in unloading, bulk storage and bottling of LPG in cylinders at pressurized conditions and ambient temperature. Dow F&E Index has been determined for the LPG Bottling Plant at Raiganj for unloading, bulk storage and bottling of LPG in cylinder. Filled form used to compute the Dow Fire and Explosion Index is shown in Table 7.6.

Computed Fire & Explosive Index for unloading, bulk storage and bottling of LPG is 211.68, which is above 159 Dow F&E Index. Based on fire and explosion index, Raiganj LPG Bottling Plant is categorized with severe degree of hazards.

Table 7.6: Fire and Explosion Index for BPCL LPG Bottling Plant at Raiganj

FIRE AND EXPLOSION INDEX	**LOCATION:** **BPCL LPG Bottling Plant at Raiganj**		**DATE** **Jan, 2018**
PLANT	PROCESS UNIT	EVALUATED BY	REVIEWED BY
MATERIALS AND PROCESS : **Unloading, Bulk Storage and Bottling of LPGat Pressurised & Atmospheric Temperature**			
MATERIALS IN PROCESS UNIT: **Liquefied Petroleum Gas (LPG)**			
STATE OF OPERATION START-UP / SHUT-DOWN / NORMAL OPERATION	BASIC MATERIAL (S) FOR MATERIAL FACTOR **Liquefied Petroleum Gas (LPG)**		
MATERIAL FACTOR			21
1. GENERAL PROCESS HAZARDS	**PENALTY**	**PENALTY USED**	
BASE FACTOR	**1.00**	**1.00**	
EXOTHERMIC CHEMICAL REACTIONS	(FACTOR .30 to 1.25)	0	
ENDOTHERMIC PROCESSES	(FACTOR .20 to .40)	0	

MATERIAL HANDLING & TRANSFER	(FACTOR .25 to 1.05)	0.5	
ENCLOSED OR INDOOR PROCESS UNITS	(FACTOR .25 to .90)	0.6	
ACCESS	.35	0.0	
DRAINAGE AND SPILL CONTROL	(FACTOR .25 to .50)	0.3	
GENERAL PROCESS HAZARDS FACTOR (F1)		2.4	
2. SPECIAL PROCESS HAZARDS			
BASE FACTOR	**1.00**	**1.00**	
TOXIC MATERIAL (S)	(FACTOR0.20 to 0.80)	0	
Sub. ATOMOSPHERIC PRESSURE (500 mm Hg)	.50	0	
OPERATION IN OR NEAR FLAMMABLERANGE * INERTED * NOT INERTED			
1. TANK FARMS STORAGE FLAMMABLE LIQUIDS	.50	0.5	
2. PROCESS UPSET OR PURGE FAILURE	.30	0.3	
3. ALWAYS IN FLAMMABLERANGE	.80	0.8	
DUST EXPLOSION (SEE TABLE II)	(FACTOR .25 to 2.00)	0	
PRESSURE OPERATING PRESSURE ____ psig RELIEF SETTING ________ psig	0.3	0.3	
LOW TEMPERATURE	(FACTOR .20 TO .30)	0	
QUANTITY OF FLAMMABLE/ UNSTABLE MATERIAL: QUANTITY _____ lbs., HC _______BTU/ lb		0	
1. LIQUIDS. GASES AND REACTIVE MATERIALS IN PROCESS		0.3	
2. LIQUIDS OR GASES IN STORAGE		0.3	
3. COMBUSTIBLE SOLIDS IN STORAGE. DUST IN PROCESS		0	
CORROSION AND EROSION	(FACTOR .10 to .75)	0	
LEAKAGE – JOINTS AND PACKING	(FACTOR .10 to 1.50)	0.2	
USE OF FIRED HEATERS (SEE FIG. 6)		0	
HOT OIL HEAT EXCHANGE SYSTEM (SEE TABLE III)	(FACTOR .15 to 1.15)	0	
ROTATING EQUIPMENT	.50	0.3	
SPECIAL PROCESS HAZARDS FACTOR (F2)		4.2	
UNIT HAZARD FACTOR (F1 x F2 = F3)		10.8	
FIRE AND EXPLOSION INDEX (F3 x MF = F & EI)			211.68

7.9 Hazard & Operability (HAZOP)

7.9.1 HAZOP Study for LPG Handling and Storage

The existing Raiganj LPG bottling plant is engaged in unloading & storage of bulk and bottling of LPG in cylinders. At existing plant, three mounded storage vessels of 300 MT have been proposed to install. At the existing LPG bottling plant, bulk LPG is unloaded & stored and then bottled in cylinders with the desired operating parameters like temperature, pressure, flow, level, etc. In an unlikely event of any deviation in operating parameters, hazardous conditions may be arisen. Therefore, hazard and operability (HAZOP) study has been carried for storage, and handling of LPG at the Raiganj bottling plant. The main purpose of the HAZOP study is to identify specific hazard and operability issues, which could lead to risks to personnel, property and environment or operational problems during storage and handling of LPG.

7.9.2 Methodology for HAZOP Study

The methodology for the HAZOP was as adopted internationally as per guidelines of ICI, UK and CCPS, AICHE. Hazard and operability (HAZOP) study was undertaken by the application of a formal, systematic, and critical examination of the process and engineering intentions of process design. The potential for hazard was thus assessed and malfunctions of the individual items of equipment and the consequences for a whole system were identified. The examination of the design was structured around a specific set of guidewords, which ensure complete coverage of all possible problems while allowing sufficient flexibility for an imaginative approach.

The overall aims that a HAZOP study addresses are:

i. To identify all deviations from the way the design is expected to work, their causes and all the hazards and operability problems associated with these deviations.

ii. To decide whether action is required to control the hazard or the operability problem and if so to identify the ways in which the problems can be solved.

iii. To identify cases where a decision cannot be made immediately and to decide on what information or action is required.

Various terms with special meaning are used in conducting a HAZOP study. These include:

Node	Deviation
Parameter	Cause

Intention	Consequence
Guideword	Recommendation

7.9.3 Undertaking The Study

The HAZOP study team considered each part of process design in turn by applying the HAZOP guidewords and analysing the causes and consequences of possible deviations. Thus, the study sessions followed through a series of steps repeatedly. The following seven steps were repeated many times during the HAZOP.

- Apply the guideword
- Develop a deviation
- Examine possible causes
- Examine consequences
- Consider hazards or operability problems
- Decide upon action
- Make a record of the discussions and decisions.

7.9.4 Facilities Considered For HAZOP Study

LPG unloading, storage and bottling system having site layout plan, Hydrant Layout Plan and site visit observations was considered for HAZOP study. Layout plan showing pipe routing diagram and hydrant layout plan have been shown in Figure 4.1 and 4.2, respectively.

7.9.5 HAZOP Worksheets

By following the above-mentioned methodology, HAZOP worksheets were developed for representative and important nodes during HAZOP sessions. The HAZOP worksheets are given in Table 7.7.

Table 7.7: Transfer of LPG from Tank Truck to Bullet (Flow)

Node 1: Liquid Line Section from Tank Truck Decantation Shed to AG Bullets/Mounded Vessels ***Intention: Transfer of LPG from Tank Truck to Bullet***					
Parameter: Flow					
Sl.No.	***Guidewords***	***Deviations***	***Possible Cause***	***Consequences***	***Mitigation Measures***
1.	None	No Flow	• Tank Truck is empty • Valve is not open	• Delay in LPG unloading	SOPs should be followed.
			Pipeline chocked	• Transfer pipeline and hose under pressure • Delay in LPG unloading	High discharge pressure tripping system should be provided for compressor
			Failure of unloading arm/hose	• Transfer line under pressure • Leakage of LPG • Fire & Explosion Hazards	Excess flow check valve on tank truck side as well as on hose side should close automatically
			Any of the valve between tank lorry and LPG Bullet is closed	• Transfer line under pressure • Delay in LPG unloading	High discharge pressure tripping system should be provided for compressor
2.	Less	Low Flow	• Pressure differential is less between the bullet/vessel and LPG Tank Truck • Leakage in Piping • Excess Flow check valve of the tank truck is partially closing at a pressure	• More time required for decantation • Fire & Explosion Hazards	• Excess Flow check valve to be checked • SOPs should be followed. • Preventive maintenance of pump, compressor and piping need to be ensured. • LPG detectors should be installed • Fire control measures should work properly

Node 1: Liquid Line Section from Tank Truck Decantation Shed to AG Bullets/Mounded Vessels ***Intention: Transfer of LPG from Tank Truck to Bullet***					
Parameter: Flow					
Sl.No.	***Guidewords***	***Deviations***	***Possible Cause***	***Consequences***	***Mitigation Measures***
			differential less than rated.		
3.	More	High Flow	More flow is not possible as excess flow check valve provided on tank truck & pipeline.	None	None
4.	Reverse	Reverse Flow	Not possible as None Return Valve (NRV) provided in transfer line.	None	None
5.	As well as	Flow of Foreign Material water with LPG	Water present in Tank Truck and it will go to bullets	No hazardous consequence only water will go along with LPG to bullets	Water draining is required in bullet

Transfer of LPG from Tank Truck to Bullet (Temperature)

Node 1: Liquid Line Section from Tank Truck Decantation Shed to AG Bullets/Mounded Vessels					
Intention : Transfer of LPG from Tank Truck to Bullet					
Parameter : Pressure					
Sl.No.	***Guidewords***	***Deviations***	***Possible Cause***	***Consequences***	***Mitigation Measures***
1	More	High Temperature	Fire in vicinity of bay TLD	• If temperature raise is not controlled unloading hose will be ruptured, • Fire & explosion	• Regular Inspection is required • SOPs for unloading of LPG to be followed. • Cooling of tank truck by water spray

Node 1: Liquid Line Section from Tank Truck Decantation Shed to AG Bullets/Mounded Vessels					
Intention : Transfer of LPG from Tank Truck to Bullet					
Parameter : Pressure					
Sl.No.	*Guidewords*	*Deviations*	*Possible Cause*	*Consequences*	*Mitigation Measures*
				hazards/BLEVE • Danger to AG Bullets and bay TLD is located very close to AG bullets	• Water Curtain between bay TLD and Bullets needs to be provided as it is not meeting safe distance as per OISD.
			Fire in bay Tank Truck Decantation (TLD)shed causing heating of Tank Truck	Danger to AG Bullets and bay TLD is located very close to AG bullets	Ensure proper functioning of fire fighting system & cooling of AG bullets and bay TLD
2.	Less	Low Temperature	Very low Ambient Temperature	None, since freezing point of LPG is -188oC. Freezing condition in LPG pipeline will not occur because lowest temperature at Raiganj is about 10 oC.	None

Transfer of LPG from Tank Truck to Bullet (Pressure)

Node 1: Liquid Line Section from Tank Truck Decantation Shed to AG Bullets/Mounded Vessels

Intention : Transfer of LPG from Tank Truck to Bullet					*Parameter : Pressure*
Sl.No.	***Guidewords***	***Deviations***	***Possible Cause***	***Consequences***	***Mitigation Measures***
1.	More	High Pressure	By mistake isolation valves closed while compressor running	Transfer line subjected to high pressure	In case of higher pressure stop operation and check the transfer line
2.	Less	Low Pressure	• Leakage LPG from Hose/piping • Compressor is not able to create adequate differential pressure	Fire & explosion hazards	• Cooling of tank truck by water spray • Ensure proper working of LPG compressor • SOPs for unloading of LPG to be followed

Transfer of LPG Vapour to Compressor from Tank Truck (Flow)

Node 2: Vapour Line between Compressor Discharge and TLD Shed					
Intention : Transfer of LPG Vapour to Compressor from Tank Truck					***Parameter : Flow***
Sl.No.	***Guidewords***	***Deviations***	***Possible Cause***	***Consequences***	***Mitigation Measures***
1.	None	No Flow	• Compressor is not working due power failure and other reasons • Rupture of Vapour line • Valve is not open • Pipeline is chocking	• Delay in decantation • Fire and explosion hazards • Back Pressure on compressor	• Preventive maintenance and daily inspection of LPG compressor and piping should be ensured. • Open and close arrow marking at valve handles should be provided. • Fire fighting facilities should be readily available. • If power failure, DG sets should operate immediately. • There should be provision in discharge pipeline to prevent compressor from back pressure effect.

Node 2: Vapour Line between Compressor Discharge and TLD Shed					
Intention : Transfer of LPG Vapour to Compressor from Tank Truck					***Parameter : Flow***
Sl.No.	***Guidewords***	***Deviations***	***Possible Cause***	***Consequences***	***Mitigation Measures***
2.	Less	Low Flow	• Leakage in vapour line • Valve is not open • Pipeline is chocked	• Delay in decantation • Fire and explosion hazards	• Preventive maintenance and daily inspection of LPG vapour piping should be ensured. • Open and close arrow marking at valve handles should be provided. • Fire fighting facilities should be readily available.
3.	More	High Flow	• Not Likely	• None	• None
4.	Other Than	Corrosion	Pure LPG vapours are not corrosive but Mercaptan added to LPG to create odour, may corrode vapour piping.	• Vapour piping failure hence release of LPG vapour may occur. • Fire and explosion hazards	• Periodic internal inspection of LPG Vapour piping should carried out at every 5 years to detect any corrosion

Transfer of LPG Vapour to Compressor from Tank Truck (Temperature)

Node 2: Vapour Line between Compressor Discharge and TLD Shed					
Intention : Transfer of LPG Vapour to Compressor from Tank Truck					***Parameter : Temperature***
Sl.No.	***Guidewords***	***Deviations***	***Possible Cause***	***Consequences***	***Mitigation Measures***
1.	More	High	• Cylinder jacket of compressor is not being	• The compressor heats up	• Regular checking/ maintenance

Node 2: Vapour Line between Compressor Discharge and TLD Shed					
Intention : Transfer of LPG Vapour to Compressor from Tank Truck					***Parameter : Temperature***
Sl.No.	***Guidewords***	***Deviations***	***Possible Cause***	***Consequences***	***Mitigation Measures***
		Temperature	cooled properly. • The discharge line of compressor heats up due to external file or flame. • Vapour piping heated due to fire in vicinity	and then fails /trips • Pipeline hose may fail due to high temperature • Fire and explosion hazards.	cooling water line to compressor. • Fire fighting facilities should be readily available.
2.	Less	Low Temperature	Very low Ambient Temperature	None, since freezing point of LPG is -188 oC. Freezing condition in LPG vapour pipeline will not occur because lowest temperature at Raiganjis about 10oC.	None

Transfer of LPG Vapour to Compressor from Tank Truck (Pressure)

Node 2: Vapour Line between Compressor Discharge and TLD Shed	
Intention : Transfer of LPG Vapour to Compressor from Tank Truck	***Parameter : Pressure***

Sl.No.	Guidewords	Deviations	Possible Cause	Consequences	Mitigation Measures
1.	Less	Less Pressure	• Compressor is not working properly • Leakage LPG from piping	• Delay in decantation of Tank Truck • Fire & explosion hazards	• Preventive maintenance of compressor and piping • LPG detectors should be installed • Fire control measures should work properly
2.	More	High Pressure	• Higher Pressure in bullet • fire/heating on external surface of bullet	• Vapour line may leak/ burst and subsequently release of LPG • Fire and explosion	• Fire control measures should work properly • Fire hazards near piping should not be allowed.

Transfer of LPG Vapour to Compressor from Bullet (Flow)

Node 3: Vapour Line between Bullet and Compressor Suction Side					
Intention : Transfer of LPG Vapour to Compressor from Bullet					***Parameter : Flow***
Sl.No.	***Guidewords***	***Deviations***	***Possible Cause***	***Consequences***	***Mitigation Measures***
1.	None	No Flow	• Vapour line is chocked • Valve is not open.	Compressor cylinder heats up	• Need of low suction tripping system • Open and close arrow marking at valve handles
			Bullet/vessel is mistakenly over filled up and no space for vapours.	Knocking of Compressor	• High level tripping system with alarm needs to be provided on section side.
			Compressor break down due to power failure or other reasons	Decantation operation of tank truck stopped and operation delay.	• If power failure, DG sets should be operated immediately. • Preventive maintenance of Compressor

Node 3: Vapour Line between Bullet and Compressor Suction Side					
Intention : Transfer of LPG Vapour to Compressor from Bullet					***Parameter : Flow***
Sl.No.	***Guidewords***	***Deviations***	***Possible Cause***	***Consequences***	***Mitigation Measures***
2.	Less	Low Flow	• Leakage in the vapour line • Vapour line is chocked • Valve is not open.	Fire and explosion hazards	• LPG detectors need to installed • Preventive maintenance of piping • Open and close arrow marking at valve handles should be provided.
3.	More	High Flow	• More flow in case excess flow check valves not working • Pipeline/valve leak due to impact or other reasons	• LPG Vapour release hence asphyxiation problems • Fire and explosion hazards	• Inspection of line is required before starting the compressor • LPG detectors should be installed • Preventive maintenance of excess flow check valves • Fire hydrant can be operated. Hence the fire hydrant ring should always remain pressurized.
4.	Other than	Corrosion	Pure LPG is not corrosive but Mercaptan added to LPG to create odour, may corrode pipeline /bullet	Pipeline/bullet corrosion hence possibility of release of LPG vapours.	• Periodic internal inspection of pipeline and LPG bullets should carried out at every 5 years to detect any corrosion • Cathodic Protection needs to be provided to both mounded bullets to prevent from corrosion.

Transfer of LPG Vapour to Compressor from Bullet (Pressure)

Node 3: Vapour Line between Bullet and Compressor Suction Side					
Intention : Transfer of LPG Vapour to Compressor from Bullet					***Parameter : Temperature***
Sl.No.	***Guidewords***	***Deviations***	***Possible Cause***	***Consequences***	***Mitigation Measures***
1.	More	Temperature	Fire in the vicinity	• Vapour pressure/ internal pressure rise in	• Fire hazards near piping should not be allowed.

Node 3: Vapour Line between Bullet and Compressor Suction Side					
Intention : Transfer of LPG Vapour to Compressor from Bullet					**Parameter : Temperature**
Sl.No.	**Guidewords**	**Deviations**	**Possible Cause**	**Consequences**	**Mitigation Measures**
				piping /bullet due to fire in the vicinity. It may cause SRV actuation hence fire hazards. • If SRVs fails to actuate or fire is not controlled bullet may rupture.	• Regular maintenance of SRVs is desired. • Fire control measures should work properly. • Auto medium velocity water sprinkler system should be operated.
2.	Less	Low Temperature	Very low Ambient Temperature	None, since freezing point of LPG is -188 oC. Freezing condition in LPG pipeline will not occur because lowest temperature at Raiganj is about 10 oC.	None

Transfer of LPG Vapour to Compressor from Bullet (Pressure)

Node 3 : Vapour Line between Bullet and Compressor Suction Side	
Intention : Transfer of LPG Vapour to Compressor from Bullet	**Parameter : Pressure**

Sl.No.	Guidewords	Deviations	Possible Cause	Consequences	Mitigation Measures
1.	More	High Pressure	• Higher pressure in bullet • Fire/heating on external surface of bullet	• Vapour line may leak/ burst and subsequently release of LPG • Fire and explosion	• Pressure gauge with alarm should be provided to bullet • Regular maintenance of SRVs desired. • Fire control measures should work properly. • Auto medium velocity water sprinkler system should be operated.
2.	Less	Low Pressure	Leakage LPG from piping	Fire & explosion hazards	• Preventive maintenance of piping • LPG detectors should be installed • Fire control measures should work properly.

Transfer of LPG from Bullet to Pump (Flow)

Node 4: Inlet/Outlet Liquid LPG Pipeline from LPG Bullets to LPG Pump Suction					
Intention: Transfer of LPG from Bullet to Pump					***Parameter : Flow***
Sl.No.	***Guidewords***	***Deviations***	***Possible Cause***	***Consequences***	***Mitigation Measures***
1.	None	No Flow	• Valve on inlet/outlet piping to pump suction is closed. • Inlet/out pipeline chocked. • No LPG in the bullet	• Operation delay • LPG pumps heat up due to increased vibration on account of cavitations developed in the pump	• SOPs should be followed. • Pipelines should be cleaned after each two years. • Interlocking system to be provided so that if there is no flow of LPG from bullet to pipeline, pump should trip.
2.	Less	Low Flow	• Valve on inlet/out let piping to pump suction is not properly. • Inlet/out pipeline leaking.	• Operation delay • Fire & explosion hazards	• SOPs should be followed. • LPG detectors should be installed at strategic locations. • Fire fighting facilities should be kept readily available. • Interlocking system to be provided so

Node 4: Inlet/Outlet Liquid LPG Pipeline from LPG Bullets to LPG Pump Suction					
Intention: Transfer of LPG from Bullet to Pump					***Parameter : Flow***
Sl.No.	***Guidewords***	***Deviations***	***Possible Cause***	***Consequences***	***Mitigation Measures***
					that if there is low flow of LPG from bullet to pipeline, pump should trip.
3.	More	High Flow	Not Possible	None	None
4.	Other than	Corrosion	Pure LPG is not corrosive but Mercaptan added to LPG to create odour, may corrode pipeline /bullet	Pipeline/bullet corrosion hence possibility of release of LPG vapours.	• Periodic internal inspection of pipeline and LPG bullets should carried out at every 5 years to detect any corrosion • Cathodic Protection needs to be provided to both mounded bullets to prevent from corrosion.
5.	Reverse	Reverse flow of LPG inlet/out let piping	Not Likely	Operation Malfunction	As precautionary measures Non Return Valve (NRV) on the bullet side as well as on pump suction side should be provided.
6.	As well as	Flow of Foreign Material along with LPG	Flow of water along with LPG.	No hazardous consequence only water will go along with LPG	Water draining is required in bullet

Transfer of LPG from Bullet to Pump (Temperature)

Node 4: Inlet/Outlet Liquid LPG Pipeline from LPG Bullets to LPG Pump Suction					
Intention: Transfer of LPG from Bullet to Pump					***Parameter : Temperature***
Sl.No.	***Guidewords***	***Deviations***	***Possible Cause***	***Consequences***	***Mitigation Measures***
1.	More	High	External fire on Inlet/outlet pipeline or	• Pipeline Leak/Rupture	• Fire hazards near piping should not be allowed.

Node 4: Inlet/Outlet Liquid LPG Pipeline from LPG Bullets to LPG Pump Suction					
Intention: Transfer of LPG from Bullet to Pump					***Parameter : Temperature***
Sl.No.	***Guidewords***	***Deviations***	***Possible Cause***	***Consequences***	***Mitigation Measures***
		Temperature	AG Bullets	• Fire & Explosion • BLEVE on AG Bullets	• Gas detectors system should be provided at strategic locations • Fire hydrant system should be readily available to extinguish fire at initial stage • The SRVs should start functioning if the pressure in bullet is equivalent to its design pressure. Hence, proper functioning of SRV is ensured.
2	Less	Low Temperature	Very low Ambient Temperature	None, since freezing point of LPG is -188 oC. Freezing condition in LPG pipeline will not occur.	None

Transfer of LPG from Bullet to Pump (Pressure)

Node 4: Inlet/Outlet Liquid LPG Pipeline from LPG Bullets to LPG Pump Suction					
Intention: Transfer of LPG from Bullet to Pump					***Parameter : Pressure***
Sl.No.	***Guidewords***	***Deviations***	***Possible Cause***	***Consequences***	***Mitigation Measures***
1.	More	High Pressure	External fire on Inlet/outlet pipeline or AG Bullets	• Pipeline leak/rupture • Fire & explosion • BLEVE on AG Bullets	• Fire hazards near piping should not be allowed. • Gas detectors system should be provided at strategic locations • Fire hydrant system should be readily available to extinguish fire at initial stage • SRVs should start functioning if the

Node 4: Inlet/Outlet Liquid LPG Pipeline from LPG Bullets to LPG Pump Suction					
Intention: Transfer of LPG from Bullet to Pump					***Parameter : Pressure***
Sl.No.	***Guidewords***	***Deviations***	***Possible Cause***	***Consequences***	***Mitigation Measures***
					pressure in bullet is equivalent to its design pressure. Hence, proper functioning of SRVs should be ensured.
2.	Less	Low Pressure	• Pipeline leak/rupture	• Fire & explosion	• Preventive maintenance of piping • LPG detectors should be installed • Fire fighting facilities should readily available.

Pumping of LPG through Pump (Flow)

Node 5: LPG Pump Discharge Line					
Intention: Pumping of LPG through Pump					***Parameter : Flow***
Sl.No.	***Guidewords***	***Deviations***	***Possible Cause***	***Consequences***	***Mitigation Measures***
1.	None	No flow	• LPG Pump not working All liquid LPG going back to suction line through circulation line • Some valve erratically closed • Pipeline is chocked. • Grid power failure • Bullet is empty	• Operational delay • Bottling process will be stopped automatically	• Regular checking of pumps and pipeline desired. • Checking motor/pump fault, impeller mechanical seal failure preventive maintenance of pump and motor is required, • SOPs should be followed for operation of valves. • If power failure, DG sets should be operated immediately • Level gauge with alarm and interlock should be available with bullet.
2.	Less	Low flow	• Pipeline is partially	• Operational delay	• Regular checking of pumps and pipeline

Node 5: LPG Pump Discharge Line					
Intention: Pumping of LPG through Pump					***Parameter : Flow***
Sl.No.	***Guidewords***	***Deviations***	***Possible Cause***	***Consequences***	***Mitigation Measures***
			chocked. • Leakage in pipeline /LPG pump • Some valve erratically closed	• LPG pump will lose its Net Positive Suction Head (NPSH). • LPG leakage may result in fire & explosion hazards	desired. • SOPs should be followed for operation of valves. • Preventive Maintenance of pump and piping is required, • Gas detectors system should be provided at strategic locations. • Tripping system should be provided and it will trip pump as soon as it loose Net Positive Suction Head (NPSH). • Fire fighting facilities should readily available.
3.	More	High Flow	Throttle valve is not functioning properly	• The downstream discharge line will be under pressure. • LPG pump being a centrifugal pump only churning will take place and discharge pressure will increase than rated pressure.	• SOPs should be followed for operation of valves.
4.	Reverse	Reverse flow of LPG inlet/out let piping	Not Likely	Operation Malfunction	As precautionary measures Non Return Valve (NRV) on the bullet side as well as on pump suction side should be provided.

Node 5: LPG Pump Discharge Line					
Intention: Pumping of LPG through Pump					***Parameter : Flow***
Sl.No.	***Guidewords***	***Deviations***	***Possible Cause***	***Consequences***	***Mitigation Measures***
5.	Other than	Corrosion	Pure LPG is not corrosive but Mercaptan added to LPG to create odour, may corrode pipeline.	Pipeline corrosion hence possibility of release of LPG.	Periodic internal inspection of pipeline should carried out at every 5 years to detect any corrosion
6.	As well as	Flow of Water as foreign Material along with LPG	Flow of water along with LPG.	No hazardous consequence only water will go along with LPG	Water draining is required in bullet

Pumping of LPG through Pump (Temperature)

Node 5: LPG Pump Discharge Line					
Intention: Pumping of LPG through Pump					***Parameter : Temperature***
Sl.No.	***Guidewords***	***Deviations***	***Possible Cause***	***Consequences***	***Mitigation Measures***
1.	More	High Temperature	Fire in vicinity of piping	• If temperature raise is not controlled piping may leak or rupture, • Fire & explosion hazards	• Fire hazards near piping should not be allowed. • Gas detectors system should be provided at strategic locations • Fire hydrant system should be readily available to extinguish fire at initial stage
2.	Less	Low Temperature	Very low Ambient Temperature	None, since freezing point of LPG is -188 oC. Freezing condition in LPG pipeline will not occur because lowest	None

Node 5: LPG Pump Discharge Line					
Intention: Pumping of LPG through Pump					*Parameter : Temperature*
Sl.No.	***Guidewords***	***Deviations***	***Possible Cause***	***Consequences***	***Mitigation Measures***
				temperature at Raiganj is about 10oC.	

Pumping of LPG through Pump (Pressure)

Node 5: LPG Pump Discharge Line					
Intention: Pumping of LPG through Pump					*Parameter : Pressure*
Sl.No.	***Guidewords***	***Deviations***	***Possible Cause***	***Consequences***	***Mitigation Measures***
1.	More	High Pressure	Suction line pressure higher than normal	The discharge line subjected to higher pressure	• Control the discharge pressure by using the valve on the circulation line provided in pump as well as Differential Pressure (DP) Valve in the discharge line may be used. • Pop Action relief valves are provided in the pipe line segments to take care of higher discharge pressure.
2	Less	Low Pressure	Leakage from Pump/Discharge Piping	• Fire & explosion hazard	• Preventive maintenance of piping should be ensured. • LPG detectors should be installed • Fire fighting facilities should readily available.

Filling of LPG in Cylinders through Rotary Machine (Flow)

Node 6: LPG Cylinder Filling Machine	
Intention: Filling of LPG in Cylinders through Rotary Machine	*Parameter : Flow*

Sl.No.	Guidewords	Deviations	Possible Cause	Consequences	Mitigation Measures
1.	None	No Flow	• LPG pump not working • LPG discharge line/hose is chocked • Filling gun hose is ruptured • Filling gun detached from cylinder at carousal	• Filling operation will be stopped and delayed • Release of LPG gas/vapour • Fire and explosion hazards	• Regular maintenance of pumps, pipeline/ hose, and filling gun • Regular inspection and testing of discharge line/hose, and filling gun. • Proper functioning and maintenance of filling machine desired • LPG detectors should be installed • Fire fighting facilities should readily available. • Earthing and bonding of filling machine, piping, hose and gun should be ensured.
2.	Less	Low Flow	• LPG discharge line/hose is partially chocked • Filling gun hose is leaking • LPG pump not running at its rated capacity	• Operational delay in filling of cylinders. • Release of LPG gas/vapour • Fire and explosion hazards	• Regular maintenance of pumps, pipeline/hose, and filling gun • Regular inspection and testing of discharge line/hose, and filling gun. • LPG detectors should be installed • Fire fighting facilities should readily available. • Earthing and bonding of filling machine, piping, hose and gun should be ensured.
3.	More	High Flow	Not Possible	None	None
4.	As well as	Flow of Foreign Material along	Water draining is not done in bullets. Therefore water is pumped along LPG and	No hazardous consequence, only water will filled along	Water draining from bullets is required regularly.

Node 6: LPG Cylinder Filling Machine					
Intention: Filling of LPG in Cylinders through Rotary Machine					***Parameter : Flow***
Sl.No.	***Guidewords***	***Deviations***	***Possible Cause***	***Consequences***	***Mitigation Measures***
		with LPG	filled with LPG in cylinders	with LPG in cylinders	
5.	Other than	Corrosion	Pure LPG is not corrosive but Mercaptan added to LPG to create odour, may corrode pipeline.	Pipeline/hose/gun corrosion hence possibility of release of LPG.	• Periodic internal inspection of pipeline/hose/gun should carried out at every 5 years to detect any corrosion • Cylinders should be tested at regular interval.
6.	Reverse	Reverse flow	Not Likely	Operation Malfunction	As precautionary measures Non Return Valve (NRV) should be provided.

Pumping of LPG through Pump (Temperature)

Node 6: LPG Cylinder Filling Machine					
Intention: Pumping of LPG through Pump					***Parameter : Temperature***
Sl.No.	***Guidewords***	***Deviations***	***Possible Cause***	***Consequences***	***Mitigation Measures***
1.	More	High Temperature	Fire in vicinity of piping/LPG cylinders filling shed	• If temperature raise is not controlled piping may leak or rupture, • Fire & explosion hazards	• Fire hazards near piping should not be allowed. • Gas detectors system should be provided at strategic locations • Fire hydrant system should be readily available to extinguish fire at initial stage
2.	Less	Low Temperature	Very low Ambient Temperature	None, since freezing point of LPG is -188 oC.	None

Node 6: LPG Cylinder Filling Machine					
Intention: Pumping of LPG through Pump					*Parameter : Temperature*
Sl.No.	*Guidewords*	*Deviations*	*Possible Cause*	*Consequences*	*Mitigation Measures*
				Freezing condition in LPG pipeline will not occur because lowest temperature at Raiganj is about 10oC.	

Pumping of LPG through Pump (Pressure)

Node 6: LPG Cylinder Filling Machine					
Intention: Pumping of LPG through Pump					*Parameter : Pressure*
Sl.No.	*Guidewords*	*Deviations*	*Possible Cause*	*Consequences*	*Mitigation Measures*
1.	More	High Pressure	Not Possible	None	None
2.	Less	Low Pressure	• Leakage from pipe/ hose • LPG pump not running at its rated capacity	• Less flow resulting in slow rate of LPG filling in cylinders • Fire & explosion hazards	• Preventive maintenance of pump, hose, piping should be ensured. • LPG detectors should be installed • Fire fighting facilities should readily available.

Transfer/Suction Line of LPG to Compressor (Flow)

Node 7: LPG Compressor Suction Line					
Intention: Transfer/Suction Line of LPG to Compressor					*Parameter : Flow*
Sl.No.	*Guidewords*	*Deviations*	*Possible Cause*	*Consequences*	*Mitigation Measures*

Node 7: LPG Compressor Suction Line					
Intention: Transfer/Suction Line of LPG to Compressor					***Parameter : Flow***
Sl.No.	***Guidewords***	***Deviations***	***Possible Cause***	***Consequences***	***Mitigation Measures***
1.	None	No Flow	• Vapour line is chocked • Valve is not open. • There is no vapour in vessel /Tank truck • Compressor break down due to power failure or other reasons	• Compressor cylinder heats up • Knocking of Compressor • Decantation operation of tank truck stopped and operation delay.	• Need of low suction tripping system • Open and close arrow marking at valve handles • High level tripping system with alarm needs to be provided on section side. • If power failure, DG sets should be operated immediately. • Preventive maintenance of Compressor
2.	Less	Low Flow	• Leakage in the vapour line • Vapour line is chocked • Valve is not open.	Fire and explosion hazards	• LPG detectors need to installed • Preventive maintenance of piping • Open and close arrow marking at valve handles should be provided.
3.	More	High Flow	• More flow in case excess flow check valves not working • Pipeline/valve leak due to impact or other reasons	• LPG Vapour release hence asphyxiation problems • Fire and explosion hazards	• Inspection of line is required before starting the compressor • LPG detectors should be installed • Preventive maintenance of excess flow check valves • Fire hydrant can be operated. Hence, the fire hydrant ring should always remain pressurized.
4	Other than	Corrosion	Pure LPG is not corrosive but Mercaptan	Pipeline/bullet corrosion hence	• Periodic internal inspection of pipeline and LPG bullets should carried out at

Node 7: LPG Compressor Suction Line					
Intention: Transfer/Suction Line of LPG to Compressor					***Parameter : Flow***
Sl.No.	***Guidewords***	***Deviations***	***Possible Cause***	***Consequences***	***Mitigation Measures***
			added to LPG to create odour, may corrode pipeline /bullet	possibility of release of LPG vapours.	every 5 years to detect any corrosion • Cathodic protection needs to be provided to both mounded bullets to prevent from corrosion.

Transfer/Suction Line of LPG to Compressor (Temperature)

Node 7: LPG Compressor Suction Line					
Intention: Transfer/Suction Line of LPG to Compressor					***Parameter : Temperature***
Sl.No.	***Guidewords***	***Deviations***	***Possible Cause***	***Consequences***	***Mitigation Measures***
1.	More	High Temperature	Fire in the vicinity	• Vapour pressure/ internal pressure rise in piping /bullet due to fire in the vicinity. It may cause SRV actuation hence fire hazards. • If SRVs fails to actuate or fire is not controlled bullet may rupture	• Fire hazards near piping should not be allowed. • Regular maintenance of SRVs desired. • Fire control measures should work properly. • Auto medium velocity water sprinkler system should be operated.
2.	Less	Low Temperature	Very low Ambient Temperature	None, since freezing point of LPG is -188 oC. Freezing condition in LPG pipeline will not occur because lowest temperature at Raiganj is about 10oC.	None

Transfer/Suction Line of LPG to Compressor (Pressure)

Node 7: LPG Compressor Suction Line					
Intention: Transfer/Suction Line of LPG to Compressor					*Parameter : Pressure*
Sl.No.	*Guidewords*	*Deviations*	*Possible Cause*	*Consequences*	*Mitigation Measures*
1.	More	High Pressure	Higher Pressure in bullet Fire/heating on external surface of bullet	Vapour line may leak/ burst and subsequently release of LPG Fire and Explosion	• Pressure gauge with alarm should be provided to bullets • Regular maintenance of SRVs desired. • Fire control measures should work properly. • Auto medium velocity water sprinkler system should be operated.
2.	Less	Low Pressure	Leakage LPG from piping	Fire & Explosion Hazards	• Preventive maintenance of piping • LPG detectors should be installed • Fire control measures should work properly.

Transfer of LPG Vapour through Discharge Line (Flow)

Node 8: LPG Compressor Discharge Line					
Intention: Transfer of LPG Vapour through Discharge Line					*Parameter : Flow*
Sl.No.	*Guidewords*	*Deviations*	*Possible Cause*	*Consequences*	*Mitigation Measures*
1.	None	No Flow	• Compressor is not working due power failure and other	• Delay in decantation • Fire and explosion hazards	• Preventive maintenance and daily inspection of LPG of compressor and piping should be ensured.

Node 8: LPG Compressor Discharge Line					
Intention: Transfer of LPG Vapour through Discharge Line					**Parameter : Flow**
Sl.No.	**Guidewords**	**Deviations**	**Possible Cause**	**Consequences**	**Mitigation Measures**
			reasons • Rupture of vapour line • Valve is not open • Pipeline is chocking	• Back pressure on compressor	• Open and close arrow marking at valve handles should be provided. • Fire fighting facilities should be readily available. • If power failure, DG sets should be operated immediately. • There should be provision in discharge pipeline to prevent compressor from back pressure effect.
2.	Less	Low Flow	• Leakage in Vapour line • Valve is not open • Pipeline is chocking	• Delay in decantation • Fire and explosion hazards	• Preventive maintenance and daily inspection of LPG vapour piping should be ensured. • Open and close arrow marking at valve handles should be provided. • Fire fighting facilities should be readily available. .
3.	More	High Flow	• Not Likely	• None	• None
4.	Other Than	Corrosion	Pure LPG vapours are not corrosive but Mercaptan added to LPG to create odour, may corrode vapour piping.	• Vapour piping failure hence release of LPG vapour may occur. • Fire and explosion hazards	• Periodic internal inspection of LPG Vapour piping should carried out at every 5 years to detect any corrosion

Transfer of LPG Vapour through Discharge Line (Temperature)

Node 8: LPG Compressor Discharge Line					
Intention: Transfer of LPG Vapour through Discharge Line					***Parameter : Temperature***
Sl.No.	***Guidewords***	***Deviations***	***Possible Cause***	***Consequences***	***Mitigation Measures***
1.	More	High Temperature	• Cylinder jacket of compressor is not being cooled properly. • The discharge line of compressor heats up due to external file or flame. • Vapour piping heated due fire in vicinity	• The compressor heats up and then fails /trips • Pipeline hose may fail due to high temperature fire and explosion hazards.	• Regular checking/ maintenance cooling water line to compressor. • Fire fighting facilities should be readily available.
2.	Less	Low Temperature	Very low Ambient Temperature	None, since freezing point of LPG is -188 oC. Freezing condition in LPG vapour pipeline will not occur.	None

Transfer of LPG Vapour through Discharge Line (Pressure)

Node 8: LPG Compressor Discharge Line					
Intention: Transfer of LPG Vapour through Discharge Line					***Parameter : Pressure***
Sl.No.	***Guidewords***	***Deviations***	***Possible Cause***	***Consequences***	***Mitigation Measures***
1.	Less	Low Pressure	• Compressor is not working properly	• Delay in decantation of Tank	• Preventive maintenance of compressor and piping

Node 8: LPG Compressor Discharge Line					
Intention: Transfer of LPG Vapour through Discharge Line					***Parameter : Pressure***
Sl.No.	***Guidewords***	***Deviations***	***Possible Cause***	***Consequences***	***Mitigation Measures***
			• Leakage LPG from piping	Truck • Fire & explosion hazards	• LPG detectors should be installed • Fire control measures should work properly
2.	More	High Pressure	Higher Pressure in bullet Fire/heating on external surface of bullet	Vapour line may leak/ burst and subsequently release of LPG Fire and explosion	• Fire control measures should work properly • Fire hazards near piping should not be allowed.

Storage of LPG in Above Ground Bullets (Level)

Node 9: LPG above Ground Bullets					
Intention: Storage of LPG in Above Ground Bullets					***Parameter : Level***
Sl.No.	***Guidewords***	***Deviations***	***Possible Cause***	***Consequences***	***Mitigation Measures***
1.	Less	Low Level	• Leakage from bottom line. • Leakage from valve. • Leakage from drain line. • Less quantity of LPG in the bullet • Rochester Gauge is not giving correct	• Operation delay • Release of LPG • Fire and explosion hazards.	• Calibration of Rochester Gauge should be ensured. • Regular inspection and maintenance of piping, valves, level gauge.

Node 9: LPG above Ground Bullets					
Intention: Storage of LPG in Above Ground Bullets				***Parameter : Level***	
Sl.No.	***Guidewords***	***Deviations***	***Possible Cause***	***Consequences***	***Mitigation Measures***
			reading		
2.	More	High Level	Initial quantities in bullet not ascertained faulty Rochester Gauge Human Error in Reading of Rochester Gauge	Over filling of LPG in bullets Liquid may knock to compressor LPG Release from SRV Possibility fire and explosion	High Level Alarm (HLA) should be provided Ensure proper operating procedures. Ensure calibration and maintenance of Rochester Gauge High level suction tripping for compressor is required.

Storage of LPG in Above Ground Bullet (Pressure)

Node 9: LPG above Ground Bullets					
Intention: Storage of LPG in Above Ground Bullets				***Parameter : Pressure***	
Sl.No.	***Guidewords***	***Deviations***	***Possible Cause***	***Consequences***	***Mitigation Measures***
1.	Less	Low Pressure	Low Ambient Temperature Less quantity of LPG in bullet	--	--
2.	More	High Pressure	High level of LPG liquid in Bullet. Due to heat isolation by sun	Possibility of release of LPG Possibility fire and explosion	Proper function of pressure gauge required. Two Safety Release Valves (SRV) to be provided at the bullet. Regular testing of SRVs desired.

Node 9: LPG above Ground Bullets					
Intention: Storage of LPG in Above Ground Bullets					*Parameter : Pressure*
Sl.No.	***Guidewords***	***Deviations***	***Possible Cause***	***Consequences***	***Mitigation Measures***
			Fire in the vicinity above ground bullets Thermal radiation on the bullets in the event of fire in bay TLD which close bullets	LPG Liquid may knock compressor	Auto medium velocity water sprinkler system should be operated. Fire fighting facilities should be readily available. Water curtain should provide between bay TLD and above ground bullets

Storage of LPG in Above Ground Bullet (Temperature)

Node 9: LPG above Ground Bullets					
Intention: Storage of LPG in Above Ground Bullets					*Parameter : Temperature*
Sl.No.	***Guidewords***	***Deviations***	***Possible Cause***	***Consequences***	***Mitigation Measures***
1.	More	High Temperature	Heat isolation by sun in hot summer Fire in the vicinity bullet Thermal radiation on the bullets in the event of fire in bay TLD which close bullets	Possibility of raise in pressure in the bullet. Possibility of release of LPG Possibility fire and explosion	Proper function of temperature gauge is required. Two Safety Release Valves (SRV) to be provided at the bullet. Regular testing of SRVs desired. Auto medium velocity water sprinkler system should be operated. Fire fighting facilities should be readily available. Water curtain should provide between bay TLD and bullets

Node 9: LPG above Ground Bullets					
Intention: Storage of LPG in Above Ground Bullets					*Parameter : Temperature*
Sl.No.	***Guidewords***	***Deviations***	***Possible Cause***	***Consequences***	***Mitigation Measures***
2.	Less	Low Temperature	Very low Ambient Temperature	None, since freezing point of LPG is -188 oC. Freezing condition in LPG vapour pipeline will not occur.	None

Storage of LPG in Above Ground Bullet (Water Draining)

Node 9: LPG above Ground Bullets					
Intention: Storage of LPG in Above Ground Bullets					*Parameter : Water Draining*
Sl.No.	***Guidewords***	***Deviations***	***Possible Cause***	***Consequences***	***Mitigation Measures***
1.	As well as	As well as Water with LPG	Water may come along with LPG, if water draining is not done	Possibility of release of LPG during water draining Possibility fire and explosion	Water draining to be done under strict supervision and following SOPs. Written instructions on water draining mechanism to be displayed near drain point. LPG detectors should be installed near drain points. Fire fighting facilities should be readily available.

Storage of LPG in Above Ground Bullet (Corrosion)

Node 9: LPG above Ground Bullets	
Intention: Storage of LPG in Above Ground Bullets	*Parameter : Corrosion*

Sl.No.	Guidewords	Deviations	Possible Cause	Consequences	Mitigation Measures
1.	Other Than	Corrosion	Pure LPG vapours are not corrosive but Mercaptan added to LPG to create odour, may corrode vapour piping.	• Corrosion of Bullet • Fire and explosion hazards	• Periodic internal inspection/testing of LPG bullets should carried out at every 5 years to detect any corrosion

Storage of LPG in proposed Mounded Bullet (Level)

Sl.No.	Guidewords	Deviations	Possible Cause	Consequences	Mitigation Measures
Node 10: LPG Mounded Bullets					
Intention: Storage of LPG in LPG Mounded Bullet					***Parameter : Level***
Sl.No.	***Guidewords***	***Deviations***	***Possible Cause***	***Consequences***	***Mitigation Measures***
1.	Less	Low Level	• Leakage from bottom line. • Leakage from valve. • Leakage from drain line. • Less quantity of LPG in the bullet • Rochester Gauge is not giving correct reading	• Operation delay • Release of LPG • Fire and explosion hazards.	• Calibration of Rochester Gauge should be ensured. • Magnetic Level Indicator to be required. • Regular inspection and maintenance of piping, valves, level gauge. • Cathodic protection is desired to mounded bullets to prevent corrosion.
2.	More	High Level	Initial quantities in bullet not ascertained due to faulty Rochester Gauge Human error in reading	Over filling of LPG in bullets Liquid may knock to compressor LPG Release from SRV	High Level Alarm (HLA) should be provided Magnetic Level Indicator is required. Ensure proper operating procedures. Ensure calibration and maintenance of

Node 10: LPG Mounded Bullets					
Intention: Storage of LPG in LPG Mounded Bullet					***Parameter : Level***
Sl.No.	***Guidewords***	***Deviations***	***Possible Cause***	***Consequences***	***Mitigation Measures***
			of Rochester Gauge	Possibility fire and explosion	Rochester Gauge High level suction tripping for compressor is required.

Storage of LPG in Mounded Bullet (Pressure)

Node 10: LPG Mounded Bullet					
Intention: Storage of LPG in Mounded Bullet					***Parameter : Pressure***
Sl.No.	***Guidewords***	***Deviations***	***Possible Cause***	***Consequences***	***Mitigation Measures***
1.	Less	Low Pressure	Low Ambient Temperature Less quantity of LPG in Mounded bullets	--	--
2.	More	High Pressure	High level of LPG liquid in mounded bullet.	Possibility of release of LPG LPG Liquid may knock compressor No possibility of surface heating of mounded bullets and hence no possibility of BLEVE in mounded bullets	Proper function of pressure gauge required. Two Safety Release Valves (SRV) provided at the mounded bullet. Regular testing of SRVs desired. Fire fighting facilities should be readily available.

Storage of LPG in Mounded Bullet (Temperature)

Node 10: LPG Mounded Bullet					
Intention: Storage of LPG in Mounded Bullet					***Parameter : Temperature***
Sl.No.	***Guidewords***	***Deviations***	***Possible Cause***	***Consequences***	***Mitigation Measures***
1.	More	High Temperature	Heat isolation by sun in hot summer will not much affect mounded vessels as these are covered in mound.	Possibility of slight raise in pressure in the bullet.	Proper function of temperature gauge is required. Two Safety Release Valves (SRV) provided at the bullet. Regular testing of SRVs desired. Fire fighting facilities should be readily available.
2.	Less	Low Temperature	Very low Ambient Temperature	None, since freezing point of LPG is -188 oC. Freezing condition in LPG vapour pipeline will not occur becauselowest temperature at Raiganj is about 10oC.	None

Storage of LPG in Mounded Bullet (Water Draining)

Node 10: LPG Mounded Bullet					
Intention: Storage of LPG in Mounded Bullet					***Parameter : Water Draining***
Sl.No.	***Guidewords***	***Deviations***	***Possible Cause***	***Consequences***	***Mitigation Measures***
1.	As well as	As well as water with LPG	Water may come along with LPG, if water draining is	Possibility of release of LPG during water draining	Water draining to be done under strict supervision and following SOPs. Written instructions on water draining mechanism

Node 10: LPG Mounded Bullet					
Intention: Storage of LPG in Mounded Bullet					***Parameter : Water Draining***
Sl.No.	***Guidewords***	***Deviations***	***Possible Cause***	***Consequences***	***Mitigation Measures***
			not done	Possibility fire and explosion	to be displayed near drain point. LPG detectors should be installed near drain points. Fire fighting facilities should be readily available.

Storage of LPG in Mounded Bullet (Corrosion)

Node 10: LPG Mounded Bullet					
Intention: Storage of LPG in Mounded Bullet					***Parameter: Corrosion***
Sl.No.	***Guidewords***	***Deviations***	***Possible Cause***	***Consequences***	***Mitigation Measures***
1.	Other Than	Corrosion	Pure LPG vapours are not corrosive but Mercaptan added to LPG to create odour, may corrode vapour piping.	Corrosion of Bullet Fire and explosion hazards	Periodic internal inspection/testing of LPG bullets should carried out as per schedule to detect any corrosion in mounded bullets

Transfer of LPG from Tank Truck to Bullet from New TLD (Flow)

Node 11: New Tank Truck Decantation Shed for Unloading of LPG to AG Bullets/Mounded Vessels					
Intention: Transfer of LPG from Tank Truck to Bullet from proposed TLD					***Parameter: Flow***
Sl.No.	***Guidewords***	***Deviations***	***Possible Cause***	***Consequences***	***Mitigation Measures***
1.	None	No Flow	Tank Truck is empty Valve is not open	Delay in LPG unloading	SOPs should be followed.

Node 11: New Tank Truck Decantation Shed for Unloading of LPG to AG Bullets/Mounded Vessels					
Intention: Transfer of LPG from Tank Truck to Bullet from proposed TLD					**Parameter: Flow**
Sl.No.	**Guidewords**	**Deviations**	**Possible Cause**	**Consequences**	**Mitigation Measures**
			Pipeline chocked	Transfer pipeline and hose under pressure Delay in LPG unloading	High discharge pressure tripping system should be provided for compressor
			Failure of unloading arm/hose	Transfer line under pressure Leakage of LPG Fire & Explosion Hazards	Excess flow check valve on tank truck side as well as on hose side should close automatically
			Any of the valve between tank lorry and LPG Bullet is closed	Transfer line under pressure Delay in LPG unloading	High discharge pressure tripping system should be provided for compressor
2.	Less	Low Flow	Pressure differential is less between the bullet/vessel and LPG Tank Truck Leakage in Piping Excess Flow check valve of the tank truck is partially closing at a pressure differential less than rated.	More time required for decantation Fire & Explosion Hazards	Inter distances between new bay TLD and bullets need to be as OISD guidelines Excess Flow check valve to be checked SOPs should be followed. Preventive maintenance of pump, compressor and piping need to be ensured. LPG detectors should be installed Fire control measures should work properly
3.	More	High Flow	More flow is not possible as excess flow check	None	None

Node 11: New Tank Truck Decantation Shed for Unloading of LPG to AG Bullets/Mounded Vessels					
Intention: Transfer of LPG from Tank Truck to Bullet from proposed TLD					***Parameter: Flow***
Sl.No.	***Guidewords***	***Deviations***	***Possible Cause***	***Consequences***	***Mitigation Measures***
			valve provided on tank truck & pipeline.		
4.	Reverse	Reverse Flow	Not possible as None Return Valve (NRV) provided in transfer line.	None	None

Transfer of LPG from Tank Truck to Bullet from New TLD (Temperature)

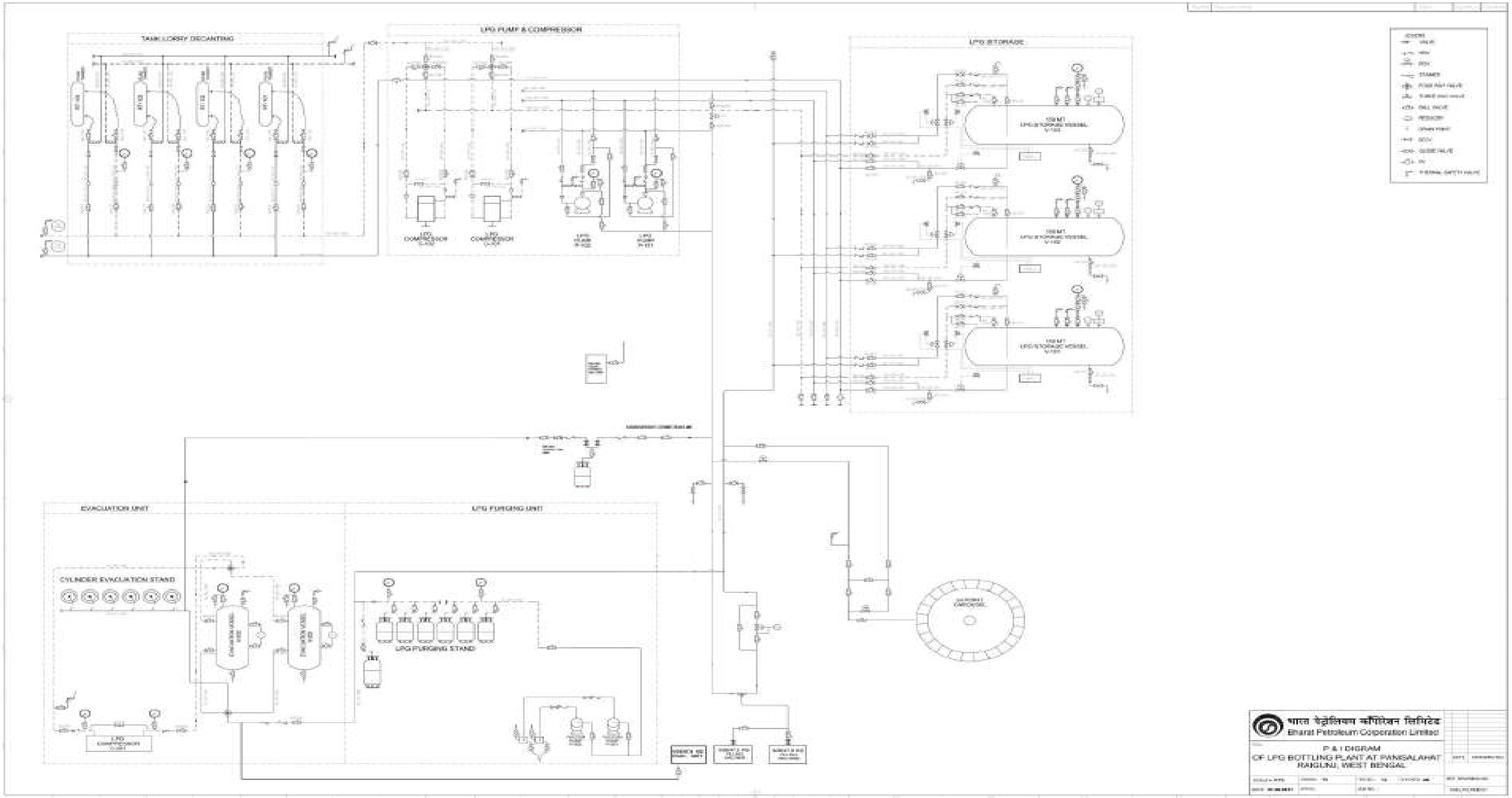
Node 11: New Tank Truck Decantation Shed for Unloading of LPG to AG Bullets/Mounded Vessels					
Intention: Transfer of LPG from Tank Truck to Bullet from proposed TLD					***Parameter: Temperature***
Sl.No.	***Guidewords***	***Deviations***	***Possible Cause***	***Consequences***	***Mitigation Measures***
1.	More	High Temperature	Fire in vicinity of new bay TLD	If temperature raise is not controlled unloading hose will be ruptured, Fire & explosion hazards/BLEVE Danger to AG Bullets and bay TLD is located very close to AG bullets	Inter distances between new bay TLD and bullets need to be as OISD guidelines SOPs for unloading of LPG to be followed. Cooling of tank truck by water spray
			Fire in Tank Truck Decantation (TLD) shed causing heating of tank truck	Danger to AG Bullets and bay TLD is located very close to AG bullets	Ensure proper functioning of fire fighting system & cooling of AG bullets and bay TLD

Node 11: New Tank Truck Decantation Shed for Unloading of LPG to AG Bullets/Mounded Vessels					
Intention: Transfer of LPG from Tank Truck to Bullet from proposed TLD					***Parameter: Temperature***
Sl.No.	***Guidewords***	***Deviations***	***Possible Cause***	***Consequences***	***Mitigation Measures***
2.	Less	Low Temperature	Very low Ambient Temperature	None, since freezing point of LPG is -188 oC. Freezing condition in LPG pipeline will not occur because lowest temperature at Raiganj is about 10oC.	None

Transfer of LPG from Tank Truck to Bullet from New TLD (Pressure)

Node 11: New Tank Truck Decantation Shed for Unloading of LPG to AG Bullets/Mounded Vessels					
Intention: Transfer of LPG from Tank Truck to Bullet from proposed TLD					***Parameter: Pressure***
Sl.No.	***Guidewords***	***Deviations***	***Possible Cause***	***Consequences***	***Mitigation Measures***
1.	More	High Pressure	By mistake isolation valves closed while compressor running	Transfer line subjected to high pressure	In case of higher pressure stop operation and check the transfer line. Auto tripping system should be provided
2.	Less	Low Pressure	Leakage LPG from Hose/piping Compressor is not able to create adequate differential pressure	Fire & explosion hazards	Cooling of tank truck by water spray Ensure proper working of LPG compressor SOPs for unloading of LPG to be followed

Source: ABC Techno Labs India Pvt. Ltd.



Source: BPCL Raiganj LPG Plant

Figure 7.1: P&I Diagram of the LPG Bottling Plant at Raiganj

7.10 CONSEQUENCE ANALYSIS

Subsequent to the accidental release of a LPG from BPCL Raiganj Bottling Plant, the consequence will depend on various factors e.g. type release and quantity, presence and location of an ignition source, meteorological conditions, etc.

7.10.1 SELECTED SCENARIOS FOR CONSEQUENCE ANALYSIS

Based on hazard identification (HAZID) and hazard & operability (HAZOP) study, the maximum credible and worst case scenarios have been selected for consequence analysis. The selected scenarios for consequence analysis are given in Table 7.8:

Table 7.8: Selected Scenarios for Consequence Analysis

<table>
<tr><th>Sl. No</th><th>Release Source</th><th>Failure Mode</th><th>Possible Outcomes</th></tr>
<tr><td rowspan="2">1.</td><td rowspan="2">Mounded Bullet (300 MT)</td><td rowspan="2">Rupture of Bottom Line</td><td>Jet Fire</td></tr>
<tr><td>Flash Fire/Vapour Cloud Explosion</td></tr>
<tr><td rowspan="2">2.</td><td rowspan="2">Mounded Bullet (300 MT)</td><td rowspan="2">Leak (25 mm) in Bottom Line</td><td>Jet Fire</td></tr>
<tr><td>Flash Fire/Vapour Cloud Explosion</td></tr>
<tr><td rowspan="2">3.</td><td rowspan="2">SRV on Mounded Bullets</td><td rowspan="2">Release from SRV on mounded bullets</td><td>Jet Fire</td></tr>
<tr><td>Flash Fire/ Vapour Cloud Explosion</td></tr>
<tr><td rowspan="3">4.</td><td rowspan="3">LPG Above Ground Bullet (150 MT)</td><td rowspan="3">Catastrophic Rupture</td><td>BLEVE</td></tr>
<tr><td>Flash Fire/ Vapour Cloud Explosion</td></tr>
<tr><td>Flash Fire/ Vapour Cloud Explosion</td></tr>
<tr><td rowspan="3">5.</td><td rowspan="3">SRV on Above Ground Bullet</td><td rowspan="3">Release of LPG from SRV on 150 AG bullet</td><td>Jet Fire</td></tr>
<tr><td>Flash Fire/ Vapour Cloud Explosion</td></tr>
<tr><td>Flash Fire/ Vapour Cloud Explosion</td></tr>
<tr><td rowspan="2">6.</td><td rowspan="2">Transfer Piping for unloading of LPG from Tank Truck</td><td rowspan="2">Rupture of Transfer Piping</td><td>Jet Fire</td></tr>
<tr><td>Flash Fire/Vapour Cloud Explosion</td></tr>
<tr><td rowspan="2">7.</td><td rowspan="2">LPG Pump</td><td rowspan="2">Leak Due to Mechanical Seal from LPG Pump</td><td>Jet Fire</td></tr>
<tr><td>Flash Fire/Vapour Cloud Explosion</td></tr>
<tr><td rowspan="2">8.</td><td rowspan="2">LPG Compressor</td><td rowspan="2">Leak from LPG Compressor</td><td>Jet Fire</td></tr>
<tr><td>Flash Fire/Vapour Cloud Explosion</td></tr>
<tr><td rowspan="2">9.</td><td rowspan="2">LPG Tank Truck</td><td rowspan="2">Catastrophic Rupture (Fire) of LPG Bullet Truck</td><td>BLEVE</td></tr>
<tr><td>Flash Fire/Vapour Cloud Explosion</td></tr>
<tr><td rowspan="2">10.</td><td rowspan="2">LPG Cylinder</td><td rowspan="2">Catastrophic Rupture (Fire) of Cylinder</td><td>BLEVE</td></tr>
<tr><td>Flash Fire/Vapour Cloud Explosion</td></tr>
<tr><td rowspan="2">11.</td><td rowspan="2">LPG Cylinder</td><td rowspan="2">Leakage from LPG Cylinder</td><td>Jet Fire</td></tr>
<tr><td>Flash Fire/Vapour Cloud Explosion</td></tr>
<tr><td rowspan="2">12.</td><td rowspan="2">LPG Filling Gun</td><td rowspan="2">Release from Filling Gun at Carousel</td><td>Jet Fire</td></tr>
<tr><td>Flash Fire/Vapour Cloud Explosion</td></tr>
<tr><td rowspan="2">13.</td><td rowspan="2">Carousel for Filling of LPG</td><td rowspan="2">Central Column Failure of Carousel Machine</td><td>BLEVE</td></tr>
<tr><td>Flash Fire/Vapour Cloud Explosion</td></tr>
<tr><td>14.</td><td>LPG Hose at Carousel</td><td>LPG Hose Failure at Carousel</td><td>Jet Fire</td></tr>
</table>

Sl. No	Release Source	Failure Mode	Possible Outcomes
			Flash Fire/Vapour Cloud Explosion

Source: ABC Techno Labs India Pvt. Ltd.

7.10.2 CONSEQUENCE ANALYSIS

The consequence analysis for the selected release scenarios for BPCL LPG Bottling Plant at Raiganj has been carried out to compute consequence distances or vulnerability zone. Once the effect distances are computed for various failure cases, risk from the can be quantified and appropriate measures can be taken for risk mitigation to eliminate possibility of damage to life and property and to enhance the safety.

❑ ***Model Used For Consequence Analysis***

The risk assessment study involves a large number of computations for which established computing aids are essential.

PHAST software of DNV has been used to perform the consequence calculations. PHAST is consequence analysis software for calculation of physical effects (fire, explosion, atmospheric dispersion) of the escape of hazardous materials. PHAST software allows detailed modelling and quantitative assessment of release of pure chemicals and mixtures.

7.10.3 CONSEQUENCE ANALYSIS FOR LPG RELEASE SCENARIOS

The consequence analysis has been carried out for various LPG release scenarios for Raiganj LPG Bottling Plant as described in Table 7.7. Outcomes of consequence analysis have been described in subsequent subsections.

7.10.3.1 CATASTROPHIC RUPTURE OF BOTTOM LINE OF 300 MT MOUNDED VESSEL

In this scenario, accidental release of LPG has been considered as result of rupture of bottom line connected with mounded bullet. Mounded bullets are located within the plant; hence, any release of LPG will be attended promptly within very short duration:

I. UEL and LEL Concentration Distances

In the event of release of LPG due to rupture of bottom line, vapour cloud will be formed if it is not getting source of ignition. LPG vapours under UEL and LEL concentration will occur at following distances.

UEL and LEL Concentration Distances

Concentration	UEL and LEL Concentration Distances (m)

	B - 3 m/s	D – 3 m/s	E - 2 m/s
UEL	1.37586	1.52465	1.26391
LEL	18.1476	20.9281	20.0941

UEL and LEL Concentration Height

Concentration	UEL and LEL Concentration Height (m)		
	B - 3 m/s	D – 3 m/s	E - 2 m/s
UEL	34.3464	34.9926	37.4822
LEL	81.0856	84.2724	93.081

II. Flash Fire Envelope

On delayed ignition of LPG vapours within UEL and LEL, flash fire envelope will form as indicated below:

	Flash Fire Envelope (m)		
	B - 3 m/s	D - 3 m/s	E - 2 m/s
Farthest Lateral Extent	18.1476	20.9281	20.0941
Farthest Vertical Extent	81.0856	84.2724	93.081

Flash fire envelope due to delayed ignition is presented in Figure 7.2.

Figure 7.2: Flash Fire Envelopes for Rupture of Bottom Line

III. Explosion Effects (Delayed Ignition)

LPG vapours within the range of UEL and LEL will form explosive mass and result in overpressure wave on ignition if some degree of confinement is present. Overpressure distances under explosion effects are given below:

Over Pressure (bar)	Overpressure Distances (m)		
	B - 3 m/s	D - 3 m/s	E - 2 m/s
0.1	64.3442	79.7352	81.9107
0.15	45.9811	59.5504	60.9908
0.2	35.7683	48.3245	49.356

Late explosion worst case distances due to delayed ignition are presented in Figure 7.3.

Figure 7.3: Late Explosion Worst Case for Rupture of Bottom Line

IV. Jet Fire on Immediate Ignition

On release of LPG in case of rupture of bottom line of mounded bullet, jet fire will occur on immediate ignition. Thermal radiation maximum distances from jet fire source are given below:

Radiation Level	Thermal Radiation Level Distances (m)		
	B - 3 m/s	D – 3 m/s	E - 2 m/s
37.5 kW/m^2	12.7051	12.7051	7.42857
12.5 kW/m^2	86.4389	86.4389	80.6368
4 kW/m^2	170.193	170.193	176.35

Thermal radiation intensities from jet fire are presented in Figure 7.4.

Figure 7.4: Intensity Radii for Jet Fire for Rupture of Bottom Line

7.10.3.2 Leak (25 mm) from Bottom Line from 300 MT Mounded Vessel

In this scenario, accidental release of LPG has been considered as result of hole (25 mm) in bottom line connected with mounded bullet, which is located within the Raiganj LPG bottling plant. Any release of LPG at the plant will be attended promptly.

I. UEL and LEL Concentration Distances

In the event of no ignition, LPG vapour cloud will be formed. The concentrations of LPG within UEL and LEL will occur at following distances.

Concentration	UEL and LEL Concentration Distances (m)		
	B - 3 m/s	D – 3 m/s	E - 2 m/s
UEL	0.226625	0.231042	0.165127
LEL	3.06972	3.14793	2.93988

II. UEL and LEL Concentration Height

Concentration	UEL and LEL Concentration Height (m)		
	B - 3 m/s	**D – 3 m/s**	**E - 2 m/s**
UEL	7.44151	7.68416	8.36371
LEL	17.9833	18.7007	22.0612

III. Flash Fire Envelope

Details of flash fire envelope formed by ignition of LPG vapours within UEL and LEL are given below:

	Flash Fire Envelope (m)		
	B - 3 m/s	**D - 3 m/s**	**E - 2 m/s**
Farthest Lateral Extent	3.06972	3.14793	2.93988
Farthest Vertical Extent	17.9833	18.7007	22.0612

Flash fire envelope due to delayed ignition is presented in Figure 7.5.

Figure 7.5: Flash Fire Envelopes for Rupture of Bottom Line

IV. Explosion Effects (Delayed Ignition)

No explosion hazard will occur under any stability class and wind speed due to this scenario.

V. Jet Fire on Immediate Ignition

On release of LPG in the event of leakage (25 mm) in bottom line of mounded bullet, jet fire will occur on immediate ignition. Thermal radiation levels from jet fire at various distances are given below:

Radiation Level	Thermal Radiation Level Distances (m)		
	B - 3 m/s	**D – 3 m/s**	**E - 2 m/s**
37.5 kW/m^2	7.29353	7.29353	4.56702
12.5 kW/m^2	24.941	24.941	24.0972
4 kW/m^2	44.5199	44.5199	46.68

Thermal radiation intensities from jet fire are presented in Figure 7.6.

Figure 7.6: Intensity Radii for Jet Fire Due Leak from Bottom Line

7.10.3.3 Release LPG from SRV on 300 MT Mounded Bullet

LPG release from Safety Release Valve (SRV) of mounded bullet of 300 MT has been considered in this scenario. Released LPG from SRV will be moved towards wind direction and flash fire will take place on getting source of ignition.

I. UEL and LEL Concentration Distances in Delayed Ignition

In the event of delayed ignition of released LPG SRV, vapour cloud will be formed and concentrations under UEL and LEL will occur at the following distances.

Concentration	**UEL and LEL Concentration Distances (m)**		
	B - 3 m/s	**D - 3 m/s**	**E - 2 m/s**
UEL	0.264049	0.271158	0.190315
LEL	4.23762	4.85747	4.04785

Concentration	**UEL and LEL Concentration Height (m)**		
	B - 3 m/s	**D - 3 m/s**	**E - 2 m/s**
UEL	16.696	16.8545	17.3753
LEL	41.2221	42.6589	47.3753

II. Flash Fire Envelope

On ignition of concentration within in UEL and LEL, flash fire envelope will take place as per details given below:

	Flash Fire Envelope (m)		
	B - 3 m/s	D - 3 m/s	E - 2 m/s
Farthest Lateral Extent	4.23762	4.85747	4.04785
Farthest Vertical Extent	41.2221	42.6589	47.3753

Flash fire envelopes for release of LPG from SRV due to delayed ignition are presented in Figure 7.7.

Figure 7.7: Flash Fire Envelopes from SRV Release

III. Explosion Effects (Delayed Ignition)

No explosion hazard will occur under any stability class and wind speed for release of LPG for SRV as there will not be explosive mass.

IV. Jet Fire on Immediate Ignition

On release of LPG from safety release valve on mounded bullet, jet fire will occur on immediate ignition. Thermal radiation levels at various distances from jet fire are given below:

Radiation Level	Thermal Radiation Level Distances (m)		
	B - 3 m/s	D - 3 m/s	E - 2 m/s
37.5 kW/m^2	Not Reached	Not Reached	Not Reached
12.5 kW/m^2	21.9175	21.9175	Not Reached
4 kW/m^2	78.477	78.477	70.848

Thermal radiation intensity radii due to jet fire as result of SRV release are presented in Figure 7.8.

Figure 7.8: Intensity Radii for Jet Fire from SRV

7.10.3.4 Catastrophic Rupture of Above Ground LPG Bullet (150 MT)

In the event of catastrophic rupture of 150 MT LPG bullets, BLEVE may be occurred on immediate ignition. Various outcomes in the event ofcatastrophic rupture of LPG bullet will be as given below under different stability classes:

I. BLEVE: Fire Ball Hazards

Outcome Parameters	Values
Duration of Fire Ball, (s)	18.89
Radius of Fire Ball, (m)	155.87
Fireball Lift Off Height (m)	311.75
Flame Emissive Power (kW/m2)	345.60

II. Thermal Radiation: Fireball Ellipse

Radiation Effects	B - 3 m/s	D - 3 m/s	E - 2 m/s
37.5 kW/m2	181.108	181.108	181.108
12.5 kW/m2	493.612	493.612	493.612
4 kW/m2	914.94	914.94	914.94

Thermal radiation intensity radii due to fireball ellipse are presented in Figure 7.9.

Figure 7.9: Fire Ball Ellipse due to Rupture of 150 MT Bullet

III. UEL & LEL Concentrations Distance (m)

Concentration	B - 3 m/s	D - 3 m/s	E - 2 m/s
UEL	99.247	99.5786	99.6033
LEL	428.956	431.03	433.085

Note: All values are in m

IV. Flash Fire Envelope

Concentration Distance (m)

Concentration	B - 3 m/s	D - 3 m/s	E - 2 m/s
Furthest Extent (LEL)	428.956	431.03	433.085

Flash fire envelopes due to delayed ignition are presented in Figure 7.10.

Figure 7.10: Flash Fire Envelope due to Rupture of 150 MT Bullet

V. Explosion Effects: Delayed Ignition

Maximum Distance (m) at Overpressure Level due to Early Explosion

Concentration	B - 3 m/s	D - 3 m/s	E - 2 m/s
Overpressure (0.1 bar)	387.526	387.526	387.526

Maximum Distance (m) at Overpressure Level due to Late Explosion

Concentration	B - 3 m/s	D - 3 m/s	E - 2 m/s
Overpressure (0.1 bar)	551.288	568.676	563.596

Late explosion worst case distances due to delayed ignition are presented in Figure 7.11.

Figure 7.11: Late Explosion Radii due to Rupture of 150 MT Bullet

7.10.3.5 Release of LPG from SRV on 150 MT Bullet

LPG release from Safety Release Valve (SRV) of 150 MT LPG bullets has been considered in this scenario.

I. UEL and LEL Concentration Distances in Delayed Ignition

In the event of delayed ignition of released LPG, vapour cloud will be formed and concentrations under UEL and LEL will occur at following distances.

Concentration	UEL and LEL Concentration Distances (m)		
	B - 3 m/s	D - 3 m/s	E - 2 m/s
UEL	0.180072	0.188149	0.141539
LEL	2.52518	3.12859	2.72517

Concentration	UEL and LEL Concentration Height (m)		
	B – 3 m/s	D - 3 m/s	E - 2 m/s
UEL	12.4526	12.6356	13.2436
LEL	27.8918	29.5237	32.8368

II. Flash Fire Envelope

On ignition of concentration within in UEL and LEL, flash fire envelope will take place as per details given below:

	Flash Fire Envelope (m)		
	B - 3 m/s	D - 3 m/s	E - 2 m/s
Farthest Lateral Extent	2.52518	3.12859	2.72517
Farthest Vertical Extent	27.8918	29.5237	32.8368

Flash fire envelopes due to delayed ignition are presented in Figure 7.12.

Figure 7.12: Flash Fire Envelopes from SRV Release (150 MT Bullet)

III. Explosion Effects (Delayed Ignition)

No explosion hazard will occur under any stability class and wind speed due to release LPG from SRV as area around the plant is open.

IV. Jet Fire on Immediate Ignition

On release of LPG from safety release valve on 150 MT above ground, jet fire will occur on immediate ignition. Thermal radiation levels at various distances from jet fire are given below:

Radiation Level	Thermal Radiation Level Distances (m)		
	B - 3 m/s	D - 3 m/s	E - 2 m/s
37.5 kW/m^2	Not Reached	Not Reached	Not Reached
12.5 kW/m^2	Not Reached	Not Reached	Not Reached
4 kW/m^2	49.0496	49.0496	43.2887

Thermal radiation intensity radii due to jet fire as result of SRV release from 150 MT bullet are presented in Figure 7.13.

Figure 7.13: Intensity Radii for Jet Fire from SRV (150 MT Bullet)

7.10.3.6 Rupture of Transfer Piping for Unloading of LPG from Tank Truck

In this scenario, accidental release of LPG has been considered as result of rupture of transfer piping for unloading of LPG Tank Truck to above ground or mounded bullets. Any release of LPG will be attended promptly.

I. UEL and LEL Concentration Distances

In the event of release of LPG due to rupture of transfer line, vapour cloud will be formed if it is not getting source of ignition. LPG vapours under UEL and LEL concentration will occur at the following distances.

UEL and LEL Concentration Distances

Concentration	UEL and LEL Concentration Distances (m)		
	B - 3 m/s	D - 3 m/s	E – 2 m/s
UEL	0.103961	0.103035	0.07026
LEL	1.47027	1.78934	1.36181

UEL and LEL Concentration Height

Concentration	UEL and LEL Concentration Height (m)		
	B - 3 m/s	D - 3 m/s	E – 2 m/s

UEL	5.97787	6.11888	6.4925
LEL	15.4008	16.5238	18.5485

II. Flash Fire Envelope

On delayed ignition of LPG vapours within UEL and LEL, flash fire envelope will form as indicated below:

	Flash Fire Envelope (m)		
	B - 3 m/s	**D - 3 m/s**	**E - 2 m/s**
Farthest Lateral Extent	1.47027	1.78934	1.36181
Farthest Vertical Extent	15.4008	16.5238	18.5485

Flash fire envelopes due to delayed ignition are presented in Figure 7.14.

Figure 7.14: Flash Fire Envelope for Jet Fire for Rupture of Transfer Piping

III. Explosion Effects (Delayed Ignition)

No explosion hazard will occur under any stability class and wind speed for rupture of top line.

IV. Jet Fire on Immediate Ignition

On release of LPG in case of rupture of transfer line, jet fire will occur on immediate ignition. Thermal radiation maximum distances from jet fire source are given below:

Radiation Level	Thermal Radiation Level Distances (m)		
	B - 3 m/s	**D - 3 m/s**	**E - 2 m/s**
37.5 kW/m^2	Not Reached	Not Reached	Not Reached
12.5 kW/m^2	9.30484	9.30484	Not Reached
4 kW/m^2	32.2113	32.2113	29.005

Thermal radiation intensities from jet fire are also presented in Figure 7.15.

Figure 7.15: Intensity Radii for Jet Fire for Rupture of Transfer Piping

7.10.3.7 Leak of LPG Due to Mechanical Seal from LPG Pump

Under this scenario, LPG release from mechanical seal of LPG pump has been considered.

I. UEL and LEL Concentration Distances

In the event of delayed ignition of released LPG, vapour cloud will be formed and UEL and LEL concentrations will occur at the following distances.

Concentration	UEL and LEL Concentration Distances (m)		
	B - 3 m/s	D - 3 m/s	E - 2 m/s
UEL	0.0245691	0.0233106	0.0154533
LEL	0.415662	0.41786	0.330061

UEL and LEL Concentration Height

Concentration	UEL and LEL Concentration Height (m)		
	B - 3 m/s	D - 3 m/s	E - 2 m/s
UEL	3.53591	3.55308	3.62097
LEL	5.09565	5.2254	5.81127

II. Flash Fire Envelope

On ignition of LPG vapours within UEL and LEL concentrations, flash fire envelope will form as indicated given below:

	Flash Fire Envelope (m)		
	B - 3 m/s	D - 3 m/s	E - 2 m/s
Farthest Lateral Extent	0.415662	0.41786	0.330061
Farthest Vertical Extent	5.09565	5.2254	5.81127

Flash fire envelopes due to delayed ignition of released LPG from mechanical seal failure pump are presented in Figure 7.16.

Figure 7.16: Flash Fire Envelop due to Release of LPG from Pump

III. Explosion Effects: Delayed Ignition

No explosion hazard will occur under any stability class and wind speed due to this scenario.

IV. Jet Fire on Immediate Ignition

On release of LPG from pump due to mechanical seal failure, jet fire will occur on immediate ignition. Thermal radiation distances from jet fire will be as given below:

Radiation Level	Thermal Radiation Level Distances (m)		
	B - 3 m/s	**D - 3 m/s**	**E - 2 m/s**
37.5 kW/m^2	Not Reached	Not Reached	Not Reached
12.5 kW/m^2	3.72639	3.72639	Not Reached
4 kW/m^2	7.81373	7.81373	7.47717

Thermal radiation intensity radii due to jet fire due to release of LPG by mechanical seal pump are shown in Figure 7.17.

Figure 7.17: Radii for Jet Fire from Release of LPG from Pump

7.10.3.8 Leak of LPG from Compressor

Under this scenario, LPG release from discharge line of compressorhas been considered.

I. UEL and LEL Concentration Distances

In the event of delayed ignition of released LPG, vapour cloud will be formed and UEL and LEL concentrations will occur at following distances.

Concentration	UEL and LEL Concentration Distances (m)		
	B - 3 m/s	**D - 3 m/s**	**E - 2 m/s**
UEL	0.125223	0.120537	0.0822639
LEL	1.67996	1.8082	1.40962

Concentration	UEL and LEL Concentration Height (m)		
	B - 3 m/s	**D - 3 m/s**	**E - 2 m/s**
UEL	5.05853	5.17363	5.53436
LEL	11.2697	11.8827	13.8824

II. Flash Fire Envelope

On ignition of LPG vapours within UEL and LEL concentrations, flash fire envelope will form as indicated given below:

	Flash Fire Envelope (m)		
	B - 3 m/s	**D - 3 m/s**	**E - 2 m/s**
Farthest Lateral Extent	1.67996	1.8082	1.40962
Farthest Vertical Extent	11.2697	11.8827	13.8824

Flash fire envelopes due to delayed ignition from release of LPG from compressor are presented in Figure 7.18.

Figure 7.18: Flash Fire Envelopes from LPG Compressor

III. Explosion Effects: Delayed Ignition

No explosion hazard will occur under any stability class and wind speed due to this scenario.

IV. Jet Fire on Immediate Ignition

On release of LPG from the compressor, jet fire will occur on immediate ignition. Thermal radiation distances from jet fire will be as given below:

Radiation Level	Thermal Radiation Level Distances (m)		
	B - 3 m/s	**D - 3 m/s**	**E-2 m/s**
37.5 kW/m^2	4.93984	4.93984	2.80294
12.5 kW/m^2	16.1172	16.1172	15.608
4 kW/m^2	28.28	28.28	29.7547

Thermal radiation intensity radii due to jet fire from compressor release are shown in Figure 7.19.

Figure 7.19: Intensity Radii for Jet Fire from LPG Compressor

7.10.3.9 Catastrophic Rupture of LPG Tank Truck (18 MT)

At the LPG bottling plant, LPG is transported by tank truck. In the event of fire in LPG tank truck at TLD shed, BLEVE may be occurred and fireball will result as outcome.

I. Fireball Hazard as a Result of BLEVE

Catastrophic rupture of LPG tank truck followed by immediate ignition will result in occurrence of BLEVE. As outcome of BLEVE, fireball will outcome as per details given below:

Fireball Radius	78.25 m
Fireball Duration	10.88 s
Flame Emissive Power	301.23 kW/m2
Fireball Lift Off Height	156.51m

II. Thermal Radiation Effect From Fireball Ellipse

Thermal radiation levels at various distances from fireball ellipse are given below:

Radiation Level	**Thermal Radiation Level Distances (m)**		
	B - 3 m/s	**D - 3 m/s**	**E - 2 m/s**
37.5 kW/m^2	78.2269	78.2269	78.2269
12.5 kW/m^2	237.853	237.853	237.853
4 kW/m^2	449.199	449.199	449.199

Thermal radiation intensity radii due to fireball ellipse are shown in Figure 7.20.

Figure 7.20: Intensity Radii for Rupture of LPG Tank

III. UEL and LEL Concentration Distances

In the event of delayed ignition of released LPG, vapour cloud will be formed and concentrations within UEL and LEL will occur at following distances.

Concentration	**UEL and LEL Concentration Distances (m)**

	B - 3 m/s	D - 3 m/s	E - 2 m/s
UEL	48.4779	49.0013	49.0132
LEL	222.883	224.435	224.706

IV. Flash Fire Envelope

On ignition of vapour cloud within UEL and LEL concentrations, flash fire envelope will form as given below:

	Flash Fire Envelope (m)		
	B - 3 m/s	**D - 3 m/s**	**E - 2 m/s**
Farthest Lateral Extent	222.883	224.435	224.706

Flash fire envelopes due to delayed ignition rupture of LPG tank truck are presented in Figure 7.21.

Figure 7.21: Flash Fire for Rupture of LPG Tank Truck

V. Explosion Effects (Delayed Ignition)

LPG vapours within the range of UEL and LEL will form an explosive mass and result in overpressure wave on getting source of ignition, if some confinement is present. Overpressure distances for various intensities of pressure wave are as given below:

Over Pressure (bar)	Overpressure Distances (m)		
	B - 3 m/s	**D - 3 m/s**	**E - 2 m/s**
0.1	483.367	494.3	491.889
0.15	375.162	384.581	382.608
0.2	321.761	330.447	328.428

Late explosion worst case radii due to delayed ignition as a result of rupture of LPG tank truckare presented in Figure 7.22.

Figure 7.22: Late Explosion Worst Case Radii for Rupture of LPG Tank Truck

7.10.3.10 CATASTROPHIC RUPTURE OF LPG CYLINDER

At the LPG bottling plant, cylinders are filled with LPG. In the event of fire in LPG cylinder, BLEVE may be occurred and fireball will result as outcome.

I. Fireball Hazard as a Result of BLEVE

Catastrophic rupture of LPG cylinder followed by immediate ignition will result in occurrence of BLEVE. As outcome of BLEVE, fireball will outcome as per details given below:

Fireball Radius	7.67 m
Fireball Duration	1.70 s
Flame Emissive Power	150.12 kW/m2
Fireball Lift Off Height	15.351m

II. Thermal Radiation Effect From Fireball Ellipse

Thermal radiation levels at various distances from fireball ellipse are given below:

Radiation Level	**Thermal Radiation Level Distances (m)**		
	B - 3 m/s	**D - 3 m/s**	**E - 2 m/s**
37.5 kW/m2	4.39453	4.39453	4.39453
12.5 kW/m2	19.3709	19.3709	19.3709
4 kW/m2	37.9695	37.9695	37.9695

Thermal radiation intensity radii due to fireball ellipse of LPG Cylinder are shown in Figure 7.23.

Figure 7.23: Intensity Radii for Rupture of LPG Cylinder

III. UEL and LEL Concentration Distances

In the event of delayed ignition of released LPG, vapour cloud will be formed and concentrations within UEL and LEL will occur at following distances.

Concentration	**UEL and LEL Concentration Distances (m)**		
	B - 3 m/s	**D - 3 m/s**	**E - 2 m/s**
UEL	4.59188	4.5956	4.59643

LEL	27.4572	27.4699	27.1581

IV. Flash Fire Envelope

On ignition of vapour cloud within UEL and LEL concentrations, flash fire envelope will form as given below:

	Flash Fire Envelope (m)		
	B – 3 m/s	**D - 3 m/s**	**E - 2 m/s**
Farthest Lateral Extent	27.4572	27.4699	27.1581

Flash fire envelopes due to delayed ignition rupture of LPG Cylinder are presented in Figure 7.24.

Figure 7.24: Flash Fire for Rupture of LPG Cylinder

V. Explosion Effects (Delayed Ignition)

LPG vapours within the range of UEL and LEL will form an explosive mass and result in overpressure wave on getting source of ignition, if some confinement is present. Overpressure distances for various intensities of pressure wave are as given below:

Over Pressure (bar)	Overpressure Distances (m)		
	B - 3 m/s	**D - 3 m/s**	**E - 2 m/s**
0.1	43.9593	43.9593	43.9593
0.15	31.4088	31.4088	31.4088
0.2	24.8642	24.8642	24.8642

Late explosion worst case radii due to delayed ignition as a result of rupture of cylinder are presented in Figure 7.25.

Figure 7.25: Late Explosion Worst Case Radii for Rupture of LPG Cylinder

7.10.3.11 LEAKAGE OF LPG CYLINDER

At the LPG bottling plant, cylinders are filled with LPG. In the event of LPG leak from cylinder, LPG will be released and thermal radiation in the event of fire and flash fire due to delayed ignition will be occurred as outcome.

I. UEL and LEL Concentration Distances

In the event of delayed ignition of released LPG due to leak from cylinder, vapour cloud will be formed and concentrations within UEL and LEL will occur at following distances.

Concentration	UEL and LEL Concentration Distances (m)		
	B - 3 m/s	**D - 3 m/s**	**E - 2 m/s**
UEL	0.0309493	0.0274352	0.0180224
LEL	0.552929	0.557775	0.565325

UEL and LEL Concentration Height

Concentration	UEL and LEL Concentration Height (m)		
	B - 3 m/s	**D - 3 m/s**	**E – 2 m/s**
UEL	1.87896	1.90922	2.03478
LEL	4.19448	4.44279	5.59894

II. Flash Fire Envelope

On delayed ignition of LPG vapours within UEL and LEL, flash fire envelope will form as indicated below:

	Flash Fire Envelope (m) Distance		
	B - 3 m/s	**D - 3 m/s**	**E - 2 m/s**
Farthest Lateral	0.552929	0.557775	0.565325
Farthest Vertical	4.19448	4.44279	5.59894

Flash fire envelopes due to LPG leak from cylinder in Figure 5.25.

III. Explosion Effects (Delayed Ignition)

No explosion hazard will occur under any stability class and wind speed due to this scenario.

Figure 7.26: Flash Fire due to LPG leak from Cylinder

IV. IV. Thermal Radiation Effect From Jet Fire

Thermal radiation levels at various distances from jet fire are given below:

Radiation Level	Thermal Radiation Level Distances (m)

	B - 3 m/s	D - 3 m/s	E - 2 m/s
37.5 kW/m^2	4.06144	4.06144	3.081
12.5 kW/m^2	6.84328	6.84328	6.45555
4 kW/m^2	11.2164	11.2164	11.0145

Thermal radiation intensity radii due to jet fire due to LPG leak from cylinder are shown in Figure 7.27.

Figure 7.27: Intensity Radii for LPG Leak from Cylinder

7.10.3.12 LPG LEAK FROM GUN AT CAROUSEL

At the LPG bottling plant, cylinders are filled with LPG. In the event of LPG leak from Gun at Carousel, LPG will be released and thermal radiation in the event of fire and flash fire due to delayed ignition will be occurred as outcome.

I. UEL and LEL Concentration Distances

In the event of delayed ignition of released LPG due to LPG leak from Gun at Carousel, vapour cloud will be formed and concentrations within UEL and LEL will occur at following distances.

Concentration	UEL and LEL Concentration Distances (m)		
	B - 3 m/s	D - 3 m/s	E - 2 m/s
UEL	0.0344968	0.0321595	0.0200565
LEL	0.611208	0.568291	0.587933

UEL and LEL Concentration Height

Concentration	UEL and LEL Concentration Height (m)		
	B - 3 m/s	D - 3 m/s	E – 2 m/s
UEL	1.95984	2.00738	2.13027
LEL	4.39923	4.60188	5.84534

II. Flash Fire Envelope

On delayed ignition of LPG vapours within UEL and LEL, flash fire envelope will form as indicated below:

	Flash Fire Envelope (m) Distance		
	B - 3 m/s	**D - 3 m/s**	**E - 2 m/s**
Farthest Lateral	0.611208	0.568291	0.587933
Farthest Vertical	4.39923	4.60188	5.84534

Flash fire envelopes due to LPG leak from Gun at Carousel are presented in Figure 7.28.

Figure 7.28: Flash Fire due to LPG leak from Gun at Carousel

III. Explosion Effects (Delayed Ignition)

No explosion hazard will occur under any stability class and wind speed due to this scenario.

IV. Thermal Radiation Effect From Jet Fire

Thermal radiation levels at various distances from jet fire are given below:

Radiation Level	Thermal Radiation Level Distances (m)		
	B - 3 m/s	**D - 3 m/s**	**E - 2 m/s**
37.5 kW/m^2	3.97721	3.97721	2.75176
12.5 kW/m^2	7.17481	7.17481	6.65368
4 kW/m^2	11.7697	11.7697	11.6282

Thermal radiation intensity radii due to jet fire due to LPG leak from Gun at Carouselare shown in Figure 7.29.

Figure 7.29: Intensity Radii for LPG Leak from Gun at Carousel

7.10.3.13 LPG Leak from Central Column Failure of Carousel Machine

At the LPG bottling plant cylinders are filled with LPG. In the event of LPG leak from central column failure of carousel machine, LPG will be released and thermal radiation in the event of fire and flash fire due to delayed ignition will be occurred as outcome.

I. UEL and LEL Concentration Distances

In the event of delayed ignition of released LPG due to LPG leak from central column failure of carousel machine, vapour cloud will be formed and concentrations within UEL and LEL will occur at following distances.

Concentration	UEL and LEL Concentration Distances (m)		
	B - 3 m/s	D - 3 m/s	E - 2 m/s
UEL	0.0744763	0.0726893	0.0434608
LEL	0.964388	1.00384	0.878793

UEL and LEL Concentration Height

Concentration	UEL and LEL Concentration Height (m)		
	B - 3 m/s	D - 3 m/s	E – 2 m/s
UEL	2.98001	3.08343	3.26655
LEL	6.80635	7.21695	8.80816

II. Flash Fire Envelope

On delayed ignition of LPG vapours within UEL and LEL, flash fire envelope will form as indicated below:

	Flash Fire Envelope (m) Distance		
	B - 3 m/s	D - 3 m/s	E - 2 m/s
Farthest Lateral	0.964388	1.00384	0.878793
Farthest Vertical	6.80635	7.21695	8.80816

Flash fire envelopes due to LPG leak from central column failure of carousel machine are presented in Figure 7.30.

Figure 7.30: Intensity Radii for LPG leak from central column failure of carousel

III. Explosion Effects (Delayed Ignition)

No explosion hazard will occur under any stability class and wind speed due to this scenario.

IV. Thermal Radiation Effect From Jet Fire

Thermal radiation levels at various distances from jet fire are given below:

Radiation Level	Thermal Radiation Level Distances (m)		
	B - 3 m/s	D - 3 m/s	E - 2 m/s

37.5 kW/m^2	5.25184	5.25184	3.61403
12.5 kW/m^2	11.0949	11.0949	10.6413
4 kW/m^2	18.6364	18.6364	19.1993

Thermal radiation intensity radii due to jet fire due to LPG leak from G central column failure of carousel machineare shown in Figure 7.31.

Figure 7.31: Intensity Radii for LPG Leak from Gun at Carousel

7.10.3.14 LPG Hose Failure at Carousel

At the LPG bottling plant, cylinders will be filled with LPG. In the event of LPG hose failure at Carousel, LPG will be released and thermal radiation in the event of fire and flash fire due to delayed ignition will be occurred as outcome.

I. UEL and LEL Concentration Distances

In the event of delayed ignition of released LPG due to hose failure at Carousel, vapour cloud will be formed and concentrations within UEL and LEL will occur at following distances.

Concentration	UEL and LEL Concentration Distances (m)		
	B - 3 m/s	D - 3 m/s	E – 2 m/s
UEL	0.0744763	0.0726893	0.0434608
LEL	0.964388	1.00384	0.878793

UEL and LEL Concentration Height

Concentration	UEL and LEL Concentration Height (m)		
	B - 3 m/s	D - 3 m/s	E – 2 m/s
UEL	2.98001	3.08343	3.26655
LEL	6.80635	7.21695	8.80816

II. Flash Fire Envelope

On delayed ignition of LPG vapours within UEL and LEL, flash fire envelope will form as indicated below:

	Flash Fire Envelope (m) Distance		
	B - 3 m/s	**D - 3 m/s**	**E - 2 m/s**
Farthest Lateral	0.964388	1.00384	0.878793
Farthest Vertical	6.80635	7.21695	8.80816

Flash fire envelopes due to hose failure at Carousel are presented in Figure 7.32.

Figure 7.32: Flash Fire due to Hose Failure of Carousel

III. Explosion Effects (Delayed Ignition)

No explosion hazard will occur under any stability class and wind speed due to this scenario.

IV. Thermal Radiation Effect From Jet Fire

Thermal radiation levels at various distances from jet fire are given below:

Radiation Level	Thermal Radiation Level Distances (m)		
	B - 3 m/s	**D - 3 m/s**	**E - 2 m/s**
37.5 kW/m^2	5.25184	5.25184	3.61403
12.5 kW/m^2	11.0949	11.0949	10.6413
4 kW/m^2	18.6364	18.6364	19.1993

Thermal radiation intensity radii due to jet fire due to hose failure at Carousel are shown in Figure 7.33.

Figure 7.33: Intensity Radii for Hose Failure of Carousel

7.11 FREQUENCY ANALYSIS

The failure frequency analysis aims at estimation of the "probability" of the incident. Failure frequencies may be classified as generic and synthesised for a particular situation, especially for more complex systems. Generic failure frequencies are preferred wherever available, as these reduce variances arising out of analyst judgement in the failure frequency estimation. Event trees make use of generic failure frequencies of components for a system or its subsystems to conclude the overall probability of failure.

The standard method of calculating the failure rate of an isolated section of equipment or a chosen set of equipment items is to count the different items and associated line lengths. The failure rate for a certain item is then broken down into the correct proportions for required release rate bands. The overall frequency for a particular set of equipment is then:

$$Ft = \sum F\ N$$

Where:

Ft = *total failure frequency/per year/per unit*
F = *individual item frequency/per year*
N = *number of items or length of piping unit*

7.11.1 FAILURE FREQUENCY DATA BASE

An incident frequency can be derived from internationally well-known generic databases in case the design is sufficiently similar to facilities represented in the historical failure records.). Failure data for process equipment items including flanges connection andvalves, etc. can be obtained from various reliability data bases derived from industry historical records.

This database can be used to meet the project scope requirements including both LPG pipeline and storage facilities failure data. Using these data, the frequencies of incidents can be estimated. The frequency of each incident is equal of the failure frequencies of all individual components. Base Event Frequencies for the LPG are given in Table 7.9.

Table 7.9: Base Event Frequencies for the LPG

Event	Frequencies
Cold catastrophic failure of storage vessel	6.72 × 10-7
Cold partial failure of storage vessel	1.17 × 10-5
Cold catastrophic failure of road tanker	1.48 × 10-7
Cold partial failure of road tanker	3.62 × 10-7
Rupture of filling line to storage vessel	5.14 × 10-7
Leak of filling line to storage vessel	7.69 × 10-7
Rupture of flexible hose	3.82 × 10-5
Leak of flexible hose	3.92 × 10-5

Event	Frequencies
Rupture of line from storage vessel to vaporizers	4.00 × 10-6
Leak of line from storage vessel to vaporizers	1.30 × 10-5
Rupture of vaporizer	3.64 × 10-8
Rupture of send-out piping downstream of vaporizers	4.00 × 10-6
Leak of send-out piping downstream of vaporizers	1.30 × 10-5
Rupture of LPG cylinder in storage shed	2.20 × 10-3
Leak of LPG cylinder in storage shed	5.72 × 10-3

Source: ABC Techno Labs India Pvt. Ltd.

7.11.2 Event Tree Analysis

Event tree analysis (ETA) is used to model the evolution of an event from the initial release through to the final outcome such as jet fire, fireball, flash fire etc. This may depend on factors such as whether immediate or delayed ignition occurs, or whether there is sufficient congestion to cause a vapour cloud explosion.

7.11.2.1 Storage Vessel Scenarios

The event tree for rupture of a storage vessel is shown in Figure 7.34. Immediate ignition is assigned a probability of 0.3 for large releases following Cox, Lees and Ang (Lees, 1996). Immediate ignition of release quantities of LPG results in a fireball. The probability of ignition with respect to leak rate is given in Table 7.10.

Table 7.10: Probability of Ignition

Leak Rate	Probability of Ignition	
	Gas Release	Liquid Release
Minor (<1 kg/s)	0.01	0.01
Major (1-50 kg/s)	0.07	0.03
Massive (>50 kg/s)	0.3	0.08

Source: ABC Techno Labs India Pvt. Ltd.

Delayed ignition is assigned a probability of 0.5.

Delayed ignition may produce a flash fire or vapour cloud explosion (VCE). To achieve a VCE, a dispersing vapour cloud must accumulate in a confined and/or congested area and subsequently be ignited. An explosion probability of 0.2 is assumed considering the fairly open nature of the surroundings.

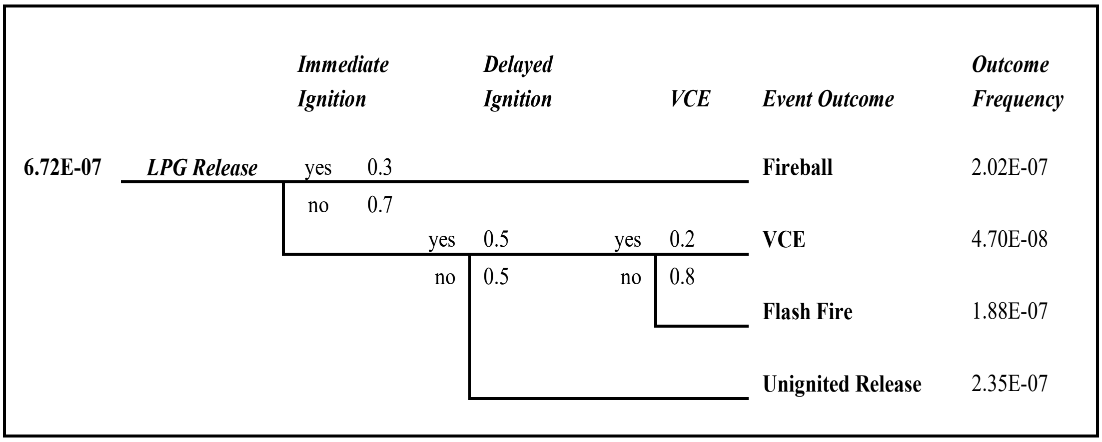


Figure 7.34: Event Tree for Catastrophic Rupture for Storage Vessel

For smaller leaks, a lower immediate ignition probability of 0.07 is applied. The event tree for partial failure of storage vessel is shown in Figure 7.35. Immediate ignition results in a jet fire, while delayed ignition may produce a flash fire or VCE.

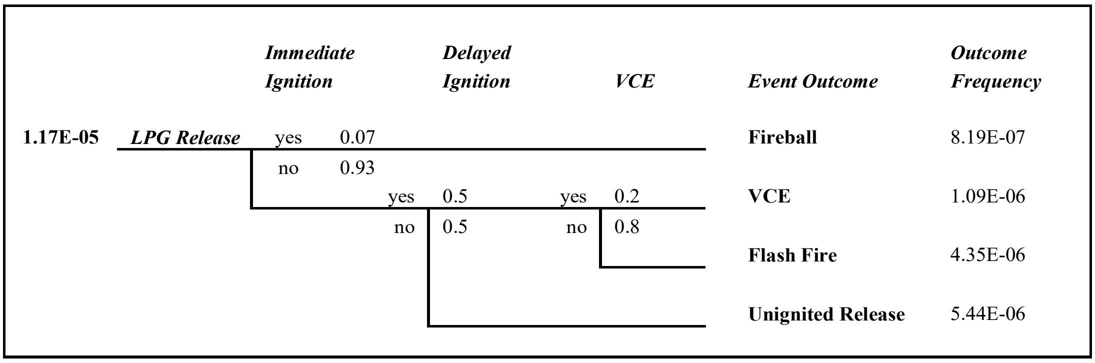


Figure 7.35: Event Tree for Partial Failure for Storage Vessel

7.11.2.2 Hose and Piping Scenarios

The event trees for leaks and ruptures of hoses and piping are essentially similar, except for different base frequencies. The event tree for a hose rupture is shown in Figure 7.36.

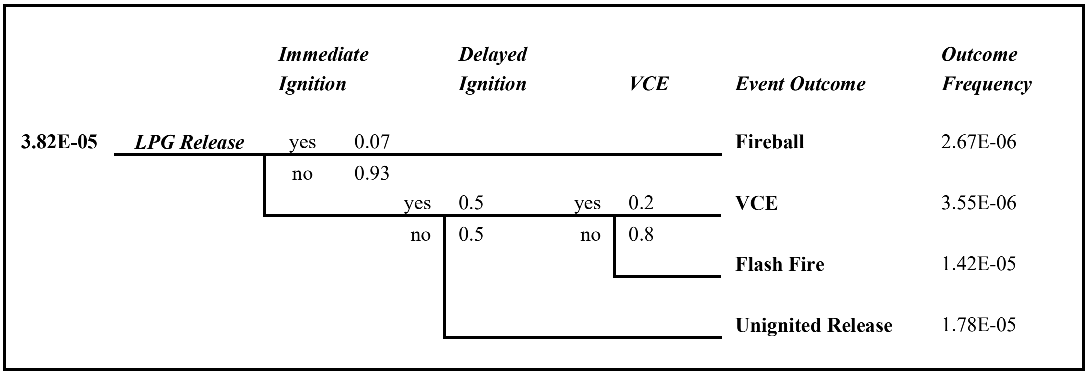


Figure 7.36: Event Tree for Hose/Piping Rupture

7.11.2.3 LPG Cylinder Scenarios

The event tree for cylinder rupture is shown in Figure 7.37. Immediate ignition results in a fireball while delayed ignition gives a flash fire. VCE is assigned a probability of zero since the inventory in a cylinder is too small to cause a VCE.

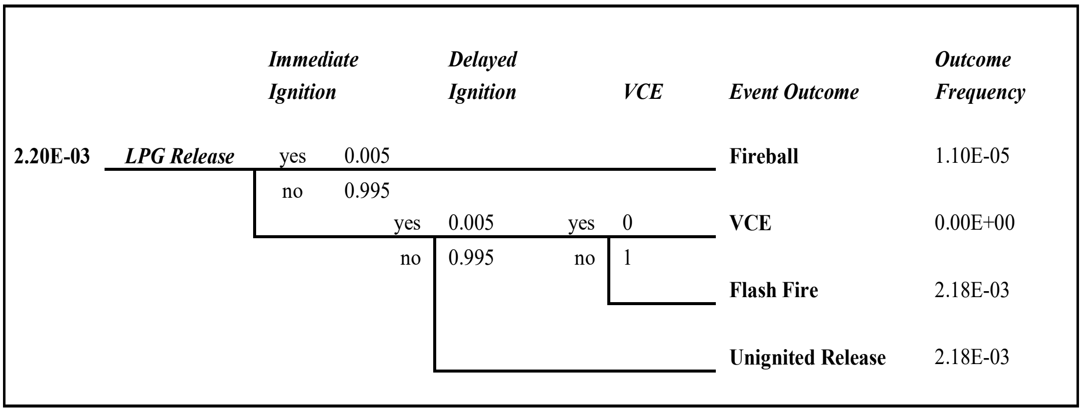


Figure 7.37: Event Tree for Cylinder Rupture

Event tree applies to failure of cylinders in filling or storage shed. Event trees for cylinders for the base frequency as shown in Table 7.9. For leaks from a cylinder, the probability of impinging on a neighbouring cylinder is taken to be 0.5. This is a rather high probability to reflect that cylinders are stored in stacks. To escalate to a BLEVE, however, it would require fire protection systems (gas detectors and water sprinklers already provided) to fail which has been assigned a probability of 0.015 (Maunsell, 2006). Event tree applies to failure of cylinders in filling or storage shed. Event trees for cylinders for the base frequency given in Table 7.9 are shown in Figure 7.38.

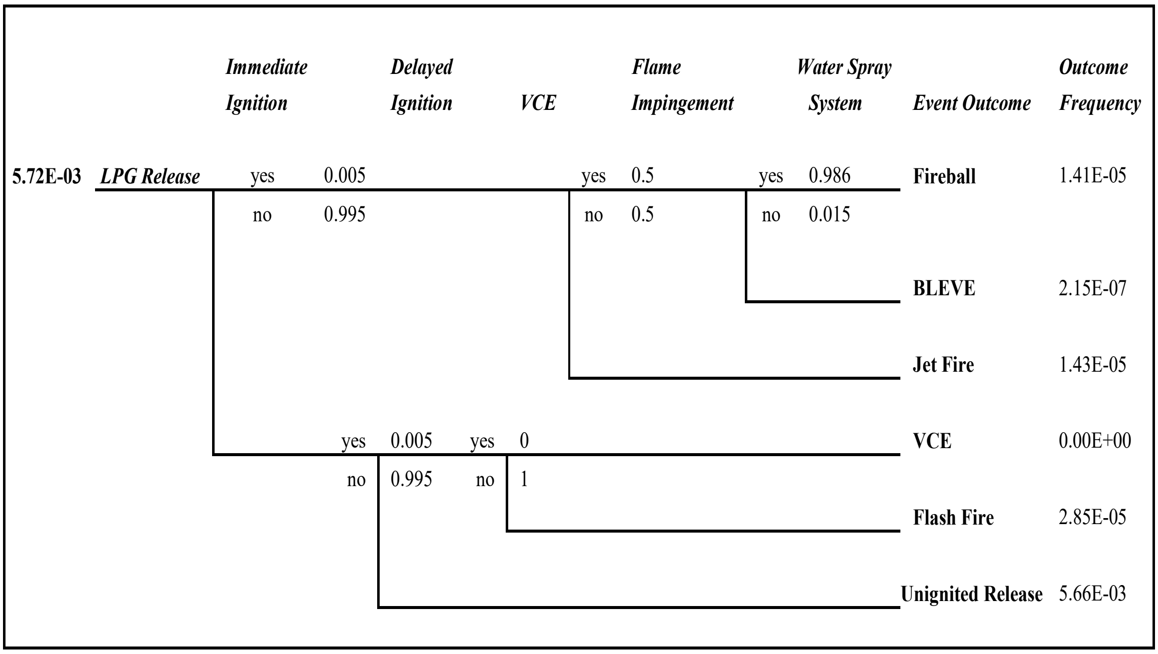


Figure 7.38: Event Tree for Hose/Piping Rupture

7.11.3 PIPELINE FAILURE FREQUENCIES

UKOPA Failure data base has been used for estimation of pipeline failure rates. The UKOPA data base is built from reports on large number of accidents, which occurred on pipeline system. The pipeline frequency rates are as given in Table 7.11.

Table 7.11: Frequencies of Pipeline Failure

Sl. No	Hole Size	Failure Rate /year
1.	5 mm	7.208E-4
2.	25 mm	4.148 E-4
3.	100 mm	1.836 E-4
4.	Rupture	8.160 E-5

Source: ABC Techno Labs India Pvt. Ltd.

7.11.3.1 PROCESS PIPING FAILURE FREQUENCIES

Most data bases of pipe failure rates are not sufficiently detailed to allow a determination of the failure frequency as a function of the size of the release (i.e. size of the hole in the pipe). The data shows that well over 90% of all failure are less than a 1-inch (25 mm) diameter hole and 3% are greater than a 3 inch (75 mm) diameter hole. Since most full rupture of piping system are caused by outside forces, full rupture are expected to occur more frequently on small-diameter pipes.

The failure frequencies of process piping are as given in Table 7.12.

Table 7.12: Frequencies of Process Piping Failure

Sl. No	Hole Size	Failure rate /year
1.	5 mm	1.476 E-5
2.	25 mm	1.312 E-5
3.	Rupture	1.64 E-6

Source: ABC Techno Labs India Pvt. Ltd.

7.11.4 Valves Failure Frequencies

In bottling, valves are a common possible source of leaks. Such leaks are usually from the packing around the valve stem. Leaks from valves are usually minor and the ratesof releases are mostly insignificant. Leak detection is typically carried out before a critical situation develops that may cause a safety problem. However, in some cases the leak from valves may be significant and could cause a hazard to people and property in the vicinity. With regard to the main body of the valve (valve casing) the wall thickness is generally quite large compared with process piping and leaks from the casing are deemed unlikely.

7.11.4.1 Control Valves

The data given in OREDA (1992) for control valves that are pneumatically operated globe valves (20 to 30 mm valves) records a critical failure rate of 3.89 failures per 106 hours, or 3.4E-2 failures per valve-year.

A breakdown of leak frequency by leak size is not given in these sources and thus additional analysis is required. All leaks from the control valves reported by OREDA (1992) are small leaks. Assuming that about 1% of all leaks could be large enough to be relevant to a risk assessment studies i.e. above pinhole size. Hence, these leaks have a frequency of 4.0E-4 per year per valve. The distribution of leak sizes is taken to be similar to that of piping. This leak frequency distribution is given in TableTable 7.13.

Table 7.13: Frequencies of Control Valve Failure

Sl. No.	Normalized Hole Size(d/D)	Failure Rate /year
1.	0.1	2.6x10-4

Sl. No.	Normalized Hole Size(d/D)	Failure Rate /year
2.	0.2	1.0x10-4
3.	0.45	34.0x10-5
4.	Total	4.0x10-4

Source: ABC Techno Labs India Pvt. Ltd.

7.11.4.2 ESD VALVES

The OREDA (1992) gives a frequency of critical external leaks from ESD valves in hydrocarbon service as 0.45 occurrences every 106 hours. This gives an annual frequency of 3.9E-3 leaks per valve year. Again, the leak frequency is not broken down by leak size. The same assumption is made that about 1% of all leaks could be large enough to be relevant to a risk assessment studies. Hence, these leaks have a frequency of 3.9E-3 per valve-year. The distribution of leak sizes is taken to be similar to that for control valves as given in Table 7.14.

Table 7.14: Frequencies of ESD Valves Failure

Sl. No	Normalized Hole Size(d/D)	Failure Rate /year
1.	0.1	2.5 E-5
2.	0.2	9.8 E-6
3.	0.45	3.9 E-6
	Total	3.9 E-5

Source: ABC Techno Labs India Pvt. Ltd.

7.11.4.3 CHECK VALVES

Check valves do not have any external mechanisms which are a likely source of a leak. All mechanisms of the valve are kept within the valve casing. The only sources of leaks are from the valve casing itself or from the flanges on the valve. Hence, when considering leaks from check valves, only the flanges associated with the valve are taken into account.

7.11.5 FLANGES

For flanges, industrial sources give figures as 6E-4 (in LPG service) failures per year. Whittle (1993) quotes a lower failure rate of 6.2E-5 failures per year, while the failure rate quoted by Sooby (1992) is even lower by over an order of magnitude of 3.3E-6 failures per year. Since the quality of the pipe flanges varies enormously with application, it seems sensible to regard this range as a reflection of flange and gasket quality. A failure frequency of 1E-5 per year is used for high quality flanges (e.g. raised face, ring type, or grey lock flanges used in high pressure, high temperature service). An analysis of flange failure hole sizes shows them to be small. The analysis shows that the maximum equivalent hole diameter for a flange leak from a 6 inch (15 mm) pipe is 12 mm. It has been assumed that for pipes greater than 6 inch (15 mm) in diameter that 10% of all flange leaks contribute to leaks in the range of 10 to 50 mm (i.e. 25 mm holes). For pipes of 6 inch (15 mm) diameter or smaller all leaks are taken to fall into the 0 to 10 mm hole size range (i.e. 5 mm holes). Table 6.7 summarizes the leak frequencies for flanges by hole size.

Table 7.15: Frequencies of Flange Failure

Sl. No	Hole size(mm)	Failure Rate /year
1.	5	9.0 E-5
2.	25	1.0 E-5
3.	Total	1.0 E-4

Source: ABC Techno Labs India Pvt. Ltd.

Leak frequencies for valve and flanges are summarized in Table 7.16 by hole size.

Table 7.16: Frequencies of Valves and Flange Failure

Sl. No	Hole size(mm)	Failure Rate /year
1.	5	4.22 E-5
2.	25	1.38 E-4
3.	Rupture	5.11 E-5

Source: ABC Techno Labs India Pvt. Ltd.

7.11.6 PRESSURE VESSEL (MOUNDED BULLET STORAGE)

Fire frequencies for pressure vessel have been considered two sections upper side of the bullet and bottom side of the bullet because in upper side portion release purely vapour jet from relief valve, this is mostly due to external fire but in bottom side leak probably non-equilibrium situation occur and liquid does not have sufficient time to flash during the discharge process. The flashing occurs after discharge once the liquid reaches the equilibrium state. Frequencies of pressure vessel failure are given in Table 7.17.

Table 7.17: Frequencies of Pressure Vessel Failure

Sl. No	Hole size(mm)	Failure Rate /year

Sl. No	Hole size(mm)	Failure Rate /year
1.	5	3.7 E-5
2.	25	9.6 E-5
3.	100	9.7 E-6
4.	Rupture	6.5 E-6

Source: ABC Techno Labs India Pvt. Ltd.

7.11.7 PUMPS FAILURE FREQUENCIES

The NPRDS Annual Reliability Report gives the most detailed leak data records for pumps. Most of the pumps failures is detected whilst the system is in service,The failure modes "leak" and "crack" contribute to the 5 mm leak category. The failure modes "breach", "collapse" and "fracture/break" contribute to the 25 mm leak category. All failures are considered as common-mode failures. The pump leak frequencies are summarized in Table 7.18.

Table 7.18: Frequencies for Leakage of Pump

Equivalent Hole Size (mm)	Leak Frequency/Item year	
	Centrifugal	
	Single Seal	Double Seal
5	5.2 E-2	7.5 E-3
25	1.0 E-3	1.0 E-3
100 or Rupture	1.0 E-4	1.0 E-4
Total	5.31E-2	8.6 E-3

Note: Maximum equivalent hole size for pumps is considered to be 100 mm.

Source: ABC Techno Labs India Pvt. Ltd.

7.11.8 FREQUENCIES DATA BASE FROM TNO

- ***For leakage and rupture of piping and pipelines***

Several studies from the past have led to a distribution in failure probability for two categories of pipelines. The figures accounts for the following assumptions:

Regarding the more fluctuating process conditions in and more frequent activities around process pipelines, it is expected that failure probabilities in this group are higher than for transport pipelines.

It is assumed that larger diameter pipeline will have a larger integrity and consequently a lower frequency of being damaged than small ones. For pipeline with a D>6" (150 mm) guillotine rupture in not credible.

Generic failure case frequencies per year per meter for transfer and process pipelines are given below.

Diameter	Transfer Pipeline			Process Piping		
	Rupture	**Hole 10"**	**Hole 1%**	**Rupture**	**Hole 10"**	**Hole 1%**
d<3"	1E-6	3E-6	1E-5	3E-6	1E-5	3E-5
3"<d<6"	1E-7	1E-6	3E-6	1E-6	3E-6	1E-5
d>6"	--	3E-7	1E-6		1E-6	3E-6

Source: ABC Techno Labs India Pvt. Ltd.

Catastrophic Failure for Pressure Vessels

Pressure Vessel : 1E-5/Yr

7.12 PROBABILITY OF IGNITION

For the frequency assessment, it is necessary to estimate the probability of ignition if a leak occurs. Ignition of a leak may occur either at the point or at some distance from it. The cause of ignition may be the leak itself (e.g. a leak may generate static electricity) or an ignition source, which then gives a spark and ignites the leak.

For small (0-25 mm) leaks probability

- Jet Fire (Immediate ignition- 25% probability)
- Flash Fire (75% probability)

For Medium (25-100mm) leaks probability

- Jet Fire (Immediate ignition- 25% probability)
- Flash Fire (75% probability)

The probability of ignition depends on the availability of a flammable mixture, the flammable mixture and ignition source and the type of ignition source (energy etc).

7.13 RISK ANALYSIS AND SUMMATION

Risk comprises of two variables: magnitude of consequences and the probability of occurrence. The risk analysis and summation are most often presented in terms of individual and group or societal risk.

Individual Risk is the probability of death occurring as a result of accidents at a plant, installation or a transport route expressed as a function of the distance from such an activity. Such a risk actually exists only when a person is permanently at that spot (out of doors). The individual risk is well illustrated with the aid of risk - curves or Iso-risk contours.

Societal or group risk is the probability of a certain number of victims per year. In calculating the group risk demographic data relating to the presence of humans is necessary. The societal risk is represented as an F-N curve, which depicts the frequency of occurrence per year (F) of a certain number of fatalities, (N).

The individual and societal risks from Raiganj LPG bottling plant are the result of the cumulating of risks connected with all possible scenarios. From the standpoint of what constitutes acceptable risk levels from a complex, both the Individual as well as Societal Risks should be within the acceptance criteria.

7.13.1 SOFTWARE MODEL USED RISK SUMMATION

The DNV Software model SAFETI (PHAST RISK) has been used for plotting the iso-risk contour of individual risk and F-N curves of Societal Risk. The 'PHAST RISK' program package is a very powerful tool to combine the probabilities and consequences of all release scenarios considered into risk and then sum them.

Data input to SAFETI (PHAST RISK) comprises of results of effects-consequence and frequency analyses for the scenarios included for risk summation, along with population and meteorological data for the locality in question.

7.13.2 RISK SUMMATION

The results of risk summation have been reproduced as individual and societal risks. Individual and societal risks are defined as below:

- ***Individual Risk***

The individual risk at a certain distance from LPG storage and handling facilities at Raiganj LPG Bottling Plant is the result of the cumulation of risks connected with all possible scenarios. The calculation of individual risk at a geographical location near a LPG storage and handling facilityassumes that the contributions of all incident outcome cases are additive. Thus, the total individual risk at each point is equal to the sum of the individual risks, at that point, of all incident outcome cases associated with the LPG bottling plant.

$$IR_{x,y} = \sum_{i=1}^{n} IR_{x,y,i}$$

Where

IR x, y = the total individual risk of fatality at geographical location x,y (Chances of fatality per year)

IR x, y, i = the individual risk of fatality at geographical location x, y from incident outcome case i (chances of fatality per year)

n = the total number of incident outcome cases considered in the analysis.

The individual risk of fatality at particular geographical location is calculated by the following equation:

$$IR_{x,y,I} = Pa.Ps.Pw.fr$$

Where

Pa = accident probability (per year)

Ps = Weather stability probability

Pw = Wind direction probability

fr = response fraction

The calculation of individual risk requires the application of these equations at every geographical location surrounding the facility.

- ***Societal Risk***

Societal risk is the probability of a certain number of victims per year. In calculating the group risk, demographic data relating to the presence of humans is necessary. From the stand point of what constitutes an acceptable risk level from a complex, both the Individual as well as societal risk should be within the acceptance criteria.

The need for the societal risk computation arises due to the fact that society views multiple fatalities from the same accident far more seriously than single fatalities from numerous accidents. All of the information required for individual risk calculation is also required for societal risk estimation. Additionally information on the population surrounding the facility and its distribution is also required.

The number of people affected by each incident outcome case is given by

$$\mathbf{Ni = Px,y.\ Pf,i}$$

Where

Ni = *number of fatalities resulting from incident outcome case i*

Px,y = *number of people at location x, y*

Pf,i = *the probability that incident outcome case i will result in a fatality at location x, y from the consequence and effects model.*

7.13.3 RISK ACCEPTANCE CRITERIA

The risk analysis provides a measure of the risk resulting from LPG Storage and handling facility at Raiganj LPG Bottling Plant. The methodology for calculating risk levels has been well defined and consistent results can therefore be expected. However, the assessment of the acceptability or otherwise of that risk is left to the judgement and experience of the people undertaking and/or using the risk assessment study. The normal approach adopted is to relate the risk measures obtained to risk acceptance criteria.

❑ ***Criteria Adopted for Individual Risk***

As per "Code of Practices for Emergency Response and Disaster Management Plan Regulation 2010" formulated by Petroleum and Natural Gas Regulatory Board, under Petroleum and Natural Gas Regulatory Board Act 2006, Individual Risk per Annum (IRPA) has been adopted as given below:

- 10^{-5} per year for tolerable risk
- 10^{-6} per year for acceptable risk.
- Lower than 10^{-6} per year for negligible risk.

Individual Risk from 10^{-3} to 10^{-5} per Annum is considered tolerable in As Low As Reasonably Practicable (ALARP Zone)

❑ ***Criteria Adopted for Societal Risk Criteria***

In the assessment of the societal risk, demographic data on the offsite of the LPG storage and handling facilities at Raiganj LPG Bottling Plant have been used. Only the employees working in the concerned LPG bottling plant are not included in the 'society'. With regard to the risk of people employed in nearby industries with similar risk, it is debatable to consider them as population. Internationally consensus is lacking on this aspect. However, in the present study employees in the adjoining industries have been considered as 'society' in the assessment of societal risk.

	FN Curve Slope	Intolerable Intercept With N=1	Negligible Intercept With N=1	Limit on N
Existing and New MSVs	-1	10^{-3}	10^{-5}	-

Source: ABC Techno Labs India Pvt. Ltd.

7.13.4 INDIVIDUAL RISK DUE TO LPG BOTTLING PLANT FACILITIES

Individual risk (IR) contours for Raiganj LPG Bottling Plant are calculated and Failure frequency data for various release scenarios used for computation of Individual risk have been described in detail in Chapter 6 of RRA report.

From the figure, it is observed that IR contour of 1.0E-5/average year is within the boundary of the Raiganj LPG Bottling Plant. Other IR contours (1.0E-6) are outside the LPG plant boundary. Therefore, it is below the risk tolerance criterion of individual risk contours of 1.0E-5/average year as it remains within LPG bottling plant boundary and does not reach to populated areas.

The Individual Risk Potential for Loss of Life (Potential Loss of Life- PLL) due to LPG bottling plant is 4.71383E-005 per average year.

7.13.5 SOCIETAL RISK

The individual risk values for each location when combined with population at that location gives the societal risk at the same location i.e. the probability of a certain number of victims per year. The total Societal Risk can be obtained by adding the values for all the locations. The Societal risk is represented as F-N Curve, frequency of number of fatalities (F) from all the accidents versus number of Fatalities (N). FN curves (Figure 7.1 and 7.2) show two straight lines (with negative slope) which indicate the Societal Risk Acceptance criteria adopted for this study. The region above the upper line (1E-3) is the region of unacceptable risk, while that below the lower line ((1E-5)) is the region of acceptable risk. The region in between is the so-called ALARPZone where risk is acceptable subject to its being **As Low As Reasonably Practicable** (The ALARP principle). Major risk contributors have been identified using the Analysis Tools feature of PHAST RISK.

7.13.6 FINDINGS OF RISK ANALYSIS

Based on risk analysis and summation, the following observations can be made:

i. The major risk contributors at the Raiganj LPG Bottling Plant are 150 MT capacity above ground.

ii. Individual risk from LPG bottling plant is tolerable, as it is below the tolerance criterion of individual risk, as 4.71383E-005 per year risk contour remains within Raiganj LPG Bottling Plant boundary.

iii. Due to Raiganj LPG bottling plant, computation shows that Societal Risk potential for loss of life is 2.59097E-005 per average year.

iv. From LPG bottling plant, it is observed that maximum 47.7 fatality results for cumulative frequency of 9.823E-007 per average year, which is also below the ALARP zone, hence, societal risk is negligible.

Figure 7.39: F-N Curve for Combined for Day & Night for BPCL LPG Bottling Plant at Raiganj

Figure 7.40: F-N Curve for Day & Night for BPCL LPG Bottling Plant at Raiganj

7.14 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 can not 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.

7.15 RISK MITIGATION MEASURES LPG BOTTLING PLANT

The proposed LPG botlling plant will be major accident hazard installation 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.

The major risk mitigation measures for the Raiganj LPG bottling plant facilities are described below:

7.15.1 LPG Unloading Facilities

To reduce the risk of accidental LPG release during product transfer, excess flow check valves shall be provided in LPG loading/ unloading lines.

7.15.2 Cylinder Filling Facilities

A. Filling Machines And Weighing

i. The filling machines shall be provided with auto cut-off system so that the liquid and gas supply is cut off when the desired quantity of product has been filled in the cylinders. The filling pressure shall not be more than the design pressure of the cylinders i.e. 16.9 kg/sq.cm gauge.

ii. Filling machines in a carousel/stationary filling machines shall not have a weighment error of more than +1% of the net quantity of the LPG filled in the cylinder, with a capacity of 14.2/19/37.5 kg.

iii. It is recommended that in-line check weigh scales with a minimum of 50 gms graduation be installed so that all the cylinders can be check weighed after filling.

B. Layout And Safety

i. The cylinder filling area shall be completely open type and covered from top with asbestos roof designed to ensure good natural ventilation, RCC roofing shall not be used. The filling area will not be on upper floors of building or in cellars.

ii. As far as possible, the floor area shall not have any channels or pits. Where these are necessary for conveyors or other equipment like weigh machine etc., suitable gas detection system shall be provided. Additionally they shall be ventilated through ducts fitted with blowers to outside of the shed at safe location. The whole of the LPG filling shed flooring shall be provided with bitumenistic mastic flooring.

iii. Adequate lighting shall be provided in the cylinder filling area. Additionally emergency lighting shall also be provided at critical places.

iv. Water drains from the cylinder filling area where they enter an outside drainage system, shall be provided with vapour seals.

v. Fixed water spray system shall be installed for fire fighting inside the cylinder filling area. Besides this, access shall be made available for other fire fighting systems.

C. Cylinder Storage

Maximum cylinder storage of empty and filled cylinders combined shall be restricted to a total of 3 days bottling capacity of the plant. Storage area requirement shall be based on the stacking pattern of filled and empty cylinders.

7.15.3 SAFETY/ SECURITY SYSTEM

The features of safety/ security system for the different areas in the Raiganj LPG bottling plant shall be as follows:

7.15.3.1 AUTOMATIC FIRE PROTECTION SYSTEM

Automatic fire protection (Fixed) system based on heat detection through thermal fuses/ quartz bulbs/ EP detectors shall be employed. Sensors shall be installed at all critical places described below:

A. LPG Storage Area

In storage area these detectors shall be provided encircling each vessel, equi-spaced with a maximum spacing of 1 meter at an elevation of about 1.5 to 2.0 meter from bottom of vessel. Also minimum 2 nos. detectors shall be provided at the top of the vessel and atleast one near the liquid line ROV to take care of failure of flanges. In case of an automatic thermal fuse based fire protection system the instrument air supply pressure to thermal fuses shall be maintained through a pressure control valve and a restriction orifice.

The thermal fuses shall be designed to blow at 79 deg C temperature (max). Instrument air will start leaking as a result of thermal fuse blowing. The capacity of the restriction orifice is such that the discharge of air through even one thermal fuse will depressurise the downstream side of the restriction orifice to below set point of the pressure switch.

The actuation of pressure switch on any one of the vessels shall initiate the following:

- An audio visual alarm at the local/ main control panel and fire water station, indicating the vessel on fire.
- The Remove Operated Valve (ROV) on liquid inlet/ outlet line to the affected vessel will close.
- The ROVs on vapour balance line and liquid return line of the affected vessel will close.
- LPG pumps and compressors in LPG storage area will trip.
- The deluge valves on fire water supply lines to that vessel will open.

Additionally push buttons for initiating all the above actions shall be provided on remote operating panel and also in field at safe location for enabling manual actuation of a trip by operator. In the field, manual bypass valves of fire water deluge valves shall also be provided. Arrangements for routine test of the security system shall also be provided.

B. Other Areas

Detectors shall be placed at critical locations in LPG sheds (filling, cylinder storage, testing, evacuation, etc.) loading/ unloading gantries, LPG compressor house, piping manifold, repair sheds etc. Upon actuation there shall be alarm in central panel, LPG pumps and compressors would trip, ROVs (wherever provided) on LPG supply and return lines would trip and the deluge valves on fire water sprinkler system will get actuated.

The fire water deluge valves shall be kept outside the kerb wall at a safe distance in case of sphere/ bullet, and located 15 m away from limits of other sheds or shadows of spheres. A fire wall shall be provided for the protection of the deluge valve and for personal protection of the operator.

7.15.3.2 GAS DETECTION SYSTEM

Suitable gas detectors shall be placed at identified critical locations in the LPG storage, compressor house, pump house, filling shed, cylinder storage area, evacuation/ testing area, LPG loading/ unloading area.

This shall include the area and shall also include places where water, draining/ sampling are done on a routine basis. Audio visual alarms showing the location of gas leakage shall be provided on the control panel. First level alarm can be set at 20% LEL and second level alarm at 60% LEL.

7.15.3.3 Gas Extraction System

A gas extraction system having suction points at critical places where gas concentration is high like carousel, evacuation, valve change shed etc. shall be provided.

7.15.4 Other Equipment/ System

7.15.4.1 Bottling Pumps

There shall be a minimum of two pumps, including one standby. Pumps shall be provided with suction and discharge pressure gauges, a high point vent to safe height or flare, and a suction strainer. Mechanical seal shall be provided (double mechanical seal with seal failure alarms is preferred). A pressure switch actuating a low pressure alarm in control room shall be provided, taken from pump discharge. Pumps shall be designed to build a discharge pressure such that the pressure at the carousel filling machine is at least 5.0 kg/sq.cm.g above the vapour pressure at the operating temperature.

7.15.4.2 LPG Compressor

Gear driven compressor shall preferably be used. However belt driven compressors can also be used provided the belts used are antistatic type & fire resistant. There shall be a minimum of two compressors including one as a standby.

The operating parameters shall be decided on a case to case basis. However, typical operating conditions may be as follows:

Suction pressure	10.0 kg/sq.cm.g abs (max.) during unloading 2-11.8 kg/sq.cm.g abs during vapour recovery
Discharge pressure	13.0 kg/sqcm.g. abs during unloading 11.5 kg/sqcm.g. abs during vapour recovery

Compressor shall be provided with the following features as a minimum:

- ✓ Pressure gauges in suction and discharge.
- ✓ Temperature gauge in discharge
- ✓ Discharge safety valve and a vent valve, their outlets leading to flare/ safe height outside the shed.
- ✓ Suction and discharge block valves (lock open type)
- ✓ Suction strainer
- ✓ Check valve in discharge
- ✓ A discharge to suction recycle valve for achieving capacity turndown during startup.

7.15.4.3 Evacuation Facility For Sick/ Leaky Cylinders

The cylinder evacuation facility shall consist of:

- ✓ Cylinder emptying vessels (2 nos)
- ✓ Compressor (1 no.)
- ✓ Four way valves
- ✓ Cylinder rack, header to be provided with pressure gauge and a strainer with isolation valves.
- ✓ The LPG line exit cylinder evacuation area to be provided with a non-return valve before joining the main LPG return header.
- ✓ Independent earthing connections shall be provided.

Each of cylinder emptying vessels mentioned above shall be equipped with the following:

- ✓ Pressure gauges
- ✓ Level gauges and high level alarm switches
- ✓ Pressure relief valves and vent valves discharging to safe height.
- ✓ Other trims like drain valve, utility connection.

7.15.5 PURGING OF NEW CYLINDERS/ TANKERS

a) The new LPG cylinders containing air shall be evacuated with a vacuum pump. The vacuum pump shall be water/ oil cooled type. The evacuation facility shall consist of:

- ✓ Purging manifold
- ✓ Vacuum receiver fitted with vacuum gauge, vent and drain.
- ✓ LPG vapour header
- ✓ Purging adapters
- ✓ Portable oxygen analyzer
- ✓ Nitrogen cylinder manifold
- ✓ Vacuum pump with suction strainer
- ✓ Pressure regulator, relief valves etc.

b) Purging of tankers/ vessels shall be done using either Nitrogen or by filling water and displacing with LPG vapours.

There should be two independent lines (heads) one for evacuation of air and other for introduction of LPG.

7.15.6 ELECTRICAL AREA CLASSIFICATION

All electrical fittings/ equipments to be of Flame-proof type in vulnerable areas. For electrical area classification IS-5571, IS-5572 (Part-1) and OISD Standard -113 shall be referred.

7.15.7 MOUNDED BULLETS

The mounded storage of LPG 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 mound protects the vessel from fire engulfment, radiation from a fire in close proximity and acts of sabotage or vandalism. The area of land required to locate a mounded system is minimal compared to conventional storage.

The following measures are suggested during design, erection and operation of mounded storage bullets for LPG.

i. Provisions of "OISD Standards 150: Design and Safety Requirements For Liquefied Petroleum Gas Mounded Storage Facility" shall be included in design and operation.

ii. Each mound bullet shall have accessibility to fire tender from at least two sides.

iii. Minimum separation distance between mounded LPG storage and any other (other than LPG pump/compressor house) facility associated with LPG plant shall be 15 meters. This distance to be measured from the edge of the mound at finished ground level and also from the first valve on the vessel i.e. ROV.

iv. The minimum inter-distance between the edges of the vessel in a mound shall not be less than 2 meters.

v. Proper provision shall be made for countering the consequences of the settlement of the vessel under mound. The surrounding of the bottom connection should be filled with such material that can absorb such settlement.

vi. Provision shall be made to monitor the settlements of the mound by providing permanent reference point. A minimum of three reference points shall be installed to be able to also identify possible vessel bending (One each near the vessel ends and one in the middle.)

vii. The fire safe Remote Operated Shutdown Valve (ROV) on liquid drain line from the vessel shall be either from bottom of the vessel or from the top of the vessel as per the design considerations.

viii. In case of liquid drain line from the bottom of the vessel, the minimum distance of 3 meters from the vessel to ROV shall be maintained. The nozzle pipe shall have a slope of 1.5 Deg.

ix. There shall not be any other flanges, or any other tapping up-to the ROV except in case of liquid drain line from top of the vessels.

x. Each vessel shall have at-least two pressure relief valves. The full flow capacity of Pressure Relief Valves (PRV) on mounded vessels may be reduced to not less than

30% of the capacity required for an equivalent size of above ground vessel. For safety reasons, the discharge of Pressure Relief Valves shall be connected to flare system. In this case Pressure Relief Valves (PRVs) shall have lock open (or car seal open) type isolation valves on both sides of Pressure Relief Valve.

xi. The Pressure Relief valves shall be tested and calibrated every year by a competent person and records shall be maintained.

xii. Cathodic protection system shall be provided, maintained and tested routinely.

xiii. 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).

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

xv. Each storage vessel shall have minimum two different types of level indicators and one independent high level switch. High level alarms shall be set at not more than 85% level of the volumetric capacity of the vessel.

xvi. Audiovisual indication shall be at local panel and control room.

xvii. 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 including as described below:

- Minimum 1 detector shall be provided on each exposed portion of the vessel. However if the nozzles are covered in a dome, each group shall have 2 numbers of detectors.
- Atleast one near the each liquid line ROV to take care of failure of flanges.

xviii. Suitable gas detectors shall be placed at critical locations in the LPG storage area such as, near the ROV, in inspection tunnel, near water draining/ sampling points, etc.

xix. Audio- visual alarms showing the location of gas leakage shall be provided on the control panel in the control room. First level alarm can be set at 20% LEL and second level alarm at 60 % LEL of LPG.

xx. All mounded storage vessels, LPG Pump Houses, truck tanker gantries shall be fully covered by medium velocity water spray system.

xxi. LPG storage area, automatic detection of heat for automatic actuation of medium velocity sprinkler system having remote/ local operated deluge valve with spray density of 10 lpm/m2 of surface area shall be provided.

xxii. Hydrant and monitor coverage shall also be provided on all four sides of the mounds for adequate coverage of unprotected portions exposed to thermal radiation including for top of the mound and for piping, in the immediate vicinity of the mound. In view of accessibility of unprotected portions of the vessels, for effectiveness, installation of remote operated monitors at appropriate height shall be considered.

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

7.15.8 PROCEDURE FOR UNLOADING TANK TRUCKS

The following procedures should be followed, while, unloading LPG bullets trucks:

- ✓ Checks essential for plant safety shall be carried out for each Tank Truck before its entry to the licensed area I.
- ✓ Tank pressure, temperature and weight of filled tank truck shall be recorded.
- ✓ Tank shall be placed in drive out position with entire tank truck consisting of bullet and engine covered by sprinklers.
- ✓ After placement, engine as well as master control switch shall be switched off and minimum two wooden chokes shall be placed under wheels.

The following shall be connected:

a. Chassis and bullets both are to be earthed independently for which bare metal cleats to be provided.

b. Liquid and vapour hoses to tank trucks after examining the integrity of gaskets and using proper studs. Bolts and nuts are not be used.

c. Earthing lines to tank bare metal or earthing point to tank.

d. Liquid and vapour hoses to tank trucks.

- ✓ The tank truck valves shall be crack opened and ensured there are no leaks.
- ✓ After the above, unloading should be done preferably with LPG compressor by differential pressure method.
- ✓ Pressure and level in the tank truck shall be monitored at regular intervals so that it does not exceed safe limits. After decanting all liquid LPG, close the valve of liquid line of the bay. Thereafter, LPG vapour should be recovered such that vapour pressure in the tank truck is brought down to 1.5 kg/cm2 minimum but not below atmospheric pressure.
- ✓ On completion of unloading, following operations shall be done in sequence :

a. Isolate rigid liquid and vapour lines of bay by closing the valves and stop LPG compressor.

b. Close the valves of liquid/ vapour lines of the tank truck. Depressurise the hose through high vent - close vent valve.

c. Remove hose connections, electrical bonding wires.

d. Cap the vapour/ liquid outlet lines of tank trucks.

e. Remove chokes placed under wheels.

- ✓ Record the weight of empty tank truck along with rotogauge, pressure gauge and temperature gauge readings.

7.15.9 HANDLING & STORAGE OF LPG CYLINDERS IN CYLINDER FILLING AND CYLINDER STORAGE SHED

Handling and storage of LPG cylinders shall be governed by Gas Cylinders Rules, 1981. The following safe practices shall be observed:

a) Handling of LPG Cylinders - LPG cylinders shall not be dropped, rolled on sides and shall not be subjected to any violent contact with any other cylinder or object cylinder shall be moved by rolling on its foot ring or on conveyors or hand trolleys.

b) Defective filled cylinders - Any cylinder having body leak, bung leak, bulge, fire ravaged or spurious shall be evacuated immediately.

Any cylinder with valve leak shall be immediately capped and thereafter evacuated immediately. Cylinders requiring repairs other than valve leak/ Bung leak shall be degassed for repairs. All above cylinders shall be clearly identified, with markers, to their nature of defects and shall be kept capped during storage.

c) LPG cylinder storage - All cylinders shall be stacked vertically (with valve in upright position) in not more than 2 stack high. Cylinders of different capacity and type shall be stacked separately. All cylinders shall be capped during storage.

The cylinders shall be stacked in small lots of 4 rows and 25 cylinders length. A minimum access path of 1 m must be maintained on both sides of 4 rows and 2 m after every 5 such lots. After each length of 25 cylinders, there must be a passage of 2 m. The cylinder storage space shall be properly marked/ painted on the flooring.

Empty and filled cylinders shall be demarcated clearly. Minimum distance of 15 m from cylinder loading area and minimum distance of 10 m from filling point shall be observed for all filled cylinders stack.

7.15.10 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.

7.15.11 ELECTRICAL HAZARDS

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

- ✓ The classification of area for electrical installations at LPG storage and handling facilities shall be as per OISD Standards 113.
- ✓ Inspection of electrical equipment shall be carried out as per OISD Standards 137.
- ✓ All electrical equipments 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 equipments 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, gas, water, oil, drain piping and air conditioning ducts.
- ✓ All lights in LPG storage area, pump house, loading gantry, etc will be flame proof.
- ✓ 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.

7.15.12 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
- ✓ Deluge sprinkler system
- ✓ Portable fire extinguisher
- ✓ Fire detection and alarm system

After commissioning of additional MSVs at Raiganj LPG bottling plant, 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 Raiganj LPG bottling plant.

7.15.13 CONTROL ROOM

- ✓ Control room shall be located at a sufficient distance from operating areas
- ✓ All control room should be blast proof and shock proof.
- ✓ Critical switches and alarm should be always kept in line.
- ✓ Minimum number of doors shall be provided in the control room while at least two doors should be provided for safe exit during emergency.
- ✓ Smoke detection system shall be provided for control room.

7.15.14 PERSONAL PROTECTION EQUIPMENT

Necessary personal protection equipments such as Hand gloves, Safety shoes, Helmets, Safety belts, Safety goggles etc. shall be used (Ref. OISD STD-155).

7.15.15 WORK PERMIT SYSTEM

No maintenance/ inspection work shall be carried out without following the OISD Standard OISD-105 on "Work Permit System" and Section 4 of OISD-137 for electrical maintenance purpose.

7.15.16 SAFETY AUDIT AND INSPECTION

Checklist based routine inspection and safety audits should be carried out in line with OISD -144 for mounded bullets, pumps, piping and loading gantries, etc. Any gap or non compliance should be implemented on priority in time bound manner.

7.15.17 Induction and Refresher Safety Trainings

The provision shall be made for structured induction and refresher safety trainings for LPG handling system from senior management to contractual workers levels at the facilities.

7.15.18 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 Raiganj LPG bottling plant, to take the action in an unlikely event of emergency due to accidental release of LPG. Emergency Response Plan should be updated based on findings of mock drills.

7.15.19 Bullet Truck Checks

For bullet trucks, checks required to be carried out before allowing entry in the Raiganj LPG bottling plant:

- ✓ It has suitable spark arrestor of make and design approved by CCE, Nagpur properly fixed to exhaust.
- ✓ It carries 2 nos. 10 kg. DCP extinguishers in easily accessible and removable position with Truck No. date of checking and charging painted on it.
- ✓ It has quick closing manifold valve with lever indicating close and open status.
- ✓ There is no visible dent on the bullet.

Electrical

- ✓ All junction boxes are properly sealed
- ✓ Any loose electrical wiring
- ✓ Electrical wiring is insulated and provided with suitable over current protection.
- ✓ Truck is self starting
- ✓ Readily accessible master switch for switching off the engine is provided inside the cabin.
- ✓ Dipole wiring.

Tank Fittings

- ✓ Leakage from any fittings or joints.

- ❑ **Checks Required to be Carried Out Before Issuing Loading Memo (During The Course of Unloading opertions)**

Bullet Truck

- ✓ Height barrier provided as per specifications
- ✓ Fuel tank is protected by means of stout guard and fuel tank cap is locked.
- ✓ Paint of bullet is not peeling off.

General

- ✓ First aid kit is available.

Checks Required To Be Carried Out On Random Basis - Minimum One Day, Once In A Month:

Tank Truck

- ✓ Internals of fire extinguishers in good condition
- ✓ Carries TREM CARD, instructions booklet detailing instructions on handling emergencies en route.
- ✓ Carries route map
- ✓ Carries TREM card
- ✓ Has valid CCE license and authenticated copy of drawing
- ✓ Carries RTO permits
- ✓ RLW-ULW> Licensed capacity
- ✓ HAZCHEM sign, name of contractor with address and telephone No. displayed prominently.
- ✓ Bullet has no sign of extern corrosion.

Tank Fittings

- ✓ Excess flow check valves are functioning.

- ✓ Liquid / vapour lines are adequately anchored and are well protected by means of stout steel guard.
- ✓ Liquid/ vapour pipe lines are in single piece from excess flow check valve to discharge valves - Safety fittings viz., safety valve, roto-gauge, pressure gauge and temperature gauge are adequately protected.
- ✓ Operative fittings like roto gauge, pressure gauge and temperature gauge are operational.

7.15.20 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 likely emergency situations.

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.

7.16 SAFETY MANAGEMENT SYSTEM (SMS)

The failure probabilities largely depend upon how effectively safety is being managed. This in turn necessitates, formal documented Safety Management System (SMS) as essential and effective. The features of a Safety Management System are described below.

Analysis of industrial accidents and disasters has shown clearly that these are not simply a consequence of direct technical failure or operator tasks, which were carried out incorrectly. The underlying causes may be deeply routed in management aspects of the organization. In some cases, the incidents could have been prevented with a formal Safety Management System (SMS). In other situations, a safety management system was in place, but did not prevent the occurrence of the incident. This suggests the need for a wider application of "best practice" safety management system in industry. Moreover, it raises the question of the quality of such systems.

Safety Management System should be a function of reporting at the highest management level.

7.16.1 Elements of Safety Management

SMS management comprises of a number of elements. For the sake of completeness, the contents and elements of the Safety Management System are given below:

i. Management leadership, commitment and accountability
ii. Risk Analysis, Assessment and Management
iii. Facilities design and construction
iv. Process and facilities information and documentation
v. Personnel safety and health
vi. Personnel training
vii. Operation and maintenance procedures
viii. Work permits
ix. Inspection and Maintenance
x. Reliability and quality control of critical systems and devices
xi. Regulatory compliance
xii. Management of change
xiii. Third party audit and inspection
xiv. Incident reporting, analysis and follow-up
xv. Emergency preparedness
xvi. Community awareness
xvii. Operations integrity assessment and improvement

BPCL already implemented Safety Management System at the existing Raiganj LPG bottling plant. Effective monitoring and safety audit procedures may also be developed to ensure proper implementation and follow-up of safety management system at the facility.