CHAPTER 7

RISK ASSESSMENT AND DISASTER MANAGEMENT PLAN

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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 Depot, to surrounding areas and the populations therein.

M/s Bharat Petroleum Corporation Limited, a Government of India Maharatna PSU under Ministry of Petroleum and Natural Gas (MOP&NG), have proposed to set up a new POL Depot for Storage and Distribution of various petroleum products with Railway Siding at identified site, admeasuring approximately 77.55 Acres at village – Radhanagar, Chas Taluk, District – Bokaro of Jharkhand. The Radhanagar POL Depot will be of 29170 KL Capacity of Petroleum Products (MS, SKO, HSD, Ethanol, and Biodiesel) at Village - Radhanagar, Chas Taluk, District – Bokaro of Jharkhand. Proposed capacity of POL Depot is total 29170 KL.

Table 7.1: Petroleum Products Wise Storage Capacity of the Depot

Tank No.	Tank Type	Product	Class of Product	Dia (m)	Height/ Length (m)	Licensed Capacity (KL)
TK -1	A/G Cone Roof	HSD	B	20	17.5	5290
TK -2	A/G Cone Roof	HSD	B	20	17.5	5290
TK -3	A/G Cone Roof	HSD	B	20	17.5	5290
TK -4	A/G Floating Roof	MS	A	20	15.5	4315
TK -5	A/G Floating Roof	MS	A	20	15.5	4315
TK -6	A/G Cone Roof	ETHANOL	A	9	10	575
TK -7	A/G Cone Roof	ETHANOL	A	9	10	575

Tank No.	Tank Type	Product	Class of Product	Dia (m)	Height/ Length (m)	Licensed Capacity (KL)
TK -8	A/G Cone Roof	SKO	B	9	13.5	800
TK -9	A/G Cone Roof	SKO	B	9	13.5	800
TK -10	A/G Cone Roof	Bio-Diesel	Excluded	9	13.5	800
TK -11	A/G Cone Roof	Bio-Diesel	Excluded	9	13.5	800
TK -14	Under Ground	SKO	B	3.2	12.6	100
TK -15	Under Ground	MS	A	3.2	12.6	100
TK -16	Under Ground	HSD	B	3.2	12.6	100
TK -17	Under Ground	HSD	B	2	6.75	20
Total						**29170**

Source: BPCL, Bokaro

7.2 OISD STANDARDS TO BE FOLLOWED AT RADHANAGAR POL DEPOT

The proposed Radhanagar POL Depot will be constructed and operated by complying applicable OISD standards. Maintenance schedules and fire fighting facilities are fully in line with relevant OISD standards, guidelines and recommended practices. The OISD standards being followed at Radhanagar POL Depot are given Table 7.2.

Table 7.2: OISD Standards to be followed at Radhanagar POL Depot

Sl.No	OISD Standard/ GDN/RP No	Name of Standards, General Guidelines and Recommended Practices
1.	OISD-STD-105	Work Permit System
2.	OISD-RP-110	Recommended Practices on Static Electricity
3.	OISD-STD-117	Fire Protection Facilities for Petroleum Depots, Terminals, Pipeline Installations & Lube oil installations
4.	OISD-STD-119	Selection, Operation and Maintenance of Pumps
5.	OISD-RP-124	Predictive Maintenance Practices
6.	OISD-STD-129	Inspection of Storage Tanks
7.	OISD-STD-130	Inspection of Piping Systems
8.	OISD-STD-135	Inspection of Loading & Unloading hoses for Petroleum Products
9.	OISD-STD-137	Inspection of Electrical Equipment
10.	OISD-STD-153	Maintenance & inspection of safety instrumentation in hydrocarbon industry

Sl.No	OISD Standard/ GDN/RP No	Name of Standards, General Guidelines and Recommended Practices
11.	OISD-RP-157	Recommended Practice for Transportation of Bulk Petroleum Products
12.	OISD-GDN-165	Guidelines for Rescue & Relief Operations for POL Tank Truck Accident
13.	OISD-RP-167	POL Tank lorry Design & Safety
14.	OISD-GDN-168	Emergency Preparedness Plan for Marketing Locations of Oil Industry
15.	OISD-GDN-178	Guidelines on Management Of Change
16.	OISD-STD-244	Storage and handling of Petroleum Products at depots and terminals including standalone crude oil storage facilities

Source: BPCL, Bokaro

7.3 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 Depot 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.

7.3.1 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 increase in tankage.
- Assessment of consequences of leak or spill of petroleum products from proposed increase in storage within the proposed Depot in terms of radiation, blast waves or dispersion.

- Determination of the magnitude of all major accidents arising due to the proposed increase in storage that have the potential to cause damage to life, property and environment including:
  - ✓ Effects on are as where personnel may be located within the Depot
  - ✓ Effects on are as external to the Depot
- 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 increase in storage.

7.3.2 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 hazard assessment was based on the following methodologies:

1. Hazard classification based on properties of petroleum products
2. Past accident analysis;

7.4 HAZARD IDENTIFICATION

Hazard is defined as a chemical or physical condition that has the potential for causing damage to people, property or the environment. Hazard identification is the first step in the risk analysis and entails the process of collecting information on:

- ✓ The types and quantities of hazardous substances stored, handled and disposed in the location;
- ✓ The location of storage tanks & other facilities.
- ✓ Potential hazards associated with the spillage and release.

The starting point of the risk analysis study is the identification of hazards and selection of scenarios that are then addressed for further analysis. It is essential to have comprehensive information on the petroleum products to be handled by Radhanagar POL Depot.

7.5 HAZARDS ASSOCIATED WITH PETROLEUM PRODUCTS

7.5.1 SUPERIOR KEROSENE OIL

Superior Kerosene Oil (SKO) is low viscosity liquid, with characteristic odour. Superior kerosene oil is flammable and explosive vapour/air mixtures may be formed above 37°C. Kerosene is distillate fractions of crude oil in the boiling range of 150-250°C. They are treated mainly for reducing aromatic content to improve their smoke point (height of a smokeless flame) and hydro fining to reduce sulphur content and to improve odour, colour & burning qualities (char value).

Kerosene is used as a domestic fuel for heating/lighting. Since kerosene is less volatile than motor spirit, increase in its evaporation rate in domestic burners is achieved by increasing surface area of the oil to be burned and by increasing its temperature:

Physical properties of Superior Kerosene Oil (SKO) are as given below:

Boiling point	:	*150-300°C*
Melting point	:	*-20°C*
Relative density (water = 1)	:	*0.8*
Solubility in water	:	*none*
Relative vapour density (air = 1)	:	*4.5*
Flash point	:	*37-65°C*
Auto-ignition temperature	:	*220°C*
Explosive limits, vol% in air	:	*0.7-5*

Superior Kerosene Oil is Class B petroleum product and presents a moderate fire hazard.

7.5.2 HAZARDS ASSOCIATED WITH HIGH SPEED DIESEL

High Speed Diesel is a mixture of straight run product (150 °C and 350 °C) with varying amount of selected cracked distillates and is composed of saturated hydrocarbons (primarily paraffins including n, iso, and cycloparaffins), and aromatic hydrocarbons (including napthalenes and alkylbenzenes). Its exact composition depends on the source of crude oil from which it is produced and the refining methods used.

Physical properties of high speed diesel are as given below:

Boiling point/Range	:	*215 – 376 °C*
Physical state	:	*Liquid*
Appearance	:	*Yellowish brown*
Vapour pressure	:	*2.12 to 26mm Hg at 21°C*
Odour	:	*Perceptible odour*
Solubility in water @ 30 deg.C	:	*Insoluble*
Specific gravity	:	*0.86 - 0.90 at 20°C*
Pour Point	:	*6 - 18°C*
Flammability	:	*Yes*
LEL	:	*0.6%*
UEL	:	*6%*
Flash point	:	*32°C*
TDG Flammability	:	*Class 3*
Auto-ignition temperature	:	*225°C*

HSD is Class B petroleum product and presents a moderate fire hazard. On heating, it can cause pressure rise with risk of bursting and subsequent explosion. It also forms explosive mixture with air particularly in an empty container.

7.5.3 Hazards Associated with Motor Spirit (MS)

Motor spirit is Class A petroleum product and presents a high fire hazard. Motor spirit is a complex blend of petroleum-derived normal and branched-chain alkane, cycloalkane, alkene, and aromatic hydrocarbons. It contains antioxidant and multifunctional additives. It is orange to bronze in appearance, liquid with perceptible odor, immiscible with water, lighter than water.

Motor spirit presents an extreme fire hazard. It evaporates very quickly, even at low temperatures and forms vapour which can catch fire and burn with explosive violence. Its invisible vapours are heavier than air and spread along the ground (that is why it is more susceptible to meet an ignition source). It can be set on fire by many sources such as pilot lights, welding equipments and spark from electrical motors and switches. On heating it can cause pressure rise with risk of bursting and subsequent explosion.

Boiling point	:	*25° C to 225° C (Variable with season and Location)*
Specific Gravity		*0.72 (Range)*
Flash Point	:	*45° C*
Auto Ignition Temp	:	*280° C to 429° C*
Vapour pressure	:	*0.35 – 1.05 Kgf/cm^2 (Max.) @ 37° C*
Vapor Density	:	*3 to 4 (Range) (Air = 1)*
Percent Volatile	:	*99+*
Flammability Limits	:	*Lower (LEL) = 1.4%; Upper (UEL) = 7.4%*
Category	:	*6 - 18°C*
Flammability	:	*Class A (Flash Point <23° C)*
Reactivity	:	*On exposure to thermal energy & light, it is stable. Incompatibility with strong oxidizers. Normal Combustion forms CO2 & water. Incomplete combustion can produce Carbon Monoxide*

7.5.4 ETHANOL

Fuel grade ethanol is used for Ethanol Blended Petrol (EBP). It is essentially ethyl alcohol. It is highly volatile, flammable and miscible in water. Pure ethanol has a flash point of 16.6ºC and varies with dilution in water. There is hence a danger of flammable mixtures of ethanol and air almost through the year. However, since the quantities stored is relatively lower than MS, SKO or HSD and the fact that it is stored in underground tanks, lowers the risks.

Ethanol is combustible colourless clear liquid. It is flammable in presence of open flames and sparks, of heat, of oxidizing materials. It is soluble in water. Physical properties of Ethanol are given below:

Molecular Weight	:	*46.04 g/mole*
Boiling point	:	*78°C*
Melting point	:	*-114.1°C*
Specific Gravity	:	*0.790 (Water = 1)*
Vapor Pressure	:	*59.33 mm of Hg (@ 20°C)*
Vapor Density	:	*1.59 (Air = 1)*
Solubility	:	*Easily soluble in cold water.*

Auto-Ignition Temperature	:	*363°C*
Flash Points	:	*Closed Cup: 16.6°C Open Cup: 61.88°C*
Flammable Limits	:	*Lower: 3.3% Upper: 19.0%*

Ethanol is a flammable liquid with a flash point of 16.6ºC. It requires fire-fighting facilities like, Alcohol Type Concentrate Foam (ATC) or CO_2/Dry Chemical Powder extinguishers. In case spilled, released, and then eliminate all sources of ignition. Small spills should be flushed with large quantities of water. Large spills should be collected for waste disposal.

7.5.5 BIODIESEL

Biodiesel refers to a vegetable oil diesel fuel consisting of long-chain alkyl (methyl, ethyl or proply) esters. Biodiesel is typically made by chemically reacting lipids (e.g., vegetable oil, soybean oil, animal fat with an alcohol producing fatty acid esters.

Biodiesel is meant to be used in standard diesel engines and is thus distinct from the vegetable and waste oils used to fuel converted diesel engines. Biodiesel can be used alone or blended with petro-diesel in any proportions.

Biodiesel is clear and straw colored liquid with characteristic petroleum (like kerosene) odor. Biodiesel is flammable liquid.

Physical properties of Biodiesel are given below:

Flash point	:	*38°C*
Auto Ignition Temperature	:	*177°C*
Lower Explosive Limit		*0.3 %(V)*
Upper Explosive Limit		*10 % (V)*
Thermal Decomposition		*No decomposition, if stored and applied as directed*
Boiling Point		*148 °C*
Vapor Pressure		*< 2 mm Hg at 20 °C*
Water Solubility		*Negligible*
Percent Volatiles		*100 %*

Biodiesel should be kept away from fire, sparks and heated surfaces. It should only be stored and handled in areas with intrinsically safe electrical classification. Hydrocarbon liquids including this Biodiesel can act as a non-conductive flammable liquid (or static

accumulators), and may form ignitable vapor-air mixtures in storage tanks or other containers.

7.6 HAZARDOUS CONDITIONS

An accidental release of petroleum product from tanks or pipeline/piping would result in formation of fixed or spreading pool. In case of immediate ignition a pool fire will result. Delayed ignition may result in explosion or flash fire, if quantity of explosive mass is sufficient and some confinement is present.

7.6.1 POOL FIRE

A leak or spill of sufficient quantities of petroleum product will result in an accumulation of petroleum product on the ground. If ignited, the resulting fire is known as spreading or fixed pool fire. In case any object comes in contact with the flame above the pool, it will be severely damaged or destroyed and personnel exposed to flame will suffer extensive burn injuries. Objects and personnel outside the actual flame volume may also be affected or injured by radiant heat. The extent of damage or injury depends on the heat flux and duration of fire and exposure. If a large area of the body receives second and third degree burns, it can result in fatalities.

The extent of injury to people depends on the heat flux and duration of exposure. The extent of damage to personnel and property depends on the size of the pool and the duration of fire.

❑ ***Thermal Effects***

In case of fire, thermal effect is likely to cause injury or damage to people and 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 have been used:

37.5 kW/m^2 : Damage to process equipment. 100% fatality in 1min. 1% fatality in 10sec.

12.5 kW/m^2 : First degree burn for 10 sec exposure

4.0 kW/m^2 : First degree burn for 30 sec exposure

7.6.2 JET FIRE

If released petroleum products from piping or pipeline are ignited immediately, jet fire may take place. The extent of injury to people depends on the heat flux and duration of exposure to heat.

7.6.3 VAPOUR CLOUD EXPLOSION/FLASH FIRE

If a released petroleum products is not ignited directly, the vapour cloud will spread in the surrounding area towards wind direction. The drifting cloud will mix with air. As long as the vapour concentration is between the lower and upper explosion limits, the vapour cloud may be set on fire by an ignition source. In case of delayed ignition of a cloud, two physical effects may occur: a flash fire over the whole length of the flammable vapour cloud; a vapour cloud explosion which results in blast wave, with typical peak overpressures circular around the ignition source. For generation of overpressure effects, some degree of confinement of the flammable cloud is required. The extent of injury to people & damage to property or environment depends on the cloud size, explosive mass in the cloud and the degree of confinement at the time of ignition.

- ***Delayed Ignition & Explosion***

In case of delayed ignition of a natural vapour cloud, two physical effects may occur:

- ✓ a flash fire over the whole length of the explosive vapour cloud;
- ✓ a vapour cloud explosion that results in blast wave, with typical peak overpressures circular around the ignition source. For generation of overpressure effects, some degree of confinement of the flammable cloud is required.

The following Table 7.3 gives damage criteria with respect to the peak overpressures resulting from a blast wave:

Table 7.3: Damage Effects due to Overpressures

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

(Source: TNO)

The Table 7.4 below gives an illustrative listing of damage effects caused by peak overpressure.

Table 7.4: 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
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)

7.7 SELECTION OF SCENARIOS FOR CONSEQUENCE ANALYSIS

At Radhanagar POL Depot petroleum products inventory may be released due to loss of containment. A leak can range in size from a pinhole leak to a catastrophic failure. In general, smaller leaks have higher accident likelihood but lower consequence distances. On the other hand larger releases have lower accident likelihood but longer consequence distance.

The selected scenarios for consequence analysis are given in Table 7.5.

Table 7.5: Scenarios for consequence analysis

Scenario No.	Description	Outcomes
1	Rupture of Motor Spirit Tank followed by Immediate/Delayed ignition	Pool Fire/ Vapour Cloud Explosion/ Flash Fire
2	Rupture of HSD Tank followed by Immediate/Delayed ignition	Pool Fire/ Vapour Cloud Explosion/ Flash Fire
3	Rupture of Ethanol Tank followed by Immediate/Delayed ignition	Pool Fire/ Vapour Cloud Explosion/ Flash Fire
4	Rupture of SKO Tank followed by Immediate/Delayed ignition	Pool Fire/ Vapour Cloud Explosion/ Flash Fire
5	Release of Ethanol due to over flow at TLD bay	Pool Fire/ Vapour Cloud Explosion/ Flash Fire
6	Release of Ethanol due to Leakage in unloading arm at TLD	Pool Fire/ Vapour Cloud Explosion/ Flash Fire
7	Release of Motor Spirit piping from TWD to pump house	Pool Fire/ Vapour Cloud Explosion/ Flash Fire
8	Release of HSD piping from TWD to pump house	Pool Fire/ Vapour Cloud Explosion/ Flash Fire
9	Pipeline Leakage of HSD from storage Tank to gantry	Pool Fire/ Vapour Cloud Explosion/ Flash Fire
10	Pipeline Leakage of Motor spirit from storage Tank to gantry	Pool Fire/ Vapour Cloud Explosion/ Flash Fire
11	Overfilling Motor Spirit at TLF Bay during MS Filling at Gantry	Pool Fire/ Vapour Cloud Explosion/ Flash Fire
12	Pipeline Rupture of Motor spirit from storage Tank to gantry	Pool Fire/ Vapour Cloud Explosion/ Flash Fire
13	Fire in Motor Spirit Filled Tanker in Parking	Pool Fire/ Vapour Cloud Explosion/ Flash Fire

Source: ABC Techno Labs India Pvt. Ltd.

7.8 CONSEQUENCE ANALYSIS

Subsequent to the accidental release of petroleum products, the consequence of an accidental release depends on various factors e.g. type and quantity of release, presence and location of an ignition source, meteorological conditions, etc. Any loss of containment at Radhanagar POL Depot will lead to a release of petroleum products. The released quantity will depend on failure size and the duration of release. All the tanks at the Radhanagar POL Depot will be provided with bund (dyke). On release of containment from tanks, a fixed pool may be formed, which may or may not ignite. If immediate or delayed ignition takes place a pool fire will result. Delayed ignition may also lead to vapour cloud explosion / flash fire, if release quantities/surface areas are significant. In the event of release from transfer piping and/or pipeline, spreading pool will be formed followed by spreading pool fire on getting source of ignition.

The following effects are distinguished for consequence analyses, immediate ignition followed by pool fire, or evaporation and delayed ignition of a vapour cloud resulting in a fire and/or explosion. Representative consequences distance up to where 1% fatality-occurs among those exposed, has been calculated.

The following damage distances for thermal radiation have been used:

37.5 kW/m²	*Damage to process equipment. 100% lethality in 1min. 1% lethality in 10sec.*
12.5 kW/m²	*First degree burn for 10 sec exposure*
4 kW/m²	*First degree burn for 30 sec exposure*

The 0.1 bar overpressure due to explosion at 1% fatality has been considered for computations.

7.8.1 MODEL USED FOR CONSEQUENCE ANALYSIS

The consequence analysis study involves a large number of calculations for which established computing aids are essential. PHAST/SAFETI software of DNV has been used to perform the consequence calculations. PHAST/SAFETI is a consequence and risk assessment software for calculation of physical effects (fire, explosion, atmospheric dispersion) of the escape of hazardous materials. PHAST/SAFETI software allows detailed modelling and quantitative assessment of release of pure and mixtures of liquid and gaseous chemicals. The consequence analysis for the proposed tanks of the Radhanagar POL Depot at Bokaro is given in Table 7.6.

Table 7.6: Consequence Analysis for the Proposed Tanks at Radhanagar POL Depot

IS Ref.		Radiation Effects: Flammable Results											
		Flash Fire Envelope			Late pool Fire			Jet Fire Ellipse			Overpressure Levels		
		Furthest Extent	Distance in meters		Radiation Levels	Distance in meters		Radiation Levels	Distance in meters		Overpressure (bar)	Distance in meters	
			1.5F	5D	kW/m²	1.5F	5D	kW/m²	1.5F	5D		1.5F	5D
Motor Spirit Tank	Rupture	**UFL**	312.19	209.49	**4**	656.74	781.49	**4**	NR	NR	**0.02**	381.54	257.23
		LFL	991.36	703.07	**12.5**	417.26	427.99	**12.5**	NR	NR	**0.13**	186.05	145.68
		Extent	1011.89	798.46	**37.5**	NR	NR	**37.5**	NR	NR	**0.20**	180.2	107.28
HSD Tank	Rupture	**UFL**	98.88	86.63	**4**	911.94	596.63	**4**	NR	NR	**0.02**	156.78	161.71
		LFL	99.52	87.28	**12.5**	665.69	368.51	**12.5**	NR	NR	**0.13**	67.92	86.59
		Extent	99.65	87.42	**37.5**	NR	NR	**37.5**	NR	NR	**0.20**	65.94	84.94
Ethanol Tank	Rupture	**UFL**	35.82	34.21	**4**	648.61	687.93	**4**	NR	NR	**0.02**	333.75	271.37
		LFL	150.75	123.22	**12.5**	436.19	462.15	**12.5**	NR	NR	**0.13**	145.58	105.53
		Extent	242.38	220.25	**37.5**	281.28	313.04	**37.5**	NR	NR	**0.20**	136.49	99.65
SKO Tank	Rupture	**UFL**	36.04	34.42	**4**	394.77	443.22	**4**	NR	NR	**0.02**	100.75	113.93
		LFL	36.31	34.7	**12.5**	233.23	231.81	**12.5**	NR	NR	**0.13**	54.64	55.55
		Extent	40.84	34.77	**37.5**	NR	NR	**37.5**	NR	NR	**0.20**	48.47	49.19
Ethanol Tanker - TLD Bay	Spill/ Overflow	**UFL**	1.45	1.31	**4**	15.78	18.68	**4**	NR	NR	**0.02**	NR	NR
		LFL	2.15	2.27	**12.5**	10.62	13.07	**12.5**	NR	NR	**0.13**	NR	NR
		Extent	2.19	2.32	**37.5**	5.99	6.77	**37.5**	NR	NR	**0.20**	NR	NR
	Leak	**UFL**	0	0	**4**	8.33	9.42	**4**	NR	NR	**0.02**	NR	NR

IS Ref.		Radiation Effects: Flammable Results											
		Flash Fire Envelope			Late pool Fire			Jet Fire Ellipse			Overpressure Levels		
		Furthest Extent	Distance in meters		Radiation Levels	Distance in meters		Radiation Levels	Distance in meters		Overpressure (bar)	Distance in meters	
			1.5F	5D	kW/m²	1.5F	5D	kW/m²	1.5F	5D		1.5F	5D
		LFL	0.002	0.001	**12.5**	4.81	6.11	**12.5**	NR	NR	**0.13**	NR	NR
		Extent	0.0	0.03	**37.5**	2.65	2.86	**37.5**	NR	NR	**0.20**	NR	NR
MS release - TWD	Leak	**UFL**	1.63	1.46	**4**	20.09	23.07	**4**	4.36	4.39	**0.02**	NR	NR
		LFL	2.19	2.34	**12.5**	13.29	15.77	**12.5**	3.00	3.01	**0.13**	NR	NR
		Extent	2.22	2.36	**37.5**	5.91	7.16	**37.5**	0.0	0.0	**0.20**	NR	NR
HSD release - TWD	Spill/ Overflow	**UFL**	1.56	1.41	**4**	27.80	28.5	**4**	NR	NR	**0.02**	NR	NR
		LFL	2.37	2.51	**12.5**	18.07	19.38	**12.5**	NR	NR	**0.13**	NR	NR
		Extent	2.35	2.53	**37.5**	8.31	8.48	**37.5**	NR	NR	**0.20**	NR	NR
	Leak	**UFL**	0	0	**4**	17.32	17.32	**4**	NR	NR	**0.02**	NR	NR
		LFL	0	0	**12.5**	11.09	11.30	**12.5**	NR	NR	**0.13**	NR	NR
		Extent	0	0	**37.5**	4.62	5.21	**37.5**	NR	NR	**0.20**	NR	NR
MS transfer pipeline	Rupture	**UFL**	49.25	12.71	**4**	128.10	157.88	**4**	58.39	60.99	**0.02**	96.98	89.13
		LFL	122.79	63.43	**12.5**	57.36	62.94	**12.5**	45.47	46.61	**0.13**	64.36	56.19

IS Ref.		Radiation Effects: Flammable Results										
		Flash Fire Envelope			Late pool Fire			Jet Fire Ellipse			Overpressure Levels	
		Furthest Extent	Distance in meters		Radiation Levels	Distance in meters		Radiation Levels	Distance in meters		Overpressure (bar)	Distance in meters
			1.5F	5D	kW/m²	1.5F	5D	kW/m²	1.5F	5D		1.5F	5D
from storage Tank to gantry		**Extent**	163.78	102.49	**37.5**	NR	NR	**37.5**	37.51	38.05	**0.20**	38.25	32.13
	Leak	**UFL**	2.19	2.01	**4**	25.68	29.35	**4**	11.84	11.51	**0.02**	26.27	NR
		LFL	7.30	4.38	**12.5**	16.96	20.15	**12.5**	9.125	8.72	**0.13**	13.16	NR
		Extent	14.57	6.68	**37.5**	7.89	9.24	**37.5**	7.361	6.91	**0.20**	12.37	NR
HSD transfer pipeline from storage Tank to gantry	Leak	**UFL**	1.93	1.81	**4**	33.99	34.74	**4**	NR	NR	**0.02**	NR	NR
		LFL	3.62	3.71	**12.5**	20.58	23.22	**12.5**	NR	NR	**0.13**	NR	NR
		Extent	3.64	3.77	**37.5**	11.74	11.97	**37.5**	NR	NR	**0.20**	NR	NR
Overfilling Motor Spirit at TLF Bay during MS loading at Gantry	Spill	**UFL**	0.011	0.006	**4**	15.49	17.68	**4**	NR	NR	**0.0068**	NR	NR
		LFL	0.015	0.008	**12.5**	9.71	11.52	**12.5**	NR	NR	**0.068**	NR	NR
		Extent	0.018	0.013	**37.5**	3.37	4.32	**37.5**	NR	NR	**0.344**	NR	NR

IS Ref.		Radiation Effects: Flammable Results											
		Flash Fire Envelope			Late pool Fire			Jet Fire Ellipse			Overpressure Levels		
		Furthest Extent	Distance in meters		Radiation Levels	Distance in meters		Radiation Levels	Distance in meters		Overpressure (bar)	Distance in meters	
			1.5F	5D	kW/m²	1.5F	5D	kW/m²	1.5F	5D		1.5F	5D
Fire in Motor Spirit Filled Tanker in Parking	Rupture	**UFL**	0.079	0.079	**4**	15.32	15.18	**4**	NR	NR	**0.0068**	NR	NR
		LFL	0.224	0.216	**12.5**	9.69	10.09	**12.5**	NR	NR	**0.068**	NR	NR
		Extent	0.415	0.399	**37.5**	3.52	4.17	**37.5**	NR	NR	**0.344**	NR	NR

Source: ABC Techno Labs India Pvt. Ltd.

7.9 RISK MITIGATION MEASURES

Risk is defined as the consequences arising out of an unwanted event in relation to the probability that such consequences might in fact occur. Risk reduction thus comprises of two basic steps:

- ✓ Reduction of consequences of accidental release
- ✓ Reduction of likelihood of an accidental release

7.9.1 IMPLEMENTATION OF ADVANCE RISK MITIGATION MEASURES

At POL Depot of BPCL at Bokaro, following advance risk mitigation measures will be provided:

- ✓ Sprinkler and foam system is being provided around the storage tanks.
- ✓ HVLR foam monitor systems are being provided to combat the fire.

7.9.2 POL STORAGE TANKS

- ✓ Tank overfilling followed by immediate or delayed fire is not an infrequent happening in POL Depots of BPCL and needs to be guarded against at all costs. It is therefore desirable to ensure the continued functioning of the instrumentation such as the two independent level instruments, level alarm for all class hydrocarbon storage tanks.
- ✓ Storage Tanks will be provided with at least two numbers of level instruments of which one may be local and the other remote, located in the control room or in the office. In addition, high/low level alarms with the independent primary sensing device are also recommended.
- ✓ Open vents will be provided of goose neck type, covered with a 4 to 8 mesh screen to discharge the vapours of hydrocarbons from storage tanks,.
- ✓ Every petroleum storage tank, including its roof and all metal connections, will be electrically continuous and be effectively earthed.
- ✓ Check list for operators for checking safety system and equipment will be prepared and check records kept in safe custody.
- ✓ The critical operating steps will be displayed on the board near the location where applicable.
- ✓ All operational valves must be outside dyke area.
- ✓ Dyke will be leak proof.

- ✓ High level alarm from the radar gauge and high-high level alarm from a separate tap off will be provided.
- ✓ Piping design inside tank dyke area will ensure easy accessibility for any operations inside dyke in the tank farm.
- ✓ Thermal Safety Valve (TSV) will be provided at the operating manifold (outside dyke).
- ✓ Tank Dyke Valves will be provided with position indicator (open or close) in control room and necessary hardware and instrumentation should be provided for this.

7.9.3 Painting on Storage Tanks

- ✓ Besides tank numbers, safe filling height, reference height, etc. will be painted on the tanks to avoid operating errors.
- ✓ Tanks numbers will be painted at three positions, 120 degrees apart, below roof level and should be clearly visible from outside the dyke/roadside. Recommended size of letters for numbering is 150 mm and 12 mm thick.
- ✓ For storage tanks luminous paint will be preferred.

7.9.4 Earthing and Bonding

- ✓ Every storage tank, including its roof and all metal connections will be electrically continuous and be effectively earthed.
- ✓ For floating roof tanks, stainless steel shunts will be provided across the peripheral seals to ensure earthing of floating roof.
- ✓ The pontoon, ladder and shell of the floating roof tank will be continuously bonded with copper cable and the shell shall be independently earthed. Best practices of "OISD-RP-110 -Recommended Practices on Static Electricity" for earthing and bonding at the Depot will be followed.

7.9.5 Process Safety Management

- ✓ A dedicated, qualified and experienced officer will be designated as 'Safety Officer' of the POL Depot after training. He will be given exposure to HAZOP, risk assessment, safety audit and upkeep of fire fighting facilities and conducting safety meetings.

- ✓ The Depot Managers are trained in hazard identification techniques and be familiarized with risk assessment and risk mitigation methods.
- ✓ Annual Safety Audit by well qualified third party, which ensure that systems and procedures and safety back-ups are in place, their requirements are understood by all concerned and they are properly operated by the concerned personnel.
- ✓ Site specific "Standard Operating Procedure (SOP)" will be developed.

7.9.6 Management of Change

Management of change procedure will be prepared and implemented.

7.9.7 Accident and Near Miss Reporting System

Near miss reporting system will be followed at the Radhanagar POL Depot.

7.9.8 Work Permit System

At the Depot during construction and operational phase, work permit system for cold work, hot work, working at height, electrical and confined space entry will be followed.

7.9.9 Leakage Detection System & Monitoring System

Hydrocarbon (HC) detectors will be installed near possible potential leak sources of class 'A' and 'B' petroleum products e.g. tank dykes, tank manifolds, pump house manifolds, etc. These detectors can sense any leakages of hydrocarbon and communicate the same to the control room with audible alarm at two locations. Main objective of the hydrocarbon detectors is to detect hydrocarbon vapours concentrations in the Radhanagar POL Depot and initiate alarm or shutdown system as the case may be, at pre-defined levels to prevent any hazardous events and act as independent safety layers for mitigation of consequences to achieve overall process safety requirements of the Depot. Hydrocarbon Detection system is designed to perform its function during normal, abnormal and design basis conditions. Control system is based on open architecture system topology with fault tolerant network capabilities.

Further, Proper HC detectors should be selected and should be proof tested and maintained in good condition.

Fire Detection through Hydro Carbon Detectors and Rim Seal Fire Detection and Protection Systems will be provided. Fire Protection System will be provided through Fixed Foam System, Sprinkler System, Monitors, DCP, Mobile Foam Trolleys, High Volume

Long Range (HVLRs), Medium Expansion Foam Generators (MEFGs), Foam trolleys, Mobile Foam Monitors etc.

7.9.10 AUTOMATIC SHUTDOWN & AUTO OPERATION FIRE HYDRANT NETWORK

At the proposed Radhanagar POL Depot interlocking shut down devices (ISD) will be installed and will be connected to Automatic shutdown & auto operation fire hydrant network.

Automation at Radhanagar POL Depot mainly consists of two parts - The process PLC and the Safety PLC. The process PLC is the main controller in the Control Room which facilitates the oil filling operations such as pump start/stop, measurement of product level in tanks, calculation of oil filled in tank lorries etc. The Safety PLC takes care of all the safety related operations in Radhanagar POL Depot. The safety PLC prevents over flow of product from Tank lorries or tanks, does preventive check of all equipment, monitors unwanted oil vapors and control firefighting equipment. Our Safety related instruments consist of Jockey Pumps and Fire Engines which are connected to the safety PLC and whenever any fire or fire type hazard is detected by the PLC the jockey pumps and fire engines are switched on automatically for providing water for firefighting. The long range monitors situated all over the Depot help us in firefighting from a large distance as it is controlled by joysticks located away from the hazardous area and are also connected to the safety PLC. The tanks will be fitted with High Level switches and Remote Operated Shut off Valves which are very sensitive instruments. While filling of tank from Rail wagon or Tankers the High Level switch is activated whenever the product reaches the safe filling height. The High level switch then sends a signal to the safety PLC which in turn closes the Remote Operate shut off valve. This entire operation is extremely fast to the tune of 20-24 seconds and prevents the overflow of product. Overall our automation system is robust and is extremely fool proof as our safety related system at minimum SIL2 certified.

In addition to the above, the pressurized fire water network, MV spray systems for AG tanks, product pump houses, TWD Gantry for effective cooling during emergency, remote operated High Velocity Long Range water cum foam monitors for A Class above ground tank farm, open & point type Hydro Carbon detectors for immediate detection of leakage/spillage of mainly for A class products, emergency shutdown features in process & safety PLCs, centralized Foam system for providing blanketing on top of product

spillage, provision emergency panel with defined power distribution during emergency etc. are few more significant features conceptualized in the project to develop a full-fledged integration of safety in regular operations.

❒ **Automation System for Petroleum Product Loading Stations**

The automation system for truck loading stations consists of the following sections: This system ensures optimization of economy and safety in operation.

- ✓ Volumetric Flow Meters
- ✓ Batch Controllers
- ✓ Plant control system Programmable Logic Controller (SMPS)

Operator's Interface console

- ✓ Metering System
- ✓ Batch Controller
- ✓ Plant control system Programmable Logic Controller (SMPS)
- ✓ Control and Interlocking System
- ✓ Integrated Control System
- ✓ Emergency Shutdown System

7.9.11 SECURITY AND SURVEILLANCE OF DEPOT

- ✓ CCTVs will be installed covering tank farm areas and other critical areas. The CCTV can nowadays provide with an alarm to provide warning in case of deviation from any normal situation. The CCTV monitoring station should be provided both in the control room as well as in the Security cabin/office.
- ✓ The security supervisor at the gate will be provided with external telephone. The supervisor will be provided with telephone numbers of all officers. A board displaying the name addresses and phone numbers of the emergency contact points of the company as well as the local authorities will be provided therein.
- ✓ Adequate lighting in operational areas should be ensured.
- ✓ Vehicles with spark ignition engine should not be allowed inside the installation area except up to the Administrative Block and also to ensure continuous manning at the control room.

Communication

VHF handsets should be provided to each of the operating crew.

7.9.12 SAFETY AUDIT AND INSPECTION

Routine inspections will be carried out in line with applicable rules, regulations and OISD Standards for tankfarm area, piping and loading gantries in the Depot. Any gap or non compliance is implemented on priority in time bounded manner.

Regular inspection of piping including thickness survey and pipeline support systems are carried out and records maintained.

7.9.13 ACTION PLAN FOR FIRE FIGHTING FACILITIES AS PER OISD NORMS

Proposed Radhanagar POL Depot layout and firefighting system design are as per OISD STD 117 and have been upgraded to OISD STD 244. The fire protection and detection system are in accordance with OISD 117. Portable fire extinguishers of 10-75 kg will be installed on pump stations, tank farms and buildings, the size depending on the object concerned. Electrical rooms will be protected by Carbon dioxide (CO_2) fire extinguishers. Mobile fire fighting vehicles with foam monitors, hoses, etc. have been provided. Fixed fire fighting monitors are located at the pump station and truck loading gantries, each with a capacity of 144 m^3/hr. sufficient hydrants are installed in the POL Depot, with the hydrants spaced at a maximum distance of 30m.

The tanks will be equipped with fixed cooling water and foam pourer. Mobile vehicles and equipment (monitors, hoses, branch pipes, etc.) will be provided to handle field fires.

There will be provision of following fire fighting equipments for the proposed POL Depot:

- ✓ Dry Chemical Powder Extinguisher
- ✓ CO_2 type Extinguisher
- ✓ Mechanical foam type Extinguisher
- ✓ Water CO_2 type Extinguisher
- ✓ Water and sand buckets
- ✓ Hose Reel
- ✓ PA system
- ✓ Hydrant system
- ✓ Foam Monitor
- ✓ Water monitor
- ✓ Fire alarm system
- ✓ Foam drum
- ✓ HVLR Monitor

Table 7.6 below presents fire water pumps will be constructed at Radhanagar POL Depot:

Table 7.6: Fire Water Storage Tanks

Tank No.	Type	Dimensions	Capacity
TK-12	A/G	Dia 17.00 m X Ht 11.00 m	2500 KL
TK-13	A/G	Dia 17.00 m X Ht 11.00 m	2500 KL
28	U/G	W 4.0 m X L 6.0 m X D 1.5 m	30 KL

Source: BPCL, Bokaro

Water storage requirements should also keep in mind whether adequate supplies are available if not, the storage should be increased appropriately. Auto start of the fire water pumps may be linked with the Hydro Carbon leak detection and alarm system in order to start the sprinkler system automatically especially in tank farm area and pump house.

- ✓ The Rim Seal fire detection and protection system should be installed in all Class 'A' products in the depot.
- ✓ Remote operated long range foam monitors (1000 GPM) to fight tank fires have been provided with variable flow.
- ✓ Depot operating personnel will be given safety and simulated fire fighting training based on simulated modules of live fires in tanks, pipeline manifold and pumps, etc. Personnel from security services are also trained fully in fire fighting and rescue operations using Personal Protective Equipment.
- ✓ During all operations even after the general shift a dedicated fire fighting team will be present.
- ✓ There will be a minimum level of manning maintained apart from the security personnel for monitoring the facilities even during non operational hours.
- ✓ Flame-proof torches will be made available to inspect and keep vigil in the tankfarm areas during night.
- ✓ Fire Fighting System will be tested periodically for proper functioning and logged for records and corrective actions.
- ✓ Every fire-water pump will be tested run for at least half an hour two times a week.
- ✓ All hydrants, monitors and valves will be visually inspected every month.
- ✓ Fire hoses will be hydraulically tested at least once in six months to a minimum pressure of 7 kg/cm^2.

7.9.14 MANIFOLDS

For safety considerations, it is desirable to keep the number of inlet/outlet connections to the tanks should be minimum. This reduces the number of flanges/valves close to the tanks. For more number of lines, it is desirable to take a single header and form as manifold away from the tank. The floor underneath should be paved, have curbed walls and connected to the drainage system.

7.9.15 LOADING GANTRIES

It is desirable to consider fire proof remote operated shut off valves for loading headers so that gantry headers can be isolated in case of emergency.

7.9.16 INTEGRITY OF TANKS AND PIPING

The integrity of the tanks and pipings during its lifetime needs to be maintained by means of condition monitoring. The condition-monitoring programme should be defined on the basis of the anticipated degradation of equipment, tanks, piping, etc.

7.9.17 PERSONAL PROTECTIVE EQUIPMENT

- ✓ Personal protective equipment such as safety glasses must wore while carrying out all operations
- ✓ All other PPEs will be available at location and easily identified.
- ✓ All PPEs as well as safety equipment required for emergency use such as breathing apparatus, fire suit, fire extinguishers, monitors and sprinklers will be regularly tested in presence of safety officers and records maintained.
- ✓ All PPEs required during emergency will be located in designated safe areas.

7.9.18 PREVENTIVE AND PREDICTIVE MAINTENANCE

Predictive and preventive maintenance practices significantly help in minimizing the likelihood of an accidental release. Therefore, predictive and preventive maintenance schedule will be prepared and followed.

7.9.19 COMPLIANCE TO THE STATUTORY REGULATIONS

Radhanagar POL Depot is major accident hazard (MAH) installation under Manufacture, Storage and Import of Hazardous Chemicals (MSIHC) Rule, 2000. Hence, safety audit will be conducted every year.

7.9.20 TRAINING AND COMPETENCE CRITERIA

There will be provision for periodic training programmes for concern BPCL and contractual personnel engaged in POL handling operations. BPCL may establish competence criteria for contractual workers for allowing working in tank farm, piping, gantries, etc.

Training for Safety is currently based on OISD 154 for all categories. Safety training for operators will be based on the needs of the operation, the procedures and why these are needed. Fire training will always be an important part of his training, which is best provided by realistic fire fighting exercises in an area designated for this purpose.

Training will also be given to prevent operational malpractices such as shortcuts, on safety provision being bypassed and how they can create unmanageable risks to life and property. Training will be based on the needs of the job, and relevant to the trainee.

For Supervisors, intimate knowledge of the operator's job is essential and this will be ensured. In addition Leadership Training will be provided on Manpower management and motivation, and also on Communication which will enable them to give proper task instructions to the operators.

All Radhanagar POL Depot operating personnel, including regular contractors and security personnel will be given safety and fire fighting training with the help of reputed training institutes. The security staff will be trained as first responders for fire fighting and rescue operations along with Depot operating personnel.

For Depot Managers, safety training may include following modules

- ✓ Basics of Safety Management System
- ✓ The causes and effects of accidents
- ✓ Hazard identification
- ✓ Risk Assessment and risk mitigation
- ✓ Controlling risks and Preventing Accidents
- ✓ Emergency preparedness
- ✓ Critical Task Analysis
- ✓ Crisis Management
- ✓ Importance of trip/alarm and Safety Procedures and systems
- ✓ Learnings from case histories

Training activities will include safety training for contract employees since a number of activities will be outsourced.

7.9.21 CHECK FOR TANK TRUCKS

Before entering the truck tankers engaged in the transportation of petroleum products, following documents will be strictly checked on the main gate and trucks having following documents will be allowed to enter into Depot premises:

- ✓ Registration certificate for transportation of petroleum products
- ✓ Deriver license to drive vehicles carrying petroleum products
- ✓ Authorized license to carry the petroleum products.
- ✓ Fitness Certificate
- ✓ Valid National permit
- ✓ TREM Card
- ✓ Insurance papers
- ✓ Spark arrester with the exhaust
- ✓ Restricted item such as match box, cigarette, bidi, etc.

7.9.22 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. Hence, periodic review of an Emergency Response Plan for Radhanagar POL Depot is, therefore, essential. Emergency Response Plan will also be updated based on finding of mock drill.

Emergency procedures will be written in local language and available to all personnel in the installation outlining the actions to be taken by each during a major incident.

An emergency kit will be provided consisting of safety items viz. fire suites, various leak plugging gadgets, oil dispersants and oil absorbents, lifting jacks (for rescue of trapped workers), high intensity intrinsically safe search lights for hazardous area, etc. and will be readily available at the depot.

7.9.23 MOCK DRILL EXERCISES

Mock drill whenever conducted should include the full shut down system activation also. Shift manning should always be maintained. The person leaving site should only be allowed on a valid gate pass issued by the immediate officer.

A system will exist for informing neighbouring industries about impending danger. The company will approach and coordinate with the district authority for conducting "Off Sites Mock Drills".

Mock drill will 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 a likely emergency situation.

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

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

7.10 DISASTER MANAGEMENT PLAN

Emergency Response and Disaster Management Plan for the proposed POL Depot based on risk analysis findings will be prepared after commissioning of the Depot.