Risk Assessment and Disaster Management Plan

Risk and Hazards

Hazard analysis involves the identification and quantification of the various hazards (unsafe conditions) that exist in the proposed expansion project. On the other hand, risk analysis deals with the identification and quantification of risks, the plant equipment and personnel are exposed to, due to accidents resulting from the hazards present in the plant.

Risk analysis follows an extensive hazard analysis. It involves the identification and assessment of risks the neighboring population are exposed to as a result of hazards present. This requires a thorough knowledge of failure probability, credible accident scenario, vulnerability of population etc. Much of this information is difficult to get or generate. Consequently, the risk analysis is often confined to maximum credible accident studies.

In the sections below, the identification of various hazards, probable risks in the proposed expansion project (alumina refinery plant & co-generation plant), Maximum Credible Accident (MCA) analysis, consequence analysis are addressed, which gives a broad identification of risks involved in the plant. Based on the risk estimation for fuel and chemical storage Disaster Management Plan (DMP) has been presented.

Risk involves the occurrence or potential occurrence of some accidents consisting of an event or sequence of events. The risk assessment study covers the following:

- Identification of potential hazard areas;
- Identification of representative failure cases;
- Visualization of the resulting scenarios in terms of fire (thermal radiation) and explosion;
- Assess the overall damage potential of the identified hazardous events and the impact zones from the accidental scenarios;
- Assess the overall suitability of the site from hazard minimization and disaster mitigation points of view;
- Furnish specific recommendations on the minimization of the worst accident possibilities; and
- Preparation of broad Disaster Management Plan (DMP), On-site and Off-site Emergency Plan, which includes Occupational and Health Safety Plan.

Hazard Identification

Introduction

Identification of hazards in the proposed expansion project is of primary significance in the analysis, quantification and cost effective control of accidents involving chemicals and process. A classical definition of hazard states that hazard is in fact the characteristic of system/plant/process that presents potential for an accident. Hence, all the components of a system/plant/process need to be thoroughly examined to assess their potential for initiating or propagating an unplanned event/sequence of events, which can be termed as an accident. The following two methods for hazard identification have been employed in the study:

- Identification of major hazardous units based on Manufacture, Storage and Import of Hazardous Chemicals Rules, 1989 of Government of India (GOI Rules, 1989); and

- Identification of hazardous units and segments of plants and storage units based on relative ranking technique, viz. Fire-Explosion and Toxicity Index (FE&TI).

<u>Classification of Major Hazardous Units</u>

Hazardous substances may be classified into three main classes namely Flammable substances, unstable substances and Toxic substances. The ratings for a large number of chemicals based on flammability, reactivity and toxicity have been given in NFPA Codes 49 and 345 M. The fuel storage details and properties are given in **Table-1** and **Table-2** respectively.

TABLE-1
CATEGORY WISE SCHEDULE OF STORAGE TANKS

Sr. No.	Material	No. of Tanks	Design Capacity (KL)	Classification
1	LDO	1	25	B
2	HFO	1	4000	B

Note – B: Non-dangerous Petroleum

TABLE-2
PROPERTIES OF FUELS/CHEMICALS USED AT THE PLANT

Chemical	Codes/Label	TLV	FBP	MP	FP	UEL	LEL
			°c			%	
HFO	Flammable	5 mg/m^3	350	-26	66	6.0	0.5
LDO	Flammable	5 mg/m^3	400	-	32 - 96	7.5	0.6

TLV	:	Threshold Limit Value	FBP	:	Final Boiling Point
MP	:	Melting Point	FP	:	Flash Point
UEL	:	Upper Explosive Limit	LEL	:	Lower Explosive Limit

<u>Identification of Major Hazard Installations Based on GOI Rules, 1989</u>

Following accidents in the chemical industry in India over a few decades, a specific legislation covering major hazard activities has been enforced by Govt. of India in 1989 in conjunction with Environment Protection Act, 1986. This is referred here as GOI rules 1989. For the purpose of identifying major hazard installations the rules employ certain criteria based on toxic, flammable and explosive properties of chemicals.

A systematic analysis of the fuels/chemicals and their quantities of storage has been carried out, to determine threshold quantities as notified by GOI Rules, 1989 and the applicable rules are identified. Applicability of storage rules are summarized in **Table-3.**

TABLE-3
APPLICABILITY OF GOI RULES TO FUEL/CHEMICAL STORAGE

Sr. No.	Chemical/ Fuel	Listed in Schedule	Total Quantity (KL)	Threshold Quantity (T) for Application of Rules	
				5,7-9,13-15	10-12
1	LDO	3(1)	25	25 MT	200 MT
2	HFO	3 (1)	4000	25 MT	200 MT

Hazard Assessment and Evaluation

Methodology

An assessment of the conceptual design is conducted for the purpose of identifying and examining hazards related to feed stock materials, major process components, utility and support systems, environmental factors, proposed operations, facilities, and safeguards.

Preliminary Hazard Analysis (PHA)

A preliminary hazard analysis is carried out initially to identify the major hazards associated with storages and the processes of the plant. This is followed by consequence analysis to quantify these hazards. Finally, the vulnerable zones are plotted for which risk reducing measures are deduced and implemented. Preliminary hazard analysis for fuel storage area and whole plant is given in **Table-4** and **Table-5.**

TABLE-4
PRELIMINARY HAZARD ANALYSIS FOR STORAGE AREAS

Unit	Capacity	Hazard Identified
HFO	4000	Pool fire
LDO	25	Pool fire

TABLE-5
PRELIMINARY HAZARD ANALYSIS FOR THE WHOLE PLANT IN GENERAL

PHA Category	Description of Plausible Hazard	Recommendation	Provision
Environ-mental factors	If there is any leakage and eventuality of source of ignition.	--	All electrical fittings and cables are provided as per the specified standards. All motor starters are flame proof.
	Highly inflammable nature of the chemicals may cause fire hazard in the storage facility.	A well designed fire protection including protein foam, dry powder, and CO_2 extinguisher should be provided.	Fire extinguisher of small size and big size are provided at all potential fire hazard places. In addition to the above, fire hydrant network is also provided.

Fire Explosion and Toxicity Index (FE&TI) Approach

Fire, Explosion and Toxicity Indexing (FE & TI) is a rapid ranking method for identifying the degree of hazard. The application of FE & TI would help to make a quick assessment of the nature and quantification of the hazard in these areas. However, this does not provide precise information.

The degree of hazard potential is identified based on the numerical value of F&EI as per the criteria given below:

F&EI Range	Degree of Hazard
0-60	Light
61-96	Moderate
97-127	Intermediate
128-158	Heavy
159-up	Severe

By comparing the indices F&EI and TI, the unit in question is classified into one of the following three categories established for the purpose (**Table-6).**

TABLE-6
FIRE EXPLOSION AND TOXICITY INDEX

Category	Fire and Explosion Index (F&EI)	Toxicity Index (TI)
I	F&EI < 65	TI < 6
II	65 < or = F&EI < 95	6 < or = TI < 10
III	F&EI > or = 95	TI > or = 10

Certain basic minimum preventive and protective measures are recommended for the three hazard categories.

Results of FE and TI for Storage/Process Units

Based on the GOI Rules 1989, the hazardous fuels and chemicals used by the proposed expansion project were identified. Fire and Explosion are the likely hazards, which may occur due to the fuel and chemical storage. Hence, Fire and Explosion index has been calculated for in plant storage. Detailed estimates of FE&TI are given in **Table-7.**

TABLE-7
FIRE EXPLOSION AND TOXICITY INDEX FOR STORAGE FACILITIES

Sr. No.	Chemical/ Fuel	Total Capacity/ Quantity	F&EI	Category	TI	Category
1	LDO	25 KL	0.9	Light	-	-
2	HFO	4000 KL	3.1	Light	-	-

Conclusion

Results of FE&TI analysis show that the storage of LDO and HFO falls into ***Light*** category of fire and explosion index with a ***Nil*** toxicity index.

Maximum Credible Accident Analysis (MCAA)

Hazardous substances may be released as a result of failures or catastrophes, causing possible damage to the surrounding area. This section deals with the question of how the consequences of the release of such substances and the damage to the surrounding area can be determined by means of models. Major hazards posed by flammable storage can be identified taking recourse to MCA analysis. MCA analysis encompasses certain techniques to identify the hazards and calculate the consequent effects in terms of damage distances of heat radiation, toxic releases, vapour cloud explosion, etc. A host of probable or potential accidents of the major units in the complex arising due to use, storage and handling of the hazardous materials are examined to establish their credibility. Depending upon the effective hazardous attributes and their impact on the event, the maximum effect on the surrounding environment and the respective damage caused can be assessed.

The reason and purpose of consequence analysis are many folds like:

- Part of Risk Assessment;
- Plant Layout/Code Requirements;
- Protection of other plants;
- Protection of the public;
- Emergency Planning; and
- Design Criteria.

The results of consequence analysis are useful for getting information about all known and unknown effects that are of importance when some failure scenario occurs in the plant and also to get information as how to deal with the possible catastrophic events. It also gives the workers in the plant and people living in the vicinity of the area, an understanding of their personal situation.

Damage Criteria

The fuel storage and unloading at the storage facility may lead to fire and explosion hazards. The damage criteria due to an accidental release of any hydrocarbon arise from fire and explosion. The vapors of these fuels are not toxic and hence no effects of toxicity are expected.

Tank fire would occur if the radiation intensity is high on the peripheral surface of the tank leading to increase in internal tank pressure. Pool fire would occur when fuels collected in the dyke due to leakage gets ignited.

- **Fire Damage**

A flammable liquid in a pool will burn with a large turbulent diffusion flame. This releases heat based on the heat of combustion and the burning rate of the liquid. A part of the heat is radiated while the rest is convicted away by rising hot air and combustion products. The radiations can heat the contents of a nearby storage or process unit to above its ignition temperature and thus result in a spread of fire. The radiations can also cause severe burns or fatalities of workers or fire fighters located within a certain distance. Hence, it will be important to know beforehand the damage potential of a flammable liquid pool likely to be created due to leakage or catastrophic failure of a storage or process vessel. This will help to decide the location of other storage/process vessels, decide the type of protective clothing the workers/fire fighters need, the duration of time for which they can be in the zone, the fire extinguishing measures needed and the protection methods needed for the nearby storage/process vessels. **Table-8** tabulates the damage effect on equipment and people due to thermal radiation intensity.

TABLE-8
DAMAGE DUE TO INCIDENT RADIATION INTENSITIES

Sr. No.	Incident Radiation (kW/m^2)	Type of Damage Intensity	
		Damage to Equipment	**Damage to People**
1	37.5	Damage to process equipment	100% lethality in 1 min. 1% lethality in 10 sec.

2	25.0	Minimum energy required to ignite wood at indefinitely long exposure without a flame	50% Lethality in 1 min. Significant injury in 10 sec.
3	19.0	Maximum thermal radiation intensity allowed on thermally unprotected adjoining equipment	--
4	12.5	Minimum energy to ignite with a flame; melts plastic tubing	1% lethality in 1 min.
5	4.5	--	Causes pain if duration is longer than 20 sec, however blistering is un-likely (First degree burns)
6	1.6	--	Causes no discomfort on long exposures

Source: Techniques for Assessing Industrial Hazards by World Bank.

The effect of incident radiation intensity and exposure time on lethality is given in **Table-9.**

TABLE-9
RADIATION EXPOSURE AND LETHALITY

Radiation Intensity (kW/m^2)	Exposure Time (seconds)	Lethality (%)	Degree of Burns
1.6	--	0	No Discomfort even after long exposure
4.5	20	0	1^{st}
4.5	50	0	1^{st}
8.0	20	0	1^{st}
8.0	50	<1	3^{rd}
8.0	60	<1	3^{rd}
12.0	20	<1	2^{nd}
12.0	50	8	3^{rd}
12.5	--	1	--
25.0	--	50	--
37.5	--	100	--

Scenarios considered for MCA Analysis

Fuel and Chemical Storage

In case of fuel released in the area catching fire, a steady state fire will ensue. Failures in pipeline may occur due to corrosion and mechanical defect. Failure of pipeline due to external interference is not considered as this area is licensed area and all the work within this area is closely supervised with trained personnel.

The gas or vapour released from chemical storage either instantaneously or continuously will be spread in the surrounding area under the influence of the atmospheric turbulence. In the case of gas dispersion, a distinction must be made between neutral gas dispersion and heavy gas dispersion. The critical concentrations of the gas released in the surrounding area can be calculated by means of dispersion models. These concentrations are important for determining whether, for example, an explosive gas cloud can form or whether injuries will occur in the case of toxic gases.

Details of Models Used for MCA Analysis

- ***Pool Fire Model***

Heat Radiation program '**RADN'** has been used to estimate the steady state radiation effect from various storage of fuel and chemicals at different distances. The model has been developed by *M/s Vimta Labs Limited, Hyderabad* based on the equations compiled from various literature by Prof.J.P.Gupta, Department of Chemical Engineering, IIT Kanpur.

Properties of Fuels Considered for Modeling Scenarios

The chemical data for various fuels used for modeling is tabulated in **Table-10** and is compiled from various literatures.

TABLE-10
PROPERTIES OF FUELS CONSIDERED FOR MODELING

Sr. No.	Fuel	Molecular Weight Kg/kg. mol	Boiling Point ºF	Density Kg/m^3
1	LDO	114.24	369.0	840
2	HFO	135.0	216.0	900

*Note: * Scenarios Considered*

Results and Discussion

The results of MCA analysis are tabulated indicating the distances for various damages identified by the damage criteria, as explained earlier. Calculations are done for radiation intensities levels of 37.5, 25, 12.5, 4.5 and 1.6 kW/m^2, which are presented in **Table-11** and **Figure-1** for different scenarios. The distances computed for various scenarios are from the center of the pool fire.

TABLE-11
OCCURRENCE OF VARIOUS RADIATION INTENSITIES- POOL FIRE

Radiation and Effect	Quantity	Radiation Intensities (kW/m^2)/Distances (m)				
	KL	37.5	25.0	19.0	12.5	4.5
LDO	25	4.1	5.1	6.0	7.6	13.6
HFO	4000	61.5	77.4	90.5	114.9	205.6

Hazards in Coal Handling System

The major stages involved in coal handling are:

- Unloading of coal;
- Transport through conveyor belts to coal yard; and
- Crushing and pulverization of coal into small particles and conveyed to the coal feeders.

Basically, these are all mechanical operations and should not result in any major hazard. However, coal being combustible, can burn, given the right environment and conditions, such as smaller particle size, air, ignition sources etc. The average particle size of the coal unload at the plant is approximately 50 mm and should not result in fire or explosion. When crushed to less than 20 mm, it could result in fire and/or explosion if sufficient percentage of dust exists. However, dust explosions are only probable if a significant percentage of the particles less than 75 microns exist.

An elaborate and effective fire protection system will be provided in the plant. Further, water spray will be done during the summer on the coal yard. All the precautions as per Factory Act and guidelines of Tariff Advisory Committee (TAC) will be followed.

Hazards in Power Generation Systems

- Fire and explosion hazard due to the storage and handling of the fuel oil;
- Internal explosion hazard in the steam generator due to high-pressure steam;
- Electrical hazards due to high voltage current;
- General mechanical hazards in the turbine-generators; and
- There will not be any effect of high wind on the flame, since the boiler and calciner are closed and flame is not exposed to atmosphere.

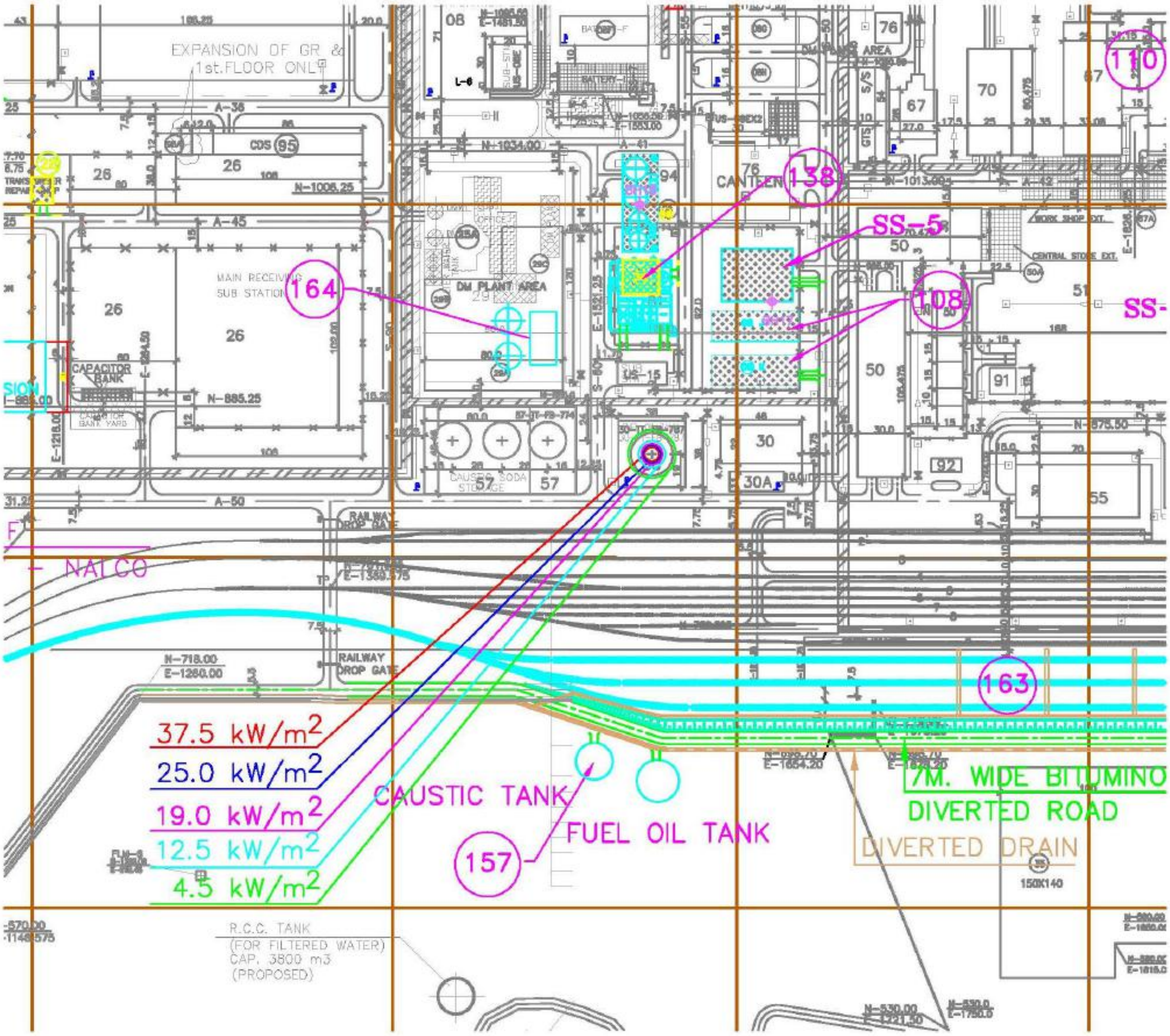

FIGURE-1(A)

POOL FIRE MODEL - RISK CONTOURS FOR LDO TANK

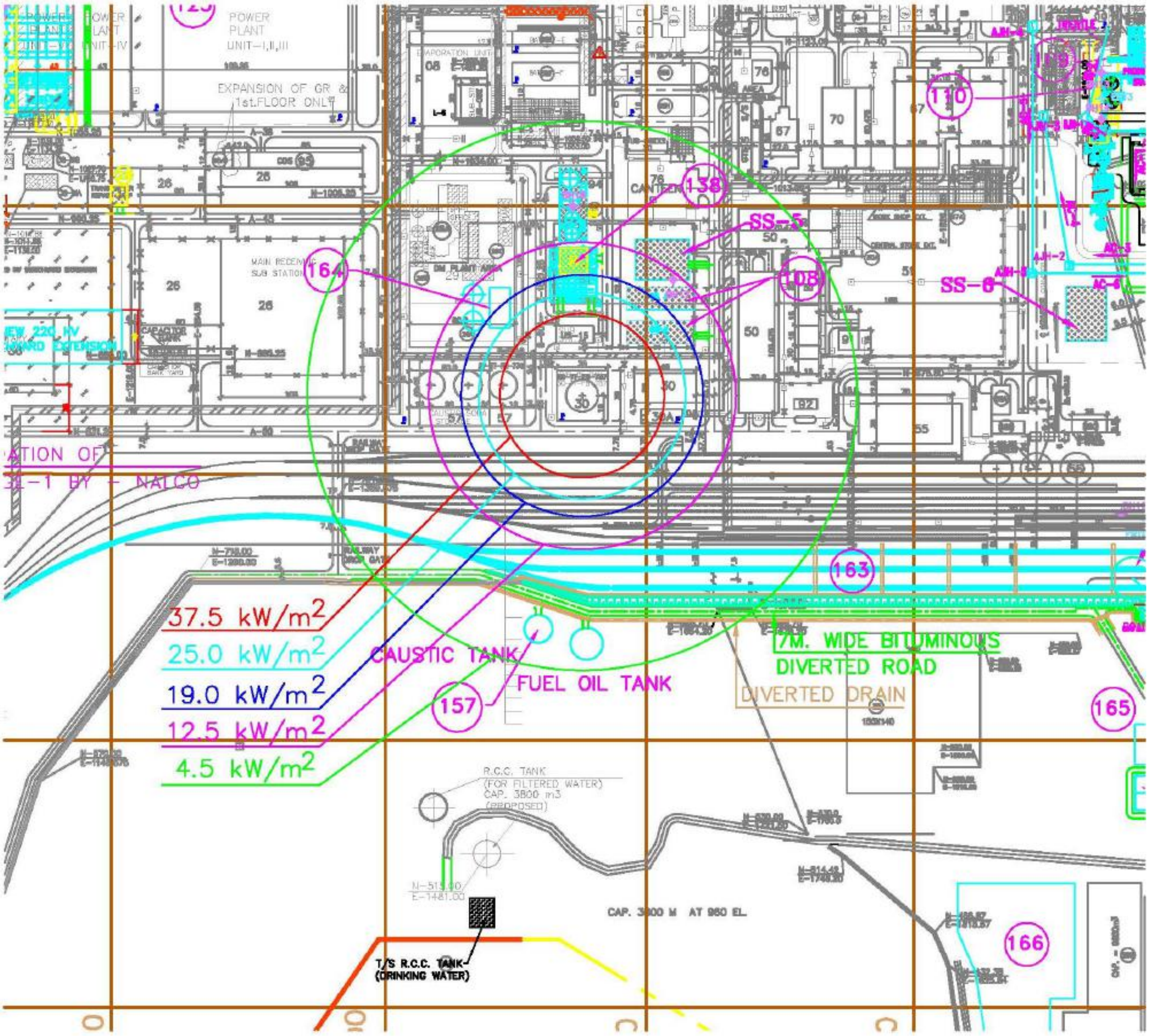

FIGURE-1(B)
POOL FIRE MODEL - RISK CONTOURS FOR HFO TANK