1.0 RISK ANALYSIS

Industrial activities, which produce, treat, store and handle hazardous substances, have a high hazard potential endangering the safety of man and environment at work place and outside. Recognizing the need to control and minimize the risks posed by such activities, the Ministry of Environment, Forests and Climate control have notified the "Manufacture Storage & Import of Hazardous Chemicals Rules" (MSIHC) in the year 1989 and subsequently modified, inserted and added different clauses in the said rule to make it more stringent. For effective implementation of the rule, Ministry of Environment, Forests and Climate Control (MoEFCC) has provided a set of guidelines. The guidelines, in addition to other aspects, set out the duties required to be performed by the occupier along with the procedure. The rule also lists out the industrial activities and chemicals, which are required to be considered as hazardous.

ONGC, Uran is an integrated facility which sweetens sour Natural Gas and produces value added products like LPG, Naphtha and other hydrocarbon products. During the process, a number of these products need to be stored at the site, of which Liquefied Petroleum Gas (LPG) is an important hazardous chemical requiring storage on the site. M/s ONGC have proposed to install mounded bullets for storage of LPG. Thus, the only hazardous substance handled at the proposed project will be LPG.

In view of this, ONGC's proposed activity of installation of mounded bullets is being scrutinized in line of the above referred "Manufacture, storage and import of hazardous chemicals rules" 1989 with amendment in 2000 and the observations / findings are presented in this chapter. An elaborate and well-documented Disaster Management Plan covering all substances/gases handled by ONGC shall be prepared for the plant.

The assessment has been made in a systematic manner covering the requirements of the above-mentioned rules. Accordingly subsequent sections have been divided as follows:

- *Process description*
- *Applicability of the rule*
- *Description of hazardous substances*
- *Hazard Identification*
- *Hazard Assessment (& hazard scenarios)*
- *Consequence analysis*
- *Brief description of the measures taken and*
- *On site emergency plan*

Accordingly next sections are elaborated.

1.1 PROCESS DESCRIPTION

LPG shall be pumped via pipelines from existing LPG processing units of ONGC Uran plant into the three (03) mounded bullets, in which ethyl mercaptan which is a clear liquid with a characteristic odour will be added and the prepared LPG mixture for ready commercial distribution will be added to the existing discharge line of the plant.

As per Oil Industry Safety Directorate (OISD) standard OISD-150, "the mounded storage of LPG has proved to be safer 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.ò Hence, the choice for storage of LPG at ONGC Uran plant was proposed as mounded LPG bullets.

The major hazardous materials to be stored, transported, handled and utilized within the proposed site is summarized in **Table 1.**

TABLE 1: List of Major Hazardous Substances to be Stored / Handled at Proposed Mounded LPG Bullets

Sn.	Hazardous substance handled/stored	Quantity stored	Type of vessel used for handling / storage	Material of construction	Nature of hazard associated
1.	Liquefied Petroleum gas[1] (major components being Propane (C_3H_8) and Butane (C_4H_{10}))	825 Tonnes per Bullet x 3 bullets = 2475 Tonnes	Horizontally placed Cylindrical tank with hemispherical ends laid within a trapezoidal mound of earth materials.	Carbon Steel (ASME SA516 Gr. 60 + A20, S-5)	Flammable pressurized liquid
[1]LPG density considered as 0.54 kg/m³ & maximum operating storage of bullets taken as 85% of gross bullet storage capacity					

1.2 APPLICABILITY OF THE RULE

As per Item no. 4 of Schedule-4 of the MSIHC Rules, 1989 with subsequent amendments, the ñ*installations for production, processing, use or treatment of energy gases, for example LPG, LNG, SNG"* are classified as an ñindustrial activityò involved in storage or handling of hazardous substances.

To decide whether the above mentioned industrial substances are likely to come within the scope of the above mentioned ñManufacture Storage and Import of Hazardous Chemicals Rules, 1989ò with subsequent amendments, the threshold quantities mentioned in the aforementioned rules are used for comparison, as given in **Table 2.**

Table 2: Threshold Quantity & Identified Hazardous Substances to be Handled at Proposed Mounded LPG Bullets as per MSIHC Rules, 1989 and its Subsequent Amendments

Sn	Hazardous substance handled/ stored	Maximum Quantity handled/ stored	Whether Included in The List of Hazardous & Toxic Chemicals	Type of vessel used for handling / storage	Lower Threshold Qty. (In Tonne) *[For application of rules 5,7 to 9 and 13 to 15]*	Upper Threshold Qty. (In Tonne) *[For application of rules 10 to 12]*	Remarks
1.	Liquefied Petroleum gas (major components being Propane (C_3H_8) and Butane (C_4H_{10}))	825 Tonnes x 3 = 2475 Tonnes	Yes, As per Sch. 1, Part-I (b)(i.a)	Mounded Steel bullet of 1800 m^3 gross water capacity (03 in nos.)	15	200	*Beyond the upper threshold limit. Requires consequence analysis.*

After comparison of the stored / handled quantity of hazardous chemical with threshold quantities, it is observed that LPG gas is coming under the purview of MSIHC rules due to its hazardous nature and is also exceeding the corresponding lower and upper threshold quantities. Accordingly, rule nos. 7,8,9,10,11,12,13,14 and 15 & 17 of the MSIHC Rules, 1989 with subsequent amendments will be applicable. Rule-7 i.e. notification of site requires submission of a written report containing among other information the followings:

- *Identification of major accident hazards*
- *The conditions or events which could be significant in bringing one about*
- *Quantified risk assessment of the process*
- *Brief descriptions of the measures taken*
- *Area likely to be affected by the major accident etc.*

Hence, owing to the deliberation above, a quantitative risk assessment of the facility has been done based on MCAA (maximum credible accident analysis) approach. As per Rule-17 of the MSIHC Rules, the material safety data sheets for LPG is also provided.

1.3 DESCRIPTION OF HAZARDOUS SUBSTANCES

LPG is the only hazardous substance which is expected to be handled at the proposed location, as presented in **Table 2** above. The brief nature of identified hazardous substance i.e. LPG is described in the following paragraphs.

Liquefied Petroleum Gas (LPG): It is a mixture of flammable gases, primarily propane and butane which is handled in liquefied form under pressurised conditions. It is a flammable mixture of hydrocarbon gases used as fuel in heating appliances, cooking equipment, and vehicles. In liquefied form, it is a colourless and odourless liquid, so small quantity of ethyl mercaptan is added to it to give it a distinct, characteristic smell. The LPG is envisaged to be stored in mounded bullets with inlet, outlet and vapour balancing lines and associated pumps, compressors etc. The mounded bullet, as per design considerations mentioned in

OISD-150, eliminates chances of a BLEVE and reduces chances of fatal hazards at design stage itself. As for the pipes which form the part of inlet, outlet and vapour balancing lines, regular inspection of the pipelines and maintenance operations along with installation of pressure detection systems in the pipelines will ensure no occurrence of pipeline failure.

The physical & chemical properties of LPG are given below:

PHYSICAL PROPERTIES*		
Form	:	Gas, liquefied under pressure
Colour	:	Colourless
Odour	:	Odourless; additional odouring agent added
Liquid density	:	0.54 kg/m^3
Molecular weight	:	~170 g/mol
Lower explosion limit (LEL)	:	4.0 %
Upper explosion limit (UEL)	:	30.0 %
Flash point	:	<60°C
Solubility in water	:	Slightly soluble in water
Toxicity	:	Acutely toxic if inhaled
Flammable nature	:	Extremely flammable

**Based on tentative data sourced from Technical Specification furnished by M/s ONGC Uran*

CHEMICAL COMPOSITION* (mol %)		
Ethane (C_2H_6)	:	0.95
Propane (C_3H_8)	:	51.93
Isobutane (C_4H_{10})	:	19.56
N-butane (C_4H_{10})	:	26.39
Isopentane (C_5H_{12})	:	0.96
N-pentane (C_5H_{12})	:	0.21
Sulphur (S)	:	40 ppm

**Based on typical data for LPG sourced from Technical specification furnished by M/s ONGC.*

1.4 HAZARD IDENTIFICATION

Hazards associated with the identified hazardous chemicals based on NFPA ratings as well as other parameters are presented in **Table 3.**

Table: 3: Type of Hazards Associated with Identified Hazardous Chemicals

Name of Chemical	Type of Hazard*	*****NFPA Hazard Rating***			IDLH Value	Flash point (°C)	Flammability range (for gases)	Remarks
		Health	*Flammability*	*Reactivity*				
Liquefied Petroleum Gas (LPG)	1,7,9	*1*	*4*	*0*	-	-104°	LEL = 1.9% (<13%) UEL = 9.5%	Gas transported directly through pipelines. *Release: Leak/rupture*

*Note: Type of Hazard

1	*Flammable substance*	*6*	*Gas or vapour not dangerous other than displacing air*
2	*Oxidising substance, reacts with reducing agents*	*7*	*Causes skin irritation or burns*
3	*Emits a toxic gas or vapour*	*8*	*Toxic substance*
4	*Emits an irritating gas or vapour*	*9*	*Explosive material under certain conditions*
5	*Emits a narcotic gas or vapour*		

**NFPA Hazard Rating

a) HEALTH				
1 - None	*2 - Minor*	*3 - Moderate, could cause temporary incapacitation or injury*	*4 - Severe, short exposure may cause serious injury*	*5 - Extreme, short exposure may cause death*
b) FLAMMABILITY				
1-None, Material does not burn	*2- Minor, material must be preheated to ignite*	*3- Moderate, moderate heating is required for ignition and volatile vapours are released*	*4- Severe, material ignites at normal temperature*	*5- Extreme, very flammable substance that readily forms explosive mixtures*
c) REACTIVITY				
***1-None, stable** when exposed to fire*	*2-Minor, unstable at high temp. or press and may react with water*	*3-Moderate, unstable but does not explode, may form explosive mixture with water*	*4-Severe, Explodes if heated or water added*	*5-Extreme, readily explosives under normal condition*

From the above table it can be observed that LPG is the hazardous material of concern for the proposed LPG mounded bullet storage due to its high flammability. The hazards associated with a release and/or subsequent ignition of LPG are primarily fire-hazards. No toxic component of the LPG indicates there will be no toxic consequences of a release.

The catastrophic potential of a hazardous substance depends on its flammability, toxicity and volatility. The ambient temperature vapour pressure of a substance is used as a measure of the ability to become air borne. As the quantity of LPG being stored at the proposed site is *beyond* the specified upper threshold limits defined under the MSIHC Rules, 1989 with subsequent amendments, there is a requirement for carrying out its consequence analysis, and consequently the fire hazards associated have been quantified owing to its high flammable nature.

1.5 HAZARD ASSESSMENT

In the earlier section, type of hazard associated with different type of substances and the event of release of these substances is being identified. It has also been identified the category of hazard associated with different chemicals.

In any plan hazardous situation arises due to:

- *Failure in the monitoring of crucial process parameters e.g. pressure, temperature, flow quantity etc.*
- *Failure in the utilities e.g. cooling water*
- *Failure control elements e.g. pressure, temperature level, flow controllers etc.*
- *Failure of components such as pumps, compressor etc.*
- *Failure of safety systems, safety valves / relief valves, sprinkler systems, alarm etc.*
- *Mechanical failure of vessels or pipe work due to excessive stress, over pressure, corrosion etc.*
- *Wrong operation, failing to adhere to the safety norms etc.*

Such a situation is possible during the storage as well as handling of LPG. It is unlikely that small leakage through pipes, gaskets, flanges or any other means (user points) will create a hazardous situation unless allowed to be released for a long time as will be established in the subsequent sections. It is expected that during such small leakage preventive steps will be taken within a specified time span. Therefore a Preliminary Hazard Analysis (PHA) is carried out first for assessment of hazard. It is to note that the storage of the LPG involves mounded storage bullets, which are designed to be intrinsically safe from the occurrence of a BLEVE condition. LPG shall be transported through steel pipelines constructed as per standards.

Effects of the above Hazards:

The effect of accidents in these areas will be confined to the facilities only and can be controlled within the areas by the operating personnel themselves. At the extreme, it may require the resources of the whole facility to control the effects but these are not at all expected to spill over to the community.

PRELIMINARY HAZARD ANALYSIS

Sn.	Project component	Incident type	Failure Scenario	Causes of failure	Proposed preventive measures
1.	Mounded Storage bullets	Release of pressurized LPG into the atmosphere, Formation of vapour cloud, fire, explosion	• Failure in inlet, outlet or vapour balancing line or associated fittings, pump or pipe-work or operator error leading to impacts including chemical or fuel	• Overfilling • Pressure increase in bullet • Rupture of hose • Gasket Failure • Leak at flanges • Wrong line-up • Non adherence to SOP for sampling • Instrumentation	• Design of storage structures / tanks to relevant standards and legislations. • Design of pipelines (i.e. wall thickness and stress relief), well sites, Central Processing Facility and related infrastructure to relevant standards and legislation. • Installation of pressure monitoring systems. • Regular inspections and maintenance. • Housekeeping activities ï site would

Sn.	Project component	Incident type	Failure Scenario	Causes of failure	Proposed preventive measures
			contamination	failure • Operator error • External fire • Corrosion	be kept clean and tidy and fire hazards removed where practicable. • Availability of firefighting equipment. • Maintenance of fire breaks to slow the progress of bushfires. • Routine hazard reduction burns. • Fire-fighting equipment located in on-site vehicles and infrastructure (wherever appropriate). • Regular inspections and maintenance of firefighting equipment and storage areas, where required. • Operator induction and ongoing training. • Operational procedures. • Material safety data sheet (MSDS) register and MSDSs kept on-site at different locations in form of signage etc. • Hazard Signage. • Location of explosive storage shall be such that it has minimum interaction with people and property.
		Sabotage	Malicious act/sabotage resulting in off-site impacts.	• Inadequate protection of facilities. • Lapse in safety procedures due to Human error.	• Restriction of access to storage areas, including securing storage facilities. • Provision of adequate lighting around storage facilities. • Signage (i.e. unauthorized entry warning and information signs). • Police would be notified as soon as possible in case of a suspected breach.

1.6 MAXIMUM CREDIBLE ACCIDENT ANALYSIS (MCAA)

A Maximum Credible Accident (MCA) can be characterized, as an accident with a maximum damage potential, this is still believed to be probable. The selection of accident scenarios representative for a MCA-Analysis has been done on the basis of engineering judgement and expertise in the field of risk analysis studies, especially accident analysis.

In the proposed Mounded Bullet storage of LPG plant involving storage and handling of pressured LPG gas, which is also identified as an "Industrial activity" handling hazardous substances as per MSIHC Rules, 1989 and its subsequent amendments, hazardous substances may be released as a result of failures or catastrophes, causing possible damage to the surrounding area.

As per **Table 1** and **Table 2,** the only hazardous substance identified of posing major threats to the facility and people working at the facility is as listed below:

- LPG – *Max. quantity stored at the site = 2475 tonnes*

MCA Analysis assists in identifying the potential major accidents arising due to flammable and/or toxic storages or handling facilities and estimate the maximum consequent effects on the surrounding environment in terms of damage distances of heat, radiation, toxic release, vapor cloud explosion etc. depending upon the effective hazardous attributes and their impact on the event.

The visualization of MCA scenarios has been done considering the chemical inventory being handled at the proposed plant, various loss of containment scenarios and subsequent accident scenarios and analysis of incident history of similar nature to establish credibility of the identified accident scenarios. Based on the above, the identified credible accident scenarios having maximum damage effects (worst case) were as follows:

i. For Mounded bullet storage of LPG:
   a. Release of LPG from Bullet Liquid Inlet, Outlet Line and/or Vapour Line resulting in
      - Jet fire
      - Flash fire
      - Vapour cloud explosion

1.7 CONSEQUENCE ANALYSIS

Subsequent to the accidental release of hazardous chemicals, the consequence depends on various factors e.g. type and inventory of released hazardous materials, presence and location of an ignition source, meteorological conditions, etc. Consequence analysis for the selected credible accident scenarios has been carried to estimate the vulnerable zones.

1.7.1 <u>Consequence Model/Software used</u>

DNV's PHAST (Version 6.4) software, which is a consequence and risk assessment software for calculation of physical effects (fire, explosion, atmospheric dispersion) of the escape of hazardous materials has been used to perform the consequence calculations. The software allows detailed modelling and quantitative assessment of release of pure chemicals as well as mixtures from different scenarios.

1.7.2 <u>Hazardous Scenarios Modeled</u>

Consequence analysis quantifies vulnerable zone for a conceived incident and once the vulnerable zone is identified for an incident, measures can be proposed to eliminate damage to plant and potential injury to personnel. Consequence analysis for pressurised LPG gas at ONGC's proposed LPG storage facility has been carried out. The release scenarios selected and associated hazards based on MCA Analysis are listed below in **Table 4:**

Table: 4: Probable Release and Accident Scenarios Identified As Per MCAA

Sn	Hazardous substance	Credible Release scenario	Credible identified accidents
1.	Pressurized LPG Gas	Release of LPG from point of inlet line, outlet line or Vapour line of LPG Bullets	Jet fire, Flash fire, Vapour Cloud explosion

1.7.3 Meteorological Conditions Considered

Minimum wind speed of 1.0 m/s and stable as well as neutral atmospheric stability conditions have been assumed to model fire effects in a worst case scenario having low chance of dilution of flammable substance concentration in the atmosphere and a higher damage effect. An average Wind speed of 3.0 m/s based on annual climatological trend of wind speeds at Uran, Maharashtra as collected from secondary sources (http://www.weather-india.in/india/maharashtra/weather-uran) with neutral atmospheric stability conditions has been assumed to predict maximum extent of dispersion of the identified hazardous substances during a release. Thus the identified weather conditions are as follows:

Sn.	Wind speed (m/s)	Atmospheric Stability Class
1.	1	F (Extremely stable condition)
2.	1	D (Neutral condition)
3.	3	D (Neutral condition)

1.7.4 Population Data:

Following population data for the Uran Plant has been considered for risk estimation:

- *Onsite personnel : 20persons;*
- *Shift duty: 10 persons*

1.7.5 Damage Criteria Considered in the Model

In order to apprehend the damage produced by various scenarios, it is appropriate to discuss the physiological/physical effects of thermal radiation intensities due to fire accidents and overpressure effects of explosions. The thermal radiation due to pool fire or jet fires usually results in burn on the human body. Furthermore, inanimate objects like equipment, piping, cable, etc. may also be affected and also need to be evaluated for damages. The effect of overpressure due to blast effect and the effect of thermal radiation due to fire on unprotected skin, as per Indian Standard IS 15656 : 2006 *HAZARD IDENTIFICATION AND RISK ANALYSIS — CODE OF PRACTICE* is presented below in **Table 5(a)** and **Table 5(b),** respectively.

TABLE: 5(a): Effect of Different Overpressures on Human Life and Property

Overpressure (bar)	Type of Damage on structure	Type of Damage on Human life
0.02	Typical window glass breakage	-
0.14	Partial collapse of buildings	Personnel knocked down
0.21	Steel framed buildings get distorted and uprooted from their foundations	Ear drum rupture (beginning of serious injury to human life)

TABLE: 5(b): Relation Between Heat Radiation Intensity, Time and Effect on Man

Heat Radiation Level (Kw/m^2)	Duration (Secs)	Effect on Humans	Effect on property
4 -6	20	Sufficient to cause pain to personnel	Impairment of escape routes
12.5	5-20	Extreme pain within 20s	Provides minimum energy required for piloted ignition of wood and melting of plastic
37.5	10	Immediate fatality (100% lethality)	Sufficient to cause severe damage to process equipment

A number of probable failure scenarios have been considered for the proposed project. The various scenarios considered are summarised below:

Sn.	Vessel/Container	Scenario considered	Description of scenario	Outcome of failure	
A	Mounded LPG Bullet storage	Scenario-1	Failure of inlet line (10ò dia) on LPG storage Bullet	1	Jetfire
				2	Flash-fire
				3	Vapour Cloud explosion
		Scenario-2	Failure of outlet line (10ò dia) on LPG storage Bullet	1	Jetfire
				2	Flash-fire
				3	Vapour Cloud explosion
		Scenario-3	Failure of Vapour line (4ò dia) on LPG storage Bullet	1	Jetfire
				2	Flash-fire
		Scenario-4	Cumulative Failure of Inlet, outlet and vapour lines simultaneously on LPG storage Bullet	1	Jetfire
				2	Flash-fire
				3	Vapour Cloud explosion

1.7.6 Results of consequence analysis for identified hazardous scenarios

A. Mounded LPG Bullet storage

- *Scenario-1: Failure of inlet line (10” dia) on LPG storage Bullet*
- *Consequent outcome-I: Release from failure of 10” wide inlet line joint on Mounded LPG bullet followed by immediate ignition resulting in Jetfire.*

The hazard effect extents for jet fire resulted due to release of pressurized LPG from failure of 10òwide inlet line joint on Mounded LPG bullet is presented below:

1. Jet Fire

Release rate of LPG = 169.7 kg/s				
Sn.	**Radiation Intensity (kW/m^2)**	**Effect distance (m) in weather conditions**		
		1F	**1D**	**3D**
1	4.0	*153.92*	*153.92*	*146.80*
2	12.50	-	-	*47.13*
3	37.50	-	-	-

The radiation vs distance graph as well as thermal intensity radii for jet fire due to LPG release from 10òInlet line are shown in **Fig. 1** and **Fig. 2** respectively.

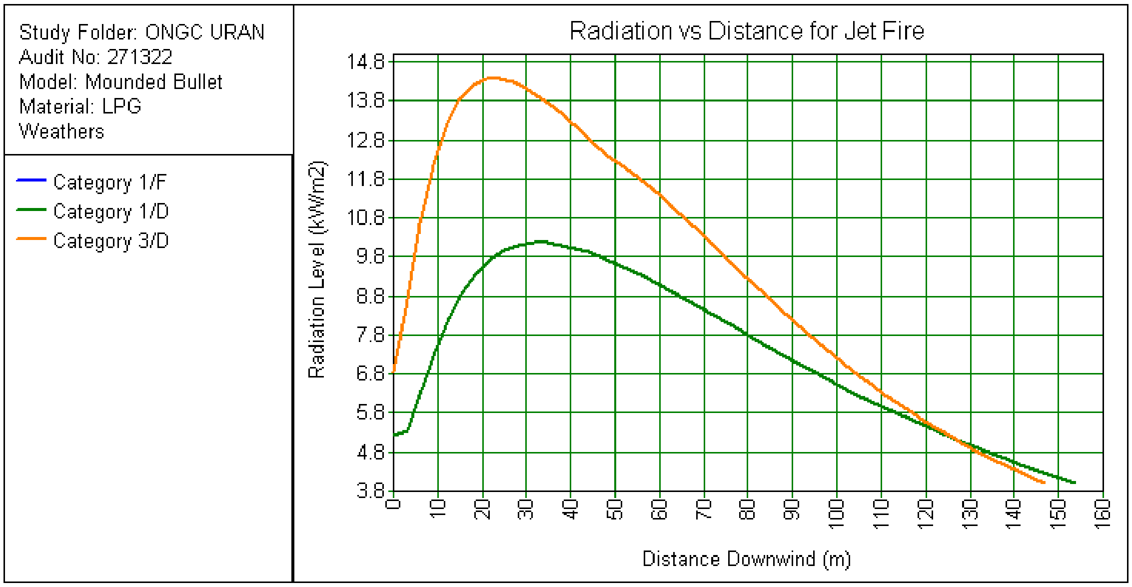

Fig.1: Variation of Radiation with Distance for Jet Fire due to LPG Fire from 10" Inlet Line

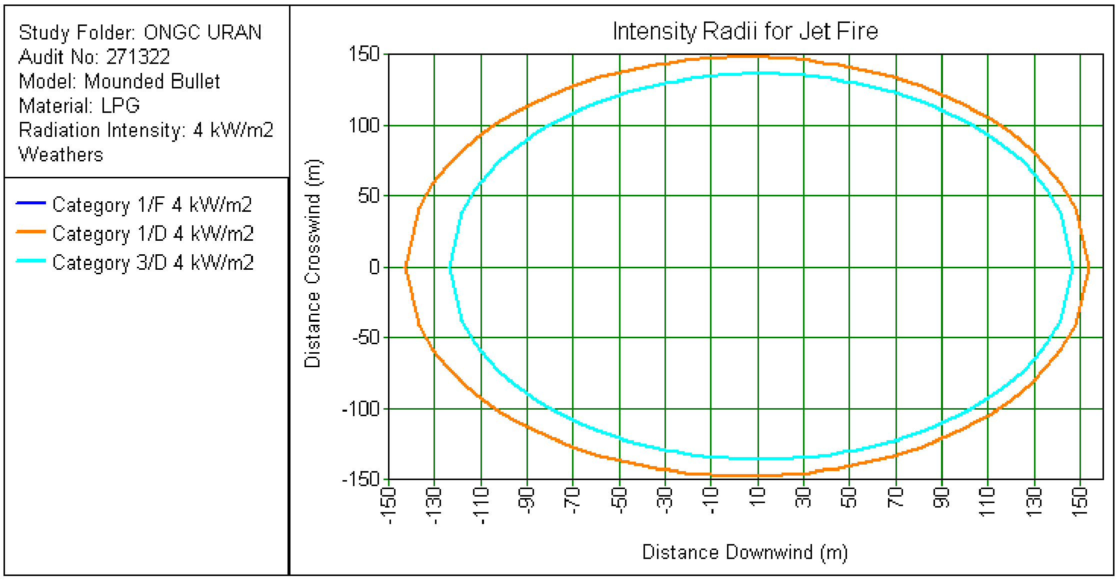

Fig. 2: Thermal Intensity Radii for Jet Fire due to LPG Fire from 10" Inlet Line

The worst case vulnerable distance (hazard effect distance) for jet fire due to release of LPG from 10ò Inlet line having significant damage to human life is observed to be up to 47.13 *(@12.5.0 KW/m^2 since higher thermal radiation is not observed.*

- *Consequent outcome-II: Release from failure of 10" wide inlet line joint on Mounded LPG bullet followed by immediate ignition resulting in Flashfire.*

The hazard effect extents for Flash fire resulted due to release of pressurized LPG from failure of 10òwide inlet line joint on Mounded LPG bullet is presented below:

2. Flash Fire

LFL concentration = 17293.28 ppm				
Sn.	**Concentration of Interest**	**Effect distance (m) in weather conditions**		
		1F	**1D**	**3D**
1	LFL	*7.71*	*8.34*	*7.05*
2	½ LFL	*18.14*	*25.42*	*19.51*

The thermal flash fire envelope due to LPG release from 10òInlet line is shown **Fig.3**

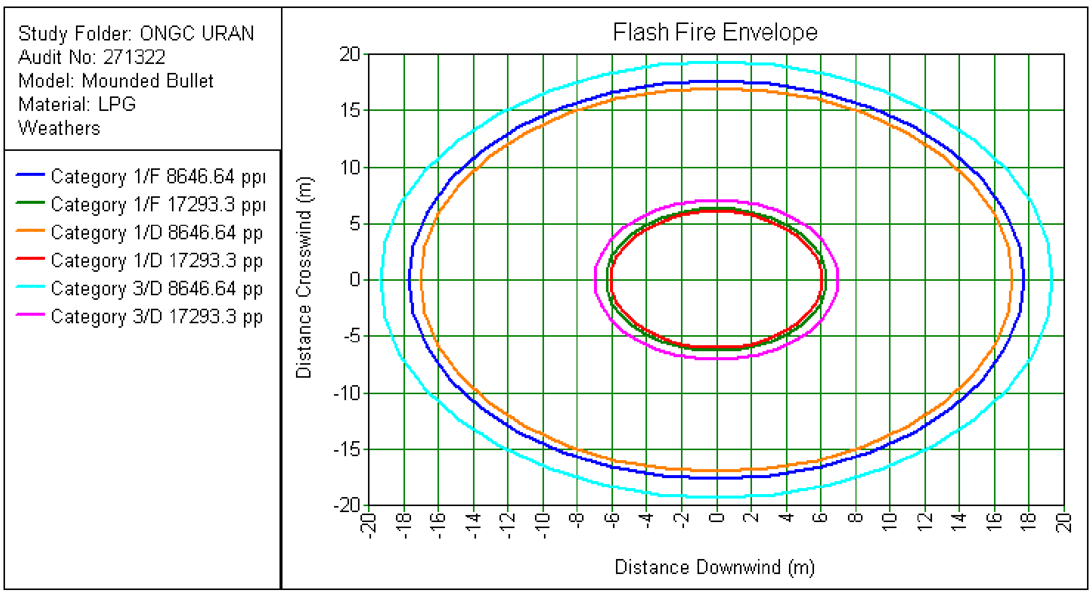

Fig.3: **Thermal Flash Fire Envelop due to LPG Release from 10" Inlet Line**

The worst case vulnerable distance (hazard effect distance) for flash-fire due to LPG release from 10òInlet line having significant damage to human life is observed to be up to 8.34m *(@LFL having 100% probability of death)* from the LPG piping.

- *Consequent outcome-III: Release from failure of 10" wide inlet line joint on Mounded LPG bullet followed by delayed remote ignition resulting in Vapour Cloud explosion.*

The hazard effect extents for Vapour Cloud explosion resulted due to LPG release from 10ò Inlet line and ignited at a distance of 10m from the tank is presented below:

3. Vapour Cloud explosion

Distance of ignition source = 10m

Sn.	**Blast overpressure**	**Effect distance (m) in weather conditions**		
		1F	**1D**	**3D**
1	0.21 bar	*48.26*	*52.48*	*42.44*
2	0.14 bar	*59.45*	*64.90*	*51.93*
3	0.02 bar	*200.97*	*222.03*	*171.92*

The Explosion overpressure vs distance as well as Late explosion worst case radii due to LPG release from 10òInlet line are shown in **Fig. 4** and **Fig.5** respectively.

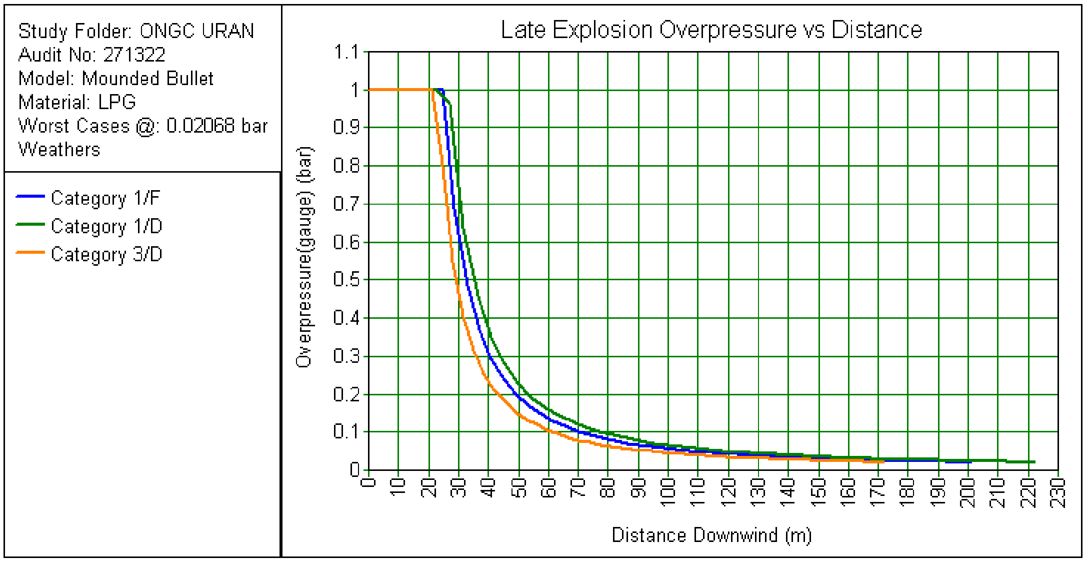

Fig.4: Late Explosion Overpressure vs Distance due to LPG Release from 10” Inlet Line

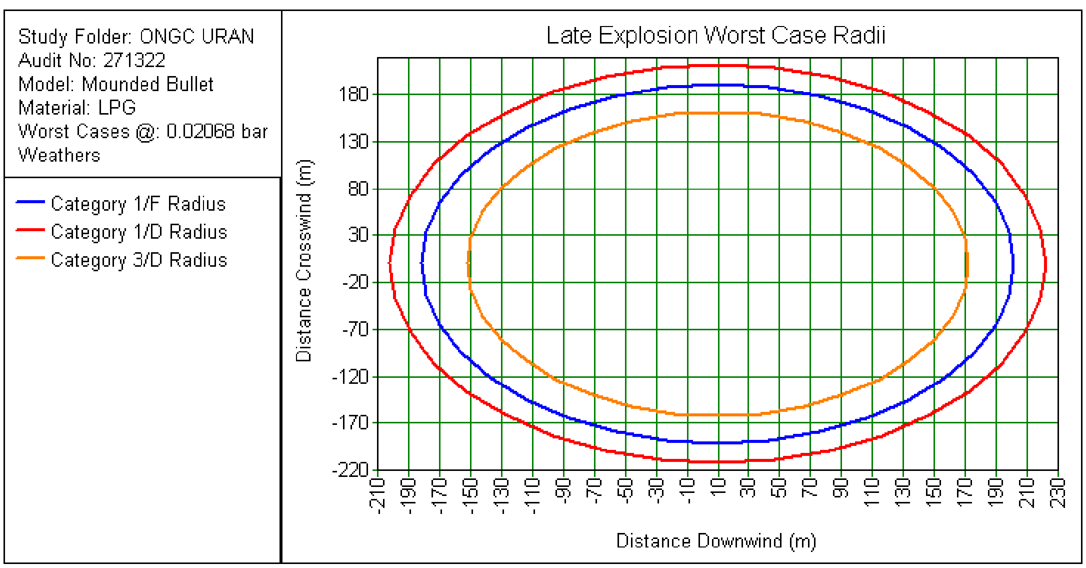

Fig. 5: Late Explosion Worst Case Radii due to LPG Release from 10” Inlet Line

The worst case vulnerable distance (hazard effect distance) for explosion due to LPG release from 10"Inlet line having significant damage to human life is observed to be up to 52.48 m *(@0.21 bar having 100% probability of death)* from the LPG piping.

- *Scenario-2: Failure of outlet line (10" dia) on LPG storage Bullet*
- *Consequent outcome-I: Release from failure of 10" wide outlet line joint on Mounded LPG bullet followed by immediate ignition resulting in Jet-fire.*

  The hazard effect extents for jet fire resulted due to release of pressurized LPG from failure of 10"wide outlet line joint on Mounded LPG bullet is presented below:

1. Jet Fire

Release rate of LPG = 169.7 kg/s				
Sn.	**Radiation Intensity (kW/m^2)**	**Effect distance (m) in weather conditions**		
		1F	**1D**	**3D**
1	4.0	*153.92*	*153.92*	*146.80*
2	12.50	-	-	*47.13*
3	37.50	-	-	-

The radiation vs distance graph as well as thermal intensity radii for jet fire due to LPG release from 10"outlet line are shown in **Fig. 6** and **Fig. 7** respectively.

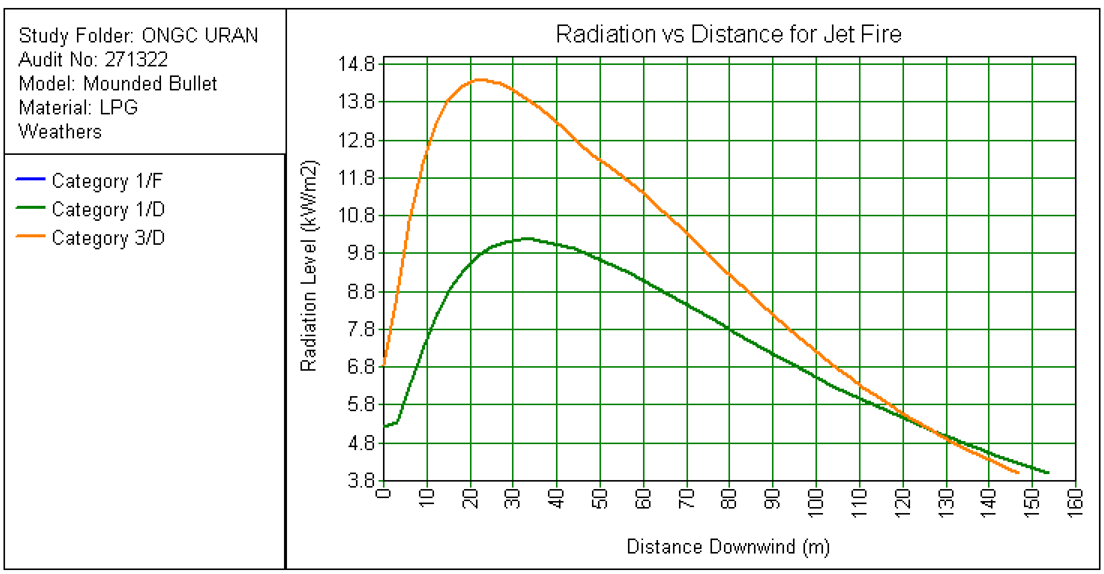

Fig.6: Radiation vs Distance for Jet Fire due to LPG Release from 10" Outlet Line

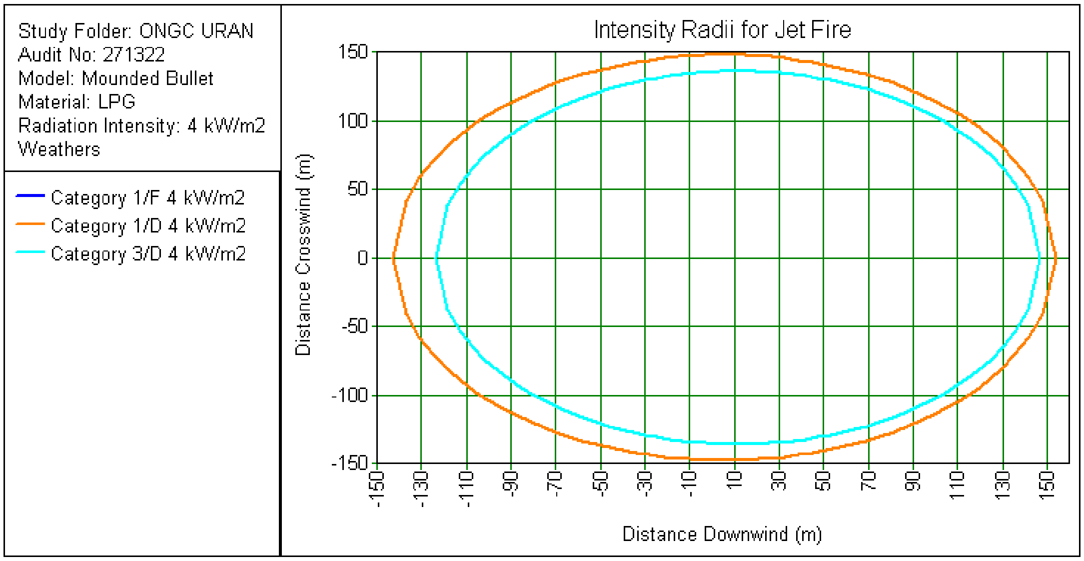

Fig.7: Thermal Intensity Radii for Jet Fire due to LPG Release from 10" Outlet Line

The worst case vulnerable distance (hazard effect distance) for jetfire due to release of LPG from 10ò outlet line having significant damage to human life is observed to be up to 47.13m *(@12.5 KW/m^2 since higher thermal radiation is not observed.*

- *Consequent outcome-II: Release from failure of 10" wide outlet line joint on Mounded LPG bullet followed by immediate ignition resulting in Flashfire.*

The hazard effect extents for Flash fire resulted due to release of pressurized LPG from failure of 10òwide outlet line joint on Mounded LPG bullet is presented below:

2. Flash Fire

LFL concentration = 17293.28 ppm				
Sn.	**Concentration of Interest**	**Effect distance (m) in weather conditions**		
		1F	**1D**	**3D**
1	LFL	*7.71*	*8.34*	*7.05*
2	½ LFL	*18.14*	*25.42*	*19.51*

The flash fire envelope due to LPG release from 10òoutlet line are shown in **Fig.8:**

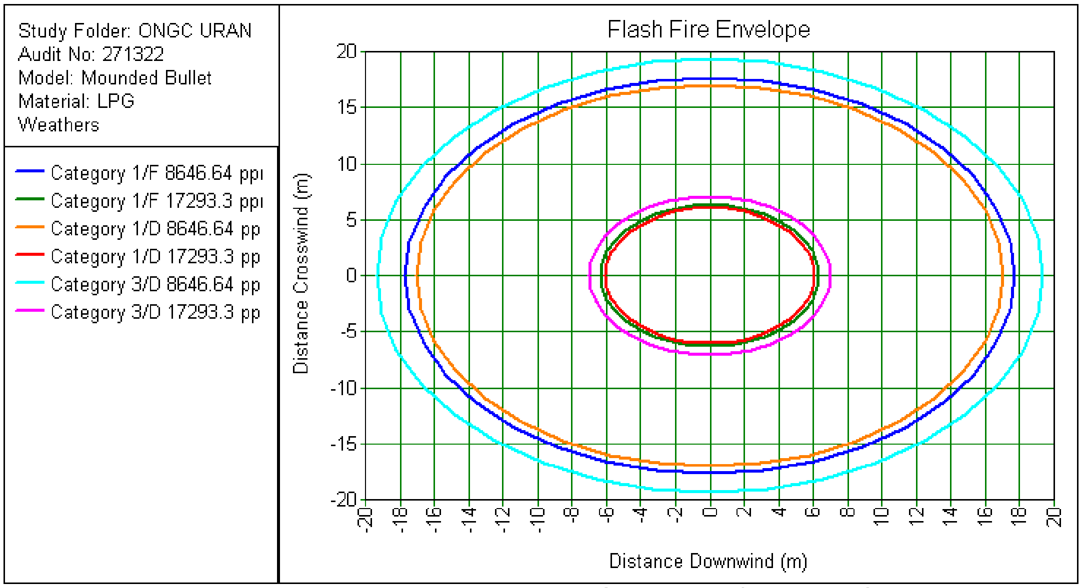

Fig.8: Flash Fire Envelope due to LPG Release from 10" Outlet Line

The worst case vulnerable distance (hazard effect distance) for flash fire due to LPG release from 10ò outlet line having significant damage to human life is observed to be up to 8.34 m *(@LFL having 100% probability of death)* from the LPG piping.

- *Consequent outcome-III: Release from failure of 10" wide outlet line joint on Mounded LPG bullet followed by delayed remote ignition resulting in Vapour Cloud explosion.*

The hazard effect extents for Vapour Cloud explosion resulted due to LPG release from 10ò Outlet line and ignited at a distance of 10m from the tank is presented below:

3. Vapour Cloud explosion

Distance of ignition source = 10m				
Sn.	**Blast overpressure**	**Effect distance (m) in weather conditions**		
		1F	**1D**	**3D**
1	0.21 bar	*48.26*	*52.48*	*42.44*
2	0.14 bar	*59.45*	*64.90*	*51.93*
3	0.02 bar	*200.97*	*222.03*	*171.92*

The Explosion overpressure vs distance as well as Late explosion worst case radii due to LPG release from 10ò outlet line are shown in **Fig. 9** and **Fig. 10** respectively:

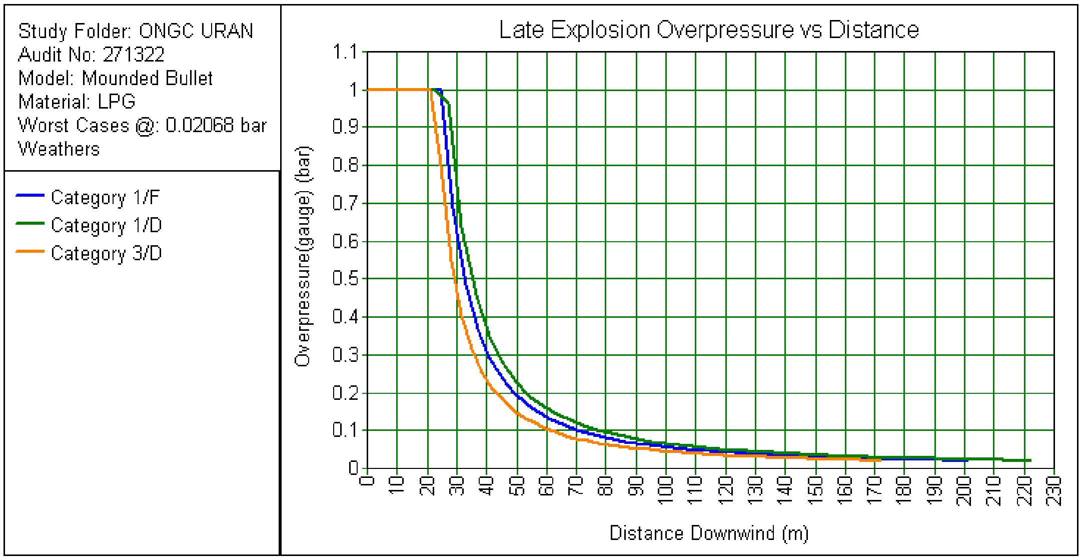

Fig. 9: Late Explosion overpressure vs distance due to LPG Release from 10” Outlet Line

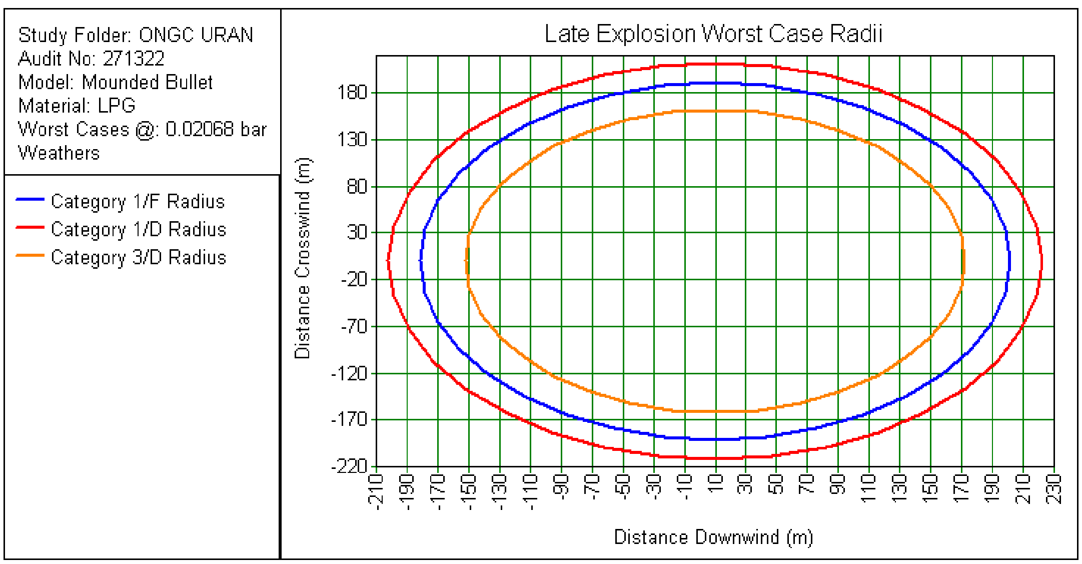

Fig.10: Late Explosion Worst Case Radii due to LPG Release from 10” Outlet Line

The worst case vulnerable distance (hazard effect distance) for explosion due to LPG release from 10ò outlet line having significant damage to human life is observed to be up to 52.48m*(@0.21 bar having 100% probability of death)* from the LPG piping.

- *Scenario-3: Failure of Vapour line (4” dia) on LPG storage Bullet*
- *Consequent outcome-I: Release from failure of 4” wide vapour line joint on Mounded LPG bullet followed by immediate ignition resulting in Jet fire.*

The hazard effect extents for jet fire resulted due to release of pressurized LPG from failure of 4ò wide vapour line joint on Mounded LPG bullet is presented below:

1. Jet Fire

Release rate of LPG = 27.15 kg/s				
Sn.	**Radiation Intensity (kW/m^2)**	**Effect distance (m) in weather conditions**		
		1F	**1D**	**3D**
1	4.0	*61.51*	*61.51*	*69.93*
2	12.50	-	-	*26.09*
3	37.50	-	-	-

The radiation vs distance graph as well as thermal intensity radii for jet fire due to LPG release from 4òVapour line are shown in **Fig. 11** and **Fig. 12** respectively.

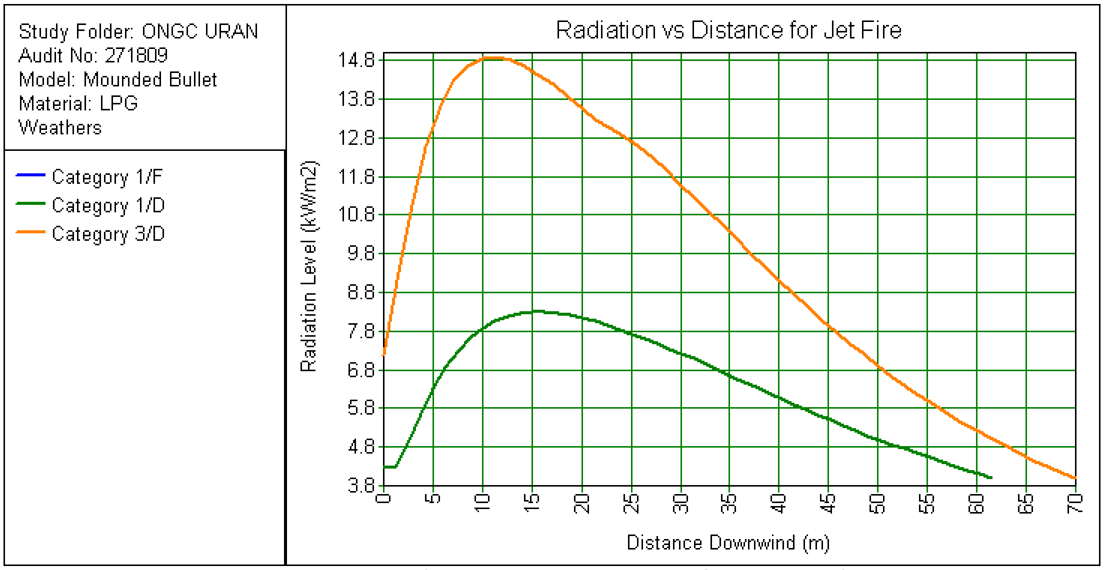

Fig. 11: Radiation vs Distance for Jet Fire due to LPG Release from 4" Vapour Line

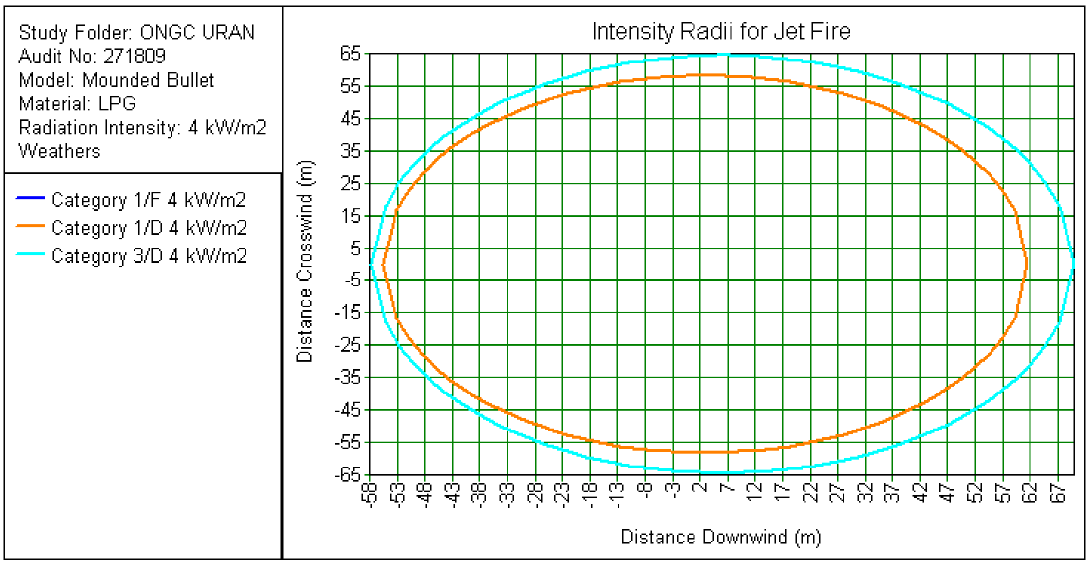

Fig. 12: Thermal Intensity Radii for Jet Fire due to LPG Release from 4" Vapour Line

The worst case vulnerable distance (hazard effect distance) for jet fire due to release of LPG from 4ò Vapour line having significant damage to human life is observed to be up to 26.09m*(@12.5 KW/m^2 since higher thermal radiation is not observed.*

- *Consequent outcome-II: Release from failure of 4" wide vapour line joint on Mounded LPG bullet followed by immediate ignition resulting in Flash fire.*

The hazard effect extents for Flash fire resulted due to release of pressurized LPG from failure of 4òwide vapour line joint on Mounded LPG bullet is presented below:

2. Flash Fire

LFL concentration = 17293.28 ppm				
Sn.	**Concentration of Interest**	**Effect distance (m) in weather conditions**		
		1F	**1D**	**3D**
1	LFL	*0.92*	*0.81*	*3.41*
2	½ LFL	*6.22*	*4.28*	*9.90*

The flash fire envelope due to LPG release from 4òVapour line are shown in **Fig.13.**

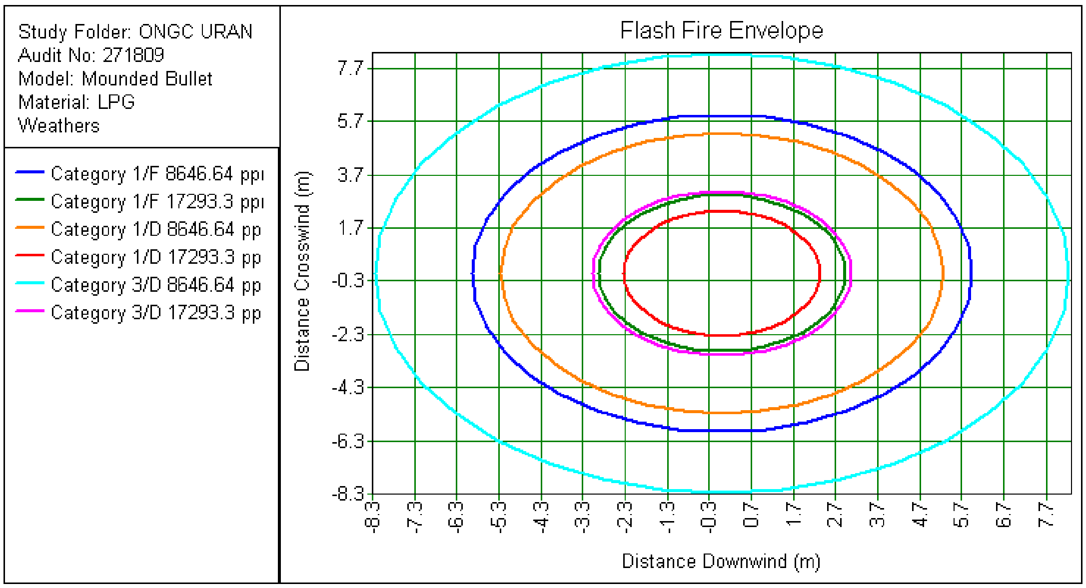

Fig. 13: Flash Fire Envelope due to LPG Release from 4" Vapour Line

The worst case vulnerable distance (hazard effect distance) for flash fire due to LPG release from 4òVapour line having significant damage to human life is observed to be up to 3.41m *(@LFL having 100% probability of death)* from the LPG piping.

- *Consequent outcome-III: Release from failure of 4" wide vapour line joint on Mounded LPG bullet followed by delayed remote ignition resulting in Vapour Cloud explosion.*

  The hazard effect extents for Vapour Cloud explosion resulted due to LPG release from 4òVapour line and ignited at a distance of 10m from the tank is presented below:

  No Vapour cloud explosion is observed due to very low flammable mass of gas being released from the 4òwide vapour line joint on Mounded LPG bullet.

- *Scenario-4: Cumulative Failure of Inlet, outlet and vapour lines simultaneously on LPG storage Bullet*
- *Consequent outcome-I: Release from failure of inlet, outlet and vapour lines simultaneously joint on Mounded LPG bullet followed by immediate ignition resulting in Jet fire.*

The hazard effect extents for jet fire resulted due to release of pressurized LPG from failure of inlet, outlet and vapour lines simultaneously joint on Mounded LPG bullet is as follows:

1. Jet Fire

Release rate of LPG = 381.83 kg/s

Sn.	Radiation Intensity (kW/m^2)	Effect distance (m) in weather conditions		
		1F	1D	3D
1	4.0	*222.21*	*222.21*	*202.70*
2	12.50	-	-	*61.59*
3	37.50	-	-	-

The radiation vs distance graph as well as thermal intensity radii for jet fire due to LPG release from Inlet, outlet and vapour lines simultaneously are shown in **Fig.14** and **Fig.15** respectively.

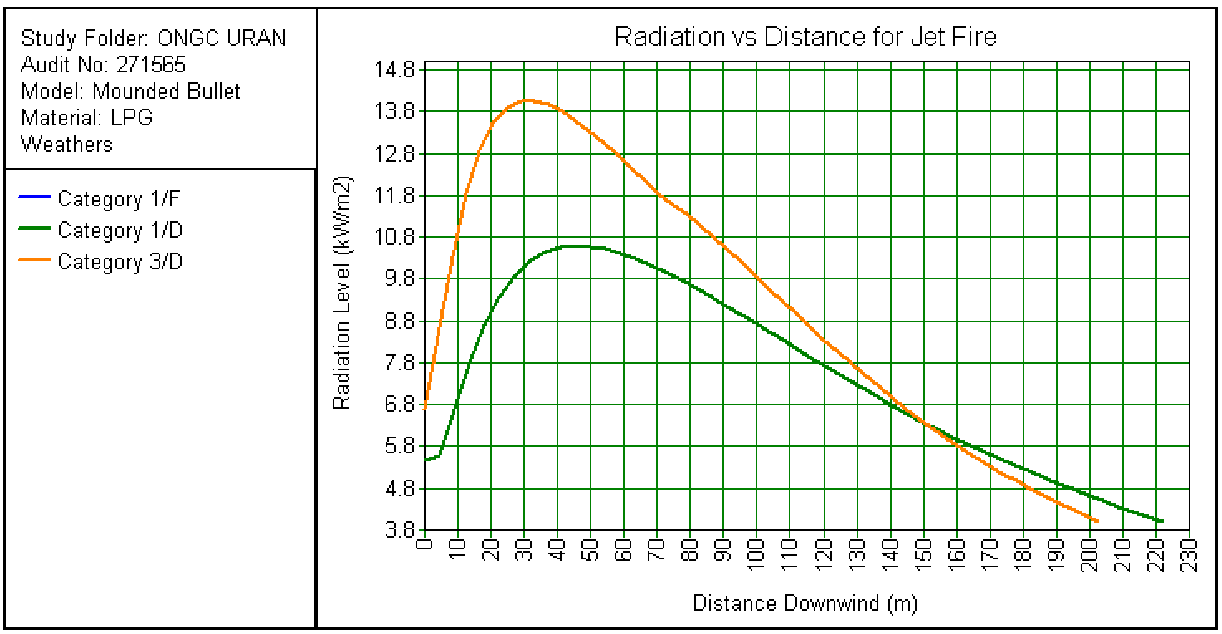

Fig. 14: Radiation vs Distance for Jet Fire due to LPG release from Inlet, Outlet and Vapour lines simultaneously

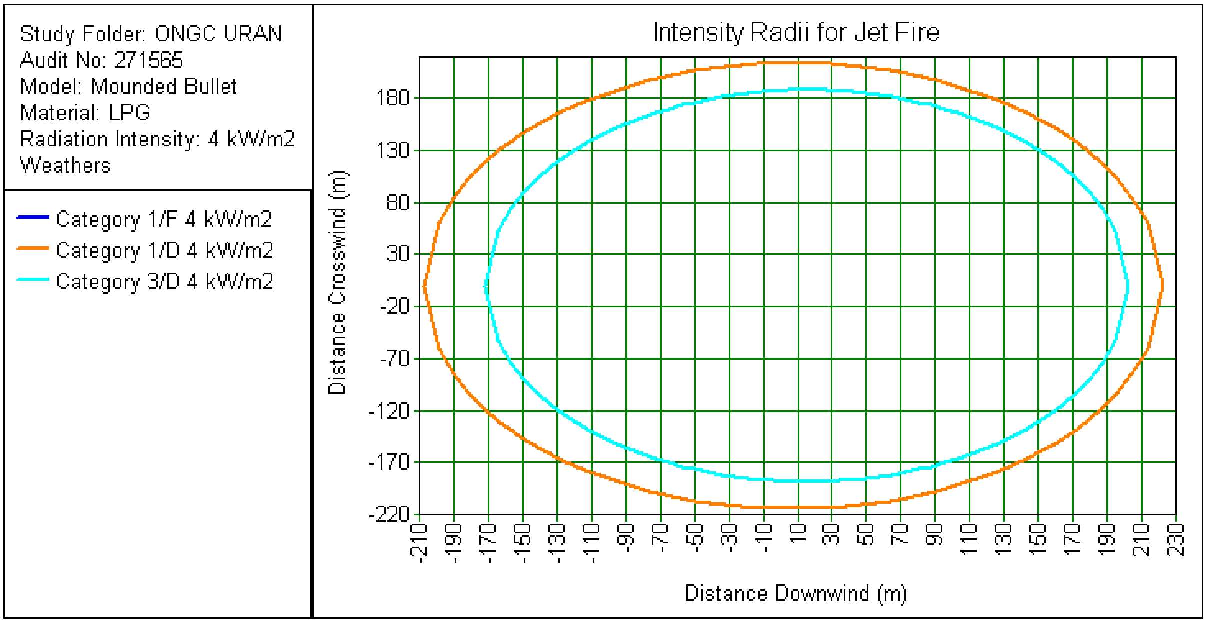

Fig. 15: Thermal Intensity Radii for Jet Fire due to LPG Release from Inlet, Outlet and Vapour Lines Simultaneously

The worst case vulnerable distance (hazard effect distance) for jet fire due to release of LPG from Inlet, outlet and vapour lines simultaneously having significant damage to human life is observed to be up to 61.59m*(@12.5 KW/m^2 since higher thermal radiation is not observed)* from the LPG piping.

- *Consequent outcome-II: Release from failure of 4" wide inlet, outlet and vapour lines simultaneously joint on Mounded LPG bullet followed by immediate ignition resulting in Flash fire.*

The hazard effect extents for Flash fire resulted due to release of pressurized LPG from failure of wide inlet, outlet and vapour lines simultaneously joint on Mounded LPG bullet is presented below:

2. Flash Fire

LFL concentration = 17293.28 ppm				
Sn.	**Concentration of Interest**	**Effect distance (m) in weather conditions**		
		1F	**1D**	**3D**
1	LFL	*19.18*	*13.73*	*10.88*
2	½ LFL	*170.38*	*31.18*	*40.26*

The flash fire envelope due to LPG release from Inlet, outlet and vapour lines simultaneously are shown in **Fig.16:**

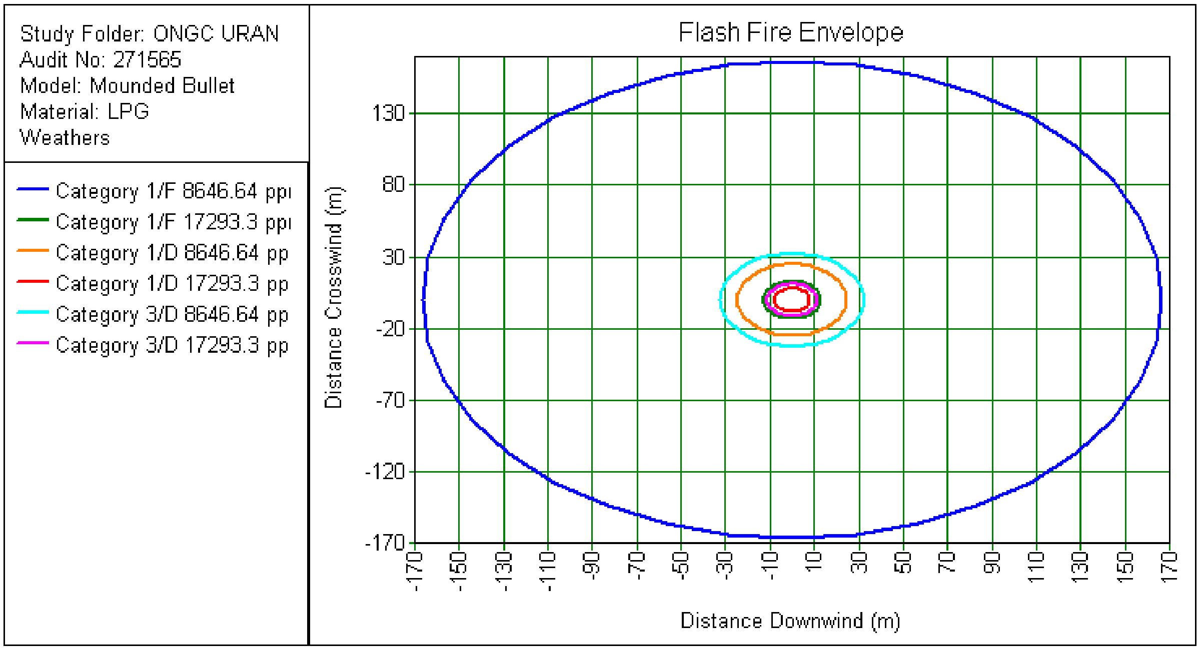

Fig. 16: Flash Fire Envelope due to LPG Release from Inlet, Outlet and Vapour Lines Simultaneously

The worst case vulnerable distance (hazard effect distance) for flash fire due to LPG release from Inlet, outlet and vapour lines simultaneously having significant damage to human life is observed to be up to 19.18m *(@LFL having 100% probability of death)* from the LPG piping.

- *Consequent outcome-III: Release from failure of wide inlet, outlet and vapour lines simultaneously joint on Mounded LPG bullet followed by delayed remote ignition resulting in Vapour Cloud explosion.*

The hazard effect extents for Vapour Cloud explosion resulted due to LPG release from Inlet, outlet and vapour lines simultaneously and ignited at a distance of 10m from the tank is presented below:

3. Vapour Cloud explosion

Distance of ignition source = 10m

Sn.	Blast overpressure	Effect distance (m) in weather conditions		
		1F	1D	3D
1	0.21 bar	*64.01*	*68.02*	*57.46*
2	0.14 bar	*79.80*	*84.99*	*71.33*
3	0.02 bar	*279.59*	*299.61*	*246.88*

The Explosion overpressure vs distance as well as Late explosion worst case radii due to LPG release from Inlet, outlet and vapour lines simultaneously are shown in **Fig. 17** and **Fig. 18** respectively.

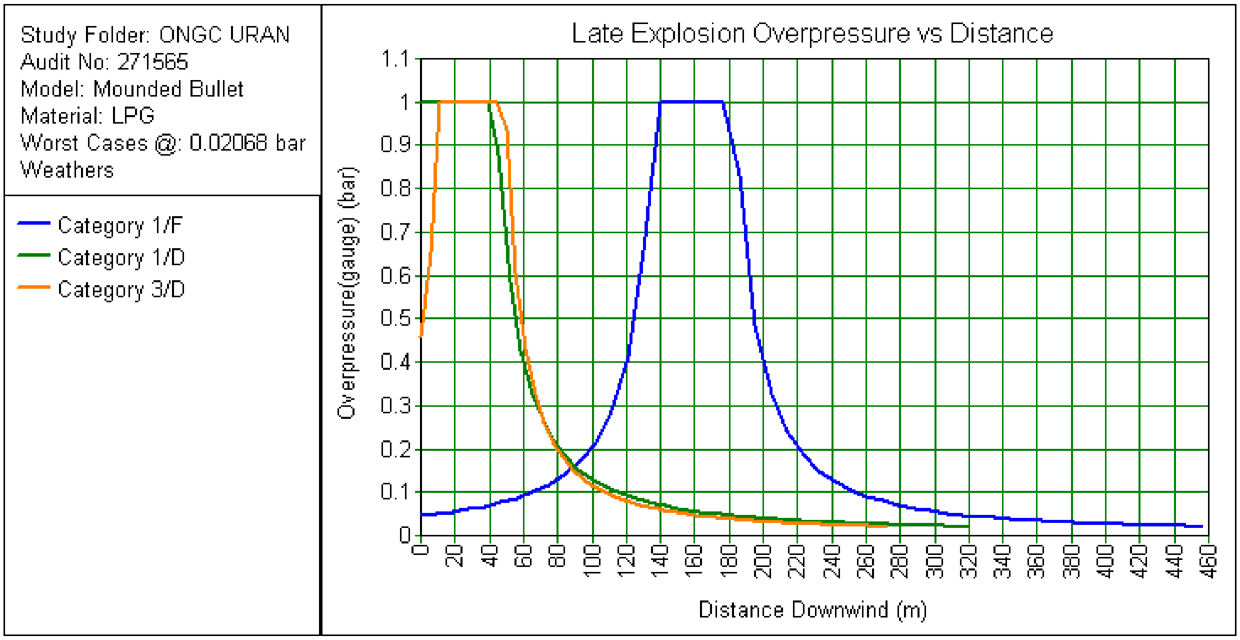

Fig. 17: Explosion Overpressure vs Distance as due to LPG Release from Inlet, Outlet and Vapour Lines Simultaneously

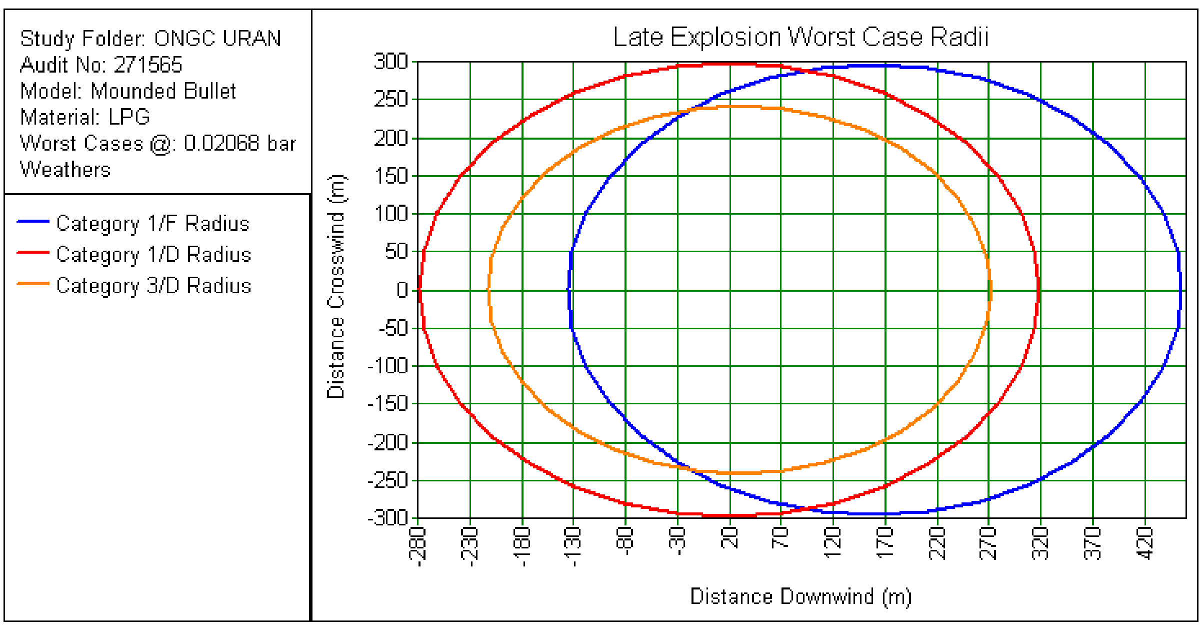

Fig. 18: Late Explosion Worst Case Radii due to LPG Release from Inlet, Outlet and Vapour Lines Simultaneously

The worst case vulnerable distance (hazard effect distance) for explosion due to LPG release from Inlet, outlet and vapour lines simultaneously having significant damage to human life is observed to be up to 68.02 m *(@0.21 bar having 100% probability of death)* from the LPG piping. The Hazard extents of all major hazardous scenarios in 3 m/s wind speed and neutral atmospheric stability class is shown in **Figs. 19, 20** and **21.**

Fig. 19: Hazard Extents for Jet Fire due to Catastrophic Release from Inlet Line on Mounded LPG Bullet

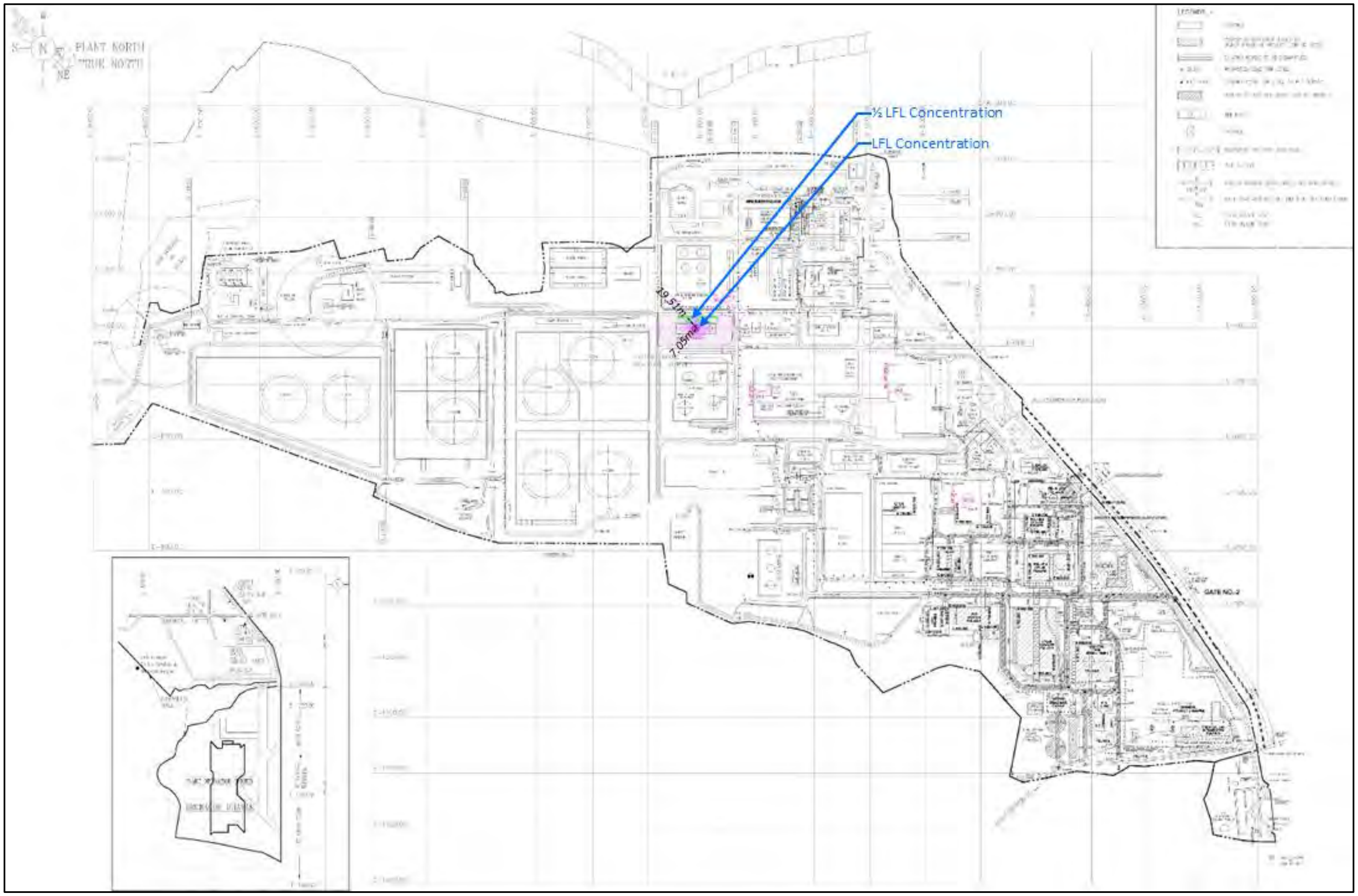

Fig. 20: Hazard Extents for Flash-fire due to Catastrophic Release from Inlet Line on Mounded LPG Bullet

Fig. 21: Hazard Extents for Vapour Cloud Explosion due to Catastrophic Release from Inlet Line on Mounded LPG Bullet

1.8 FREQUENCY ESTIMATION

Frequency estimation is carried out to calculate the likelihood of the identified accident scenarios. Frequencies for risk study are generally estimated by using generic frequencies/probabilities from historical data.

1.8.1 Representative Failure Case Frequencies Estimation

Failure frequencies for the facility are estimated by parts count. Using the basic failure frequency data and counting the numbers of vessels, valves , Flanges, pumps, heat exchangers, compressors, and pipe lengths included in the selected representative set of failure cases, the failure frequencies of various failure cases are calculated and presented below in **Table 6.**

Table 6: Failure Cases Considered for Mounded LPG Bullets

Sn	Vessel/Equipment	Failure case	Size of failure	Failure frequency
1	Fuel Gas pipe	Leakage from fuel gas line and Associated Piping	Full bore (Catastrophic)	5.90×10^{-6}

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. **Table 7** details the ignition probabilities used in the studies.

Table 7: Probabilities of Ignition for Leaks of Flammable Fluids

Description of type of ignition	Probability of occurrence
Probability of immediate ignition	0.08
Probability of delayed ignition	0.5

1.8.2 Domino Effect

For the present risk assessment study, *domino effect* scenario has also been analyzed to assess the associated risk in the most dangerous condition where failure at one facility/unit may trigger a secondary hazardous event at a nearby hazardous unit leading to multiple failures and accidents in the ONGC Uran facility.

Domino effect is basically the propagation of an accident originated from a specific equipment or inventory to adjacent equipment or areas from an industrial site. Normally the propagation of fires or explosions from one area to others is not very representative for the risk of external population because as a secondary effect, it will be highly localised event with high risk of damage to assets but low effect on people outside the limits of the installation. Also, in considering a domino effect, the possibility of a new cloud dispersion from a flammable material undergoing delayed ignition from a secondary event release is not considered as the release due to domino effect will be immediately ignited from the energy of the first event. Additionally, the secondary event occurrence take into account that the majority of people located in adjacent areas of the initial event must had taken appropriate reaction to escape in safe conditions according to Emergency Response procedures, which leads to conclude that most of the time the exposed group are the

Emergency Group inside the installation boundary, which reduce the number of fatalities related to secondary scenarios.

Identification of Domino Effects Scenarios:
For each initial events selected for the domino effect risk analysis, the occurrence probability of domino effects on adjacent areas due to overpressure were identified. These probabilities, when cumulated with the frequency of release in the worst case scenario, gives the frequency of of occurrence of an initiating event for all hazardous units in a facility/complex.

The ONGC Uran plant, has proposed the installation of Mounded bullet storage of LPG. Additionally, an additional GT-IV unit is also being contemplated which will also utilise Natural gas (another flammable material) in its operations. These new units, over and above the existing units shall contribute together to the domino effect.

Some of the most critical scenarios were selected to take part of this study, including the proposed new GT-IV unit as well as new mounded bullet storage of LPG. The Units considered as possible initiating events along with their failure frequencies for the study are listed in Table below:

Table 8: Units considered for Domino effect study along with frequency of initiating a domino effect

Units	Unit name	Frequency of occurrence of initiating event (per year) – Catastrophic ruptures
PROPOSED UNITS		
N1	New Mounded LPG Bullets	5.90×10^{-6}
N2	New Additional GT-4 units	5.90×10^{-6}
EXISTING UNITS		
E1	CFU-I	4.82×10^{-5}
E2	CFU-II	6.11×10^{-5}
E3	CSU 1 & 2	1.93×10^{-3}
E4	GSU	8.05×10^{-5}
E5	LPG-1	4.24×10^{-4}
E6	LPG-2	3.78×10^{-4}
E7	C2-C3	6.57×10^{-4}
E8	Slug Catcher-1 & 2	6.97×10^{-4}

Consequences:
From the results for initial events vulnerability it was possible to determinate which units were affected by overpressure with enough energy to cause domino effects. The **Table 9** below presents the origin and the affected units where secondary scenario can occur.

Table 9: Affected Units with Domino Effects Potential

Affected Units – Domino effect	Origin Units									
	N1	**N2**	**E1**	**E2**	**E3**	**E4**	**E5**	**E6**	**E7**	**E8**
New Mounded LPG Bullets,(N1)					xx		xx			xx
New Additional GT-4 units,(N2)										xx
CFU-1,(E1)				xx	xx	xx		xx	xx	
CFU-II,(E2)			xx			xx				
CSU 1 & 2,(E3)							xx	xx	xx	
GSU,(E4)			xx	xx	xx			xx	xx	
LPG-1,(E5)	xx	xx			xx			xx		xx
LPG-2,(E6)			xx	xx	xx		xx			
C2-C3,(E7)					xx	xx	xx			
Slug Catcher-1 & 2,(E8)		xx								

Index: xx – Affected unit

As can be seen from the table above, Domino Effects can occur in all of the units, with different source of events.

Frequency of Domino Effects Scenarios

The occurrence frequency of a domino event is equal to the sum of all initiating event frequencies that could reach a particular unit causing domino multiplied by the ignition probability and by the wind direction probabilities.

From **Table 9** above, the units affected with potential to lead to a secondary event were determined. The frequencies of domino event were calculated subsequently and the results are presented on **Table 10** below.

Table 10: Frequency of Domino Effects Scenario

Affected Units – Domino effect	Origin Units										
	N1	**N2**	**E1**	**E2**	**E3**	**E4**	**E5**	**E6**	**E7**	**E8**	**TOTAL**
New Mounded LPG Bullets,(N1)					5.22X10^{-5}		1.15X10^{-5}			1.88X10^{-5}	**8.25X10^{-5}**
New Additional GT-4 units,(N2)										1.88X10^{-5}	**1.88X10^{-5}**
CFU-1,(E1)				1.65X10^{-6}	5.22X10^{-5}	2.17X10^{-6}		1.02X10^{-5}	1.77X10^{-5}		**8.40X10^{-5}**
CFU-II,(E2)			1.30X10^{-6}			2.17X10^{-6}					**3.47X10^{-6}**
CSU 1 & 2,(E3)							1.15X10^{-5}	1.02X10^{-5}	1.77X10^{-5}		**3.94X10^{-5}**
GSU,(E4)			1.30X10^{-6}	1.65X10^{-6}	5.22X10^{-5}			1.02X10^{-5}	1.77X10^{-5}		**8.31X10^{-5}**
LPG-1,(E5)	1.59X10^{-7}	1.59X10^{-7}			5.22X10^{-5}			1.02X10^{-5}		1.88X10^{-5}	**8.16X10^{-5}**
LPG-2,(E6)			1.30X10^{-6}	1.65X10^{-6}	5.22X10^{-5}		1.15X10^{-5}				**6.66X10^{-5}**
C2-C3,(E7)					5.22X10^{-5}	2.17X10^{-6}	1.15X10^{-5}				**6.59X10^{-5}**
Slug Catcher-1 & 2,(E8)		1.59X10^{-7}									**1.59X10^{-7}**

From the values above, the calculated frequencies are between 1.6 x 10^{-7} and 8.4 x 10^{-5} /year, for all units. These are the frequencies that will be used to calculate the risk for both cases, including the domino events.

1.9 RISK ESTIMATION

Once the frequencies and consequences of each modelled accident scenario have been estimated, they have to be combined to form measures of overall risk.

1.9.1 Individual Risk

It is the frequency at which an Individual may be expected to sustain a given level of harm from the realization of specified hazards and is normally taken as the risk of death (fatality). It is expressed as a risk per year and is not significantly affected by the number of people present. Individual risk is usually presented in the form of Individual Risk Contours, which are also commonly known as ISO- Risk Curves. This is used to indicate the individual risk of fatality at a particular geographical location and is actually a risk to a hypothetical individual being present at that location continuously for 24 hours a day and 365 days a year. It is the standard output from a risk analysis.

Individual Risk Estimates

The individual risk estimated for each of the identified consequences, taking in consideration the failure frequencies as well as ignition probabilities is shown in **Table 11.**

Table 11: Estimated Individual Risks for Identified Consequences

Sn	Identified maximum credible Consequence	Individual risk (per yr)
1	Jet fire	4.72×10^{-7}
2	Flash Fire	2.44×10^{-6}
3	Vapour Cloud Explosion	2.71×10^{-7}

The overall risk for the Mounded LPG bullets is estimated to be 9.3×10^{-5} /yr which is observed to be in the ALARP region. The Individual risk contours are shown in **Fig. 22.**

However, based on the analysis of domino effects on the proposed bullets, the Individual risks of proposed mounded Bullet LPG storage *with Domino effect* is estimated to increase to 1.8×10^{-4} /yr which is also almost within the ALARP region.

Impact of proposed Mounded Bullets on existing Individual Risk levels of the plant

The detailed Quantitative Risk Assessment (QRA) for the existing ONGC's Uran plant had been conducted by IEOT, Panvel vide their report No. IEOT/RRE/18/2010-11 in 2011. Based on the findings of the report, it was deduced that the Individual Risks associated with the existing plant ranged between 1.52×10^{-4} to 3.02×10^{-3} per year. Cumulating the associated overall Individual Risk due to the proposed Mounded Bullet storage, it is found that the maximum Individual Risk will be increased only by ~6% and will still be within ALARP.

Fig. 22: Individual Risk Contours for Proposed Mounded LPG Bullet Storage Area

1.9.2 Societal (Group) Risk

Some major incidents have the potential to affect many people. Societal risk is a measure of risk to a group of people. It is the risk experienced in a given time period by the whole group of personnel exposed, reflecting the severity of the hazard and the number of people in proximity to it. It is defined as the relationship between the frequency and the number of people suffering a given level of harm (normally taken to refer to risk of death) from the realization of the specified hazards. The term "societal risk" is nothing but the group risk of the members of the general public/nearby community. It is expressed in the form of an F-N Curve, which is basically a cumulative frequency versus fatalities curve, showing the cumulative frequencies (F) of accident scenarios involving N or more fatalities. They are derived by sorting the frequency-fatality pairs from each accident outcome of each accident scenario, and adding them to form cumulative frequency-fatality (F-N) coordinates for the plot. They can be used to identify the accident scenarios with the potential to cause large number of fatalities at once.

Societal (Group) Risk Estimates

The overall Societal (Group) risk F-N curve plotted for Mounded Bullets is shown in **Fig. 23(a) .**

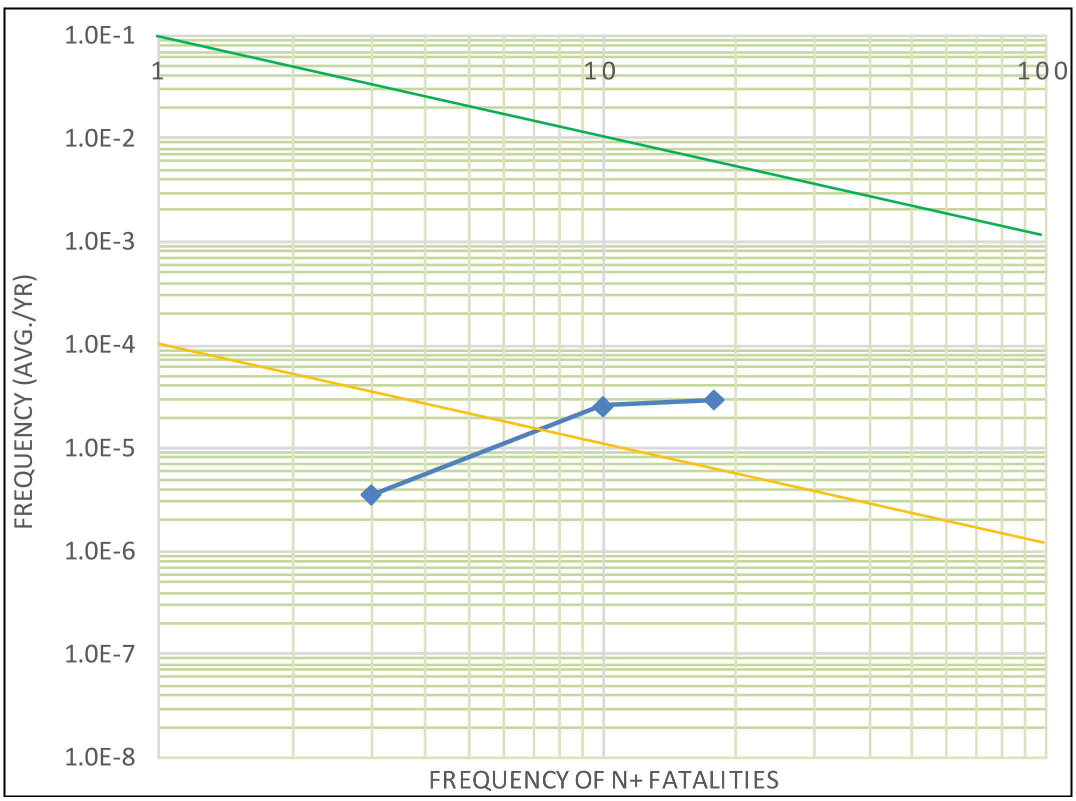

Fig. 23(a): F-N Curve for ONGC'S Uran Plant (Proposed Mounded LPG Bullet Area)

The overall Societal Risk F-N curve plotted for Mounded Bullets taking in consideration addition risks due to domino effect is shown in **Fig. 23(b).**

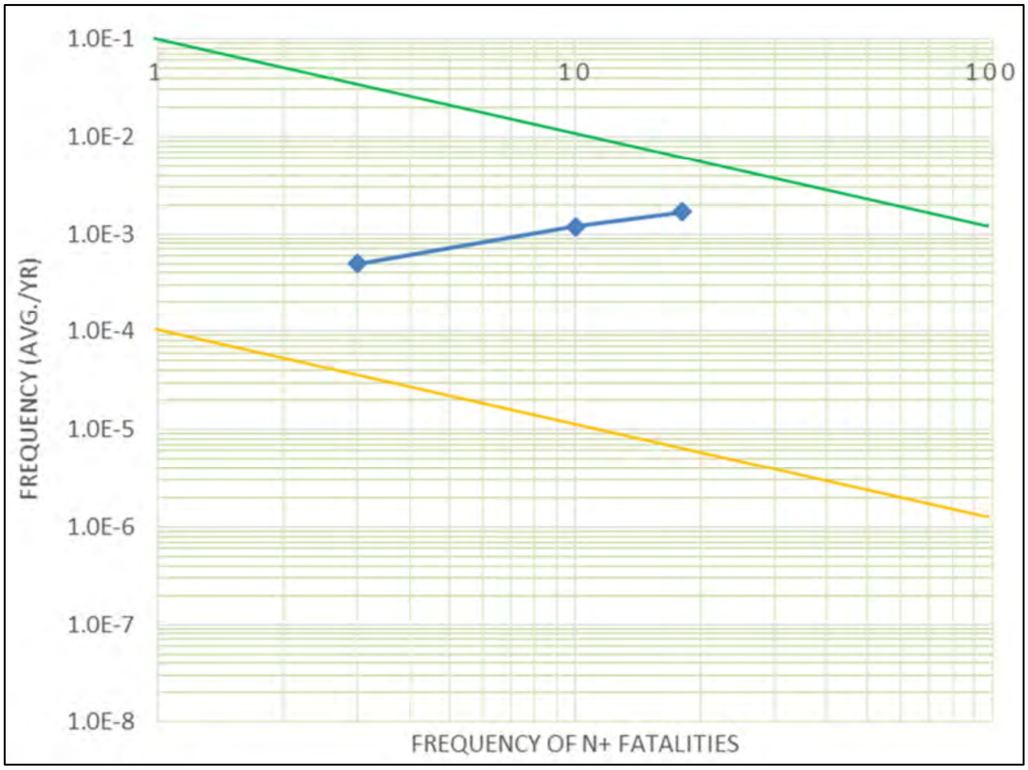

Fig. 23(b): F-N Curve for ONGC'S Uran Plant (Proposed Mounded LPG Bullet Area) *with Domino effect*

Now, after examination and evaluation of the F-N curves, the risks of different group sizes of personnel affected have been estimated and placed as follows in **Table 12**.

Table 12: Societal (Group) Risk Computed for Mounded Bullets

Estimated No. of fatalities (N)	Cumulative frequency, F of "N" or more fatalities (per year)	
	Combined without Domino effect	*Combined with Domino effect*
N=3	3.52×10^{-6}	4.99×10^{-4}
N=10	2.60×10^{-5}	1.18×10^{-3}
N=18	2.95×10^{-5}	1.68×10^{-3}

From the results it is observed that there is an increase for the societal risk, when considering Domino Effects for the proposed Bullet storage, however, in spite of the increase, it is to be noted that the FN-Curve for both cases (with & without domino effect) is within the ALARP region only.

Impact of proposed Mounded Bullets on existing Societal Risk levels of the plant

Based on aforementioned QRA conducted by IEOT, Panvel for the existing ONGCǒs Uran plant, the existing Societal risk levels when cumulated with proposed additional GT-IV unit (with domino effect) and new Mounded Bullet storages (with domino effect), the F-N curve so obtained also lied within the ALARP region even after considering the additional associated risks of the new GT-IV plant and mounded bullet storage. The F-N curve for the overall plant considering the new proposed GT-IV plant(with Domino effect) as well as mounded bullet storage of LPG (with Domino effect) is shown in **Fig. 23(c)** below:

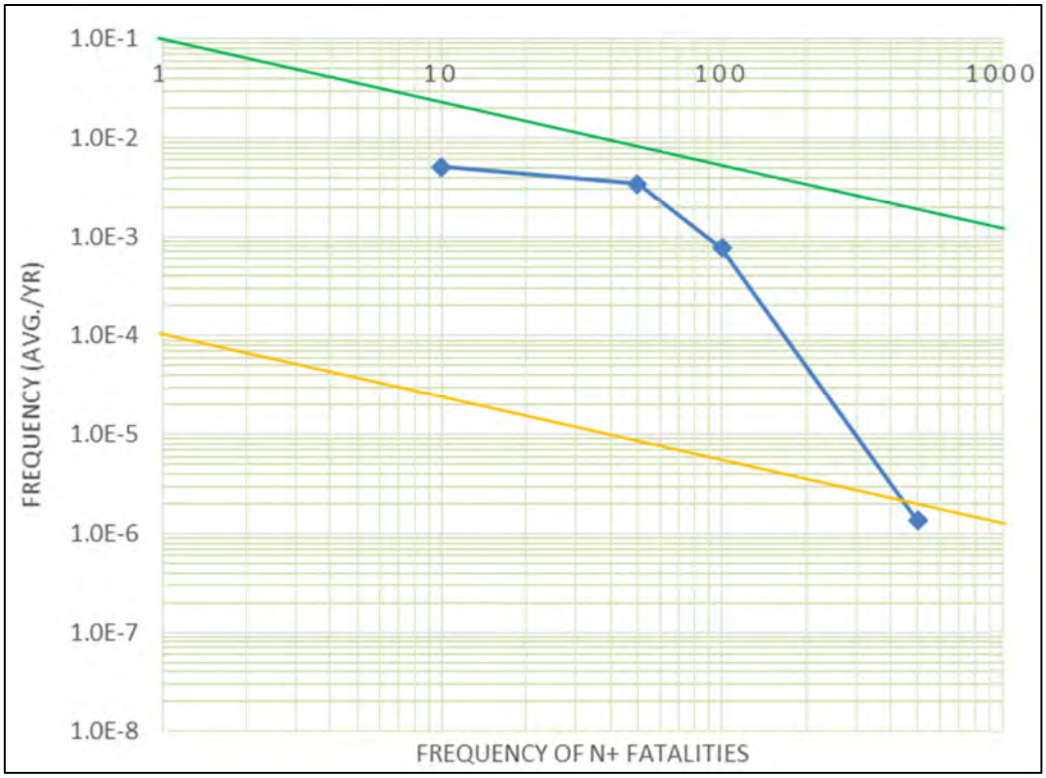

Fig. 23(c): F-N Curve for ONGC'S Uran Plant (with Proposed Mounded LPG Bullet including *Domino effect* as well as new GT-IV plant)

1.9.3 Comparison with Risk Criteria

The numerical estimate of the risk is of no inherent use as they neither ensure acceptability nor improve safety. It is the analysis of those numbers, against well- defined suitable appropriate risk criteria, that allows conclusions to be drawn and recommendations to be made. Though achieving complete safety is desirable but practically it is impossible to achieve, as any activity will have its own inherent risk. Society as a whole has to decide whether the benefits from the activity (in terms of tax revenues, employment, products, profits etc.) out weights the risks involved. The usual question "Is it safe?" has to be interpreted in the decision making as meaning "Are the Risks low enough to be tolerated? This is what a risk criteria attempts to establish.

Although since long risk analysis studies have been used in India but till date Indian Regulatory Authorities have not specified any formal regulation/guideline regarding risk criteria to be adopted. In absence of it, Individual Risk Acceptance Criteria (RAC) as suggested by Health & Safety Executive (HSEL of the Government of United Kingdom, for onshore hazardous industry has been used to assess the individual risk to public and plant personnel. This has been illustrated in **Fig. 24.**

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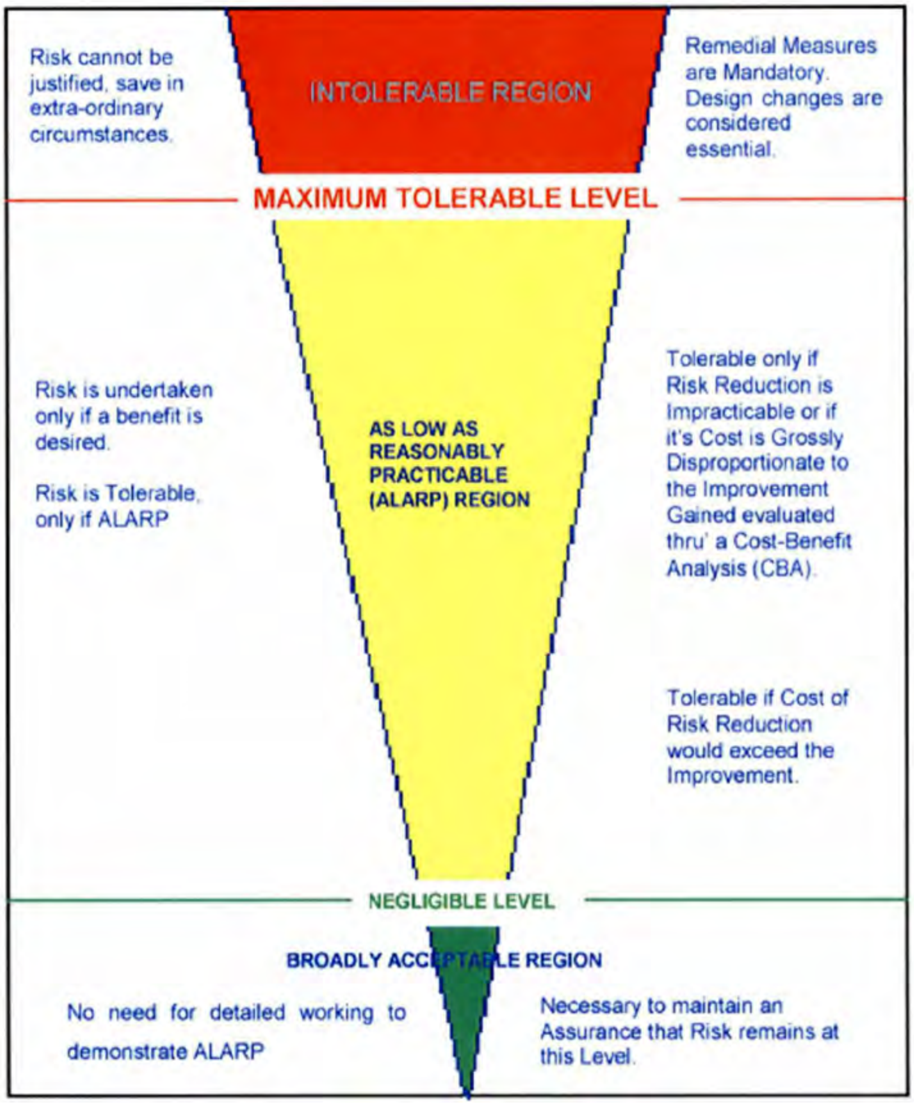

Fig 24: Risk Criteria Framework Suggested by H.S.E. U.K

Further, Society usually judges accidents, which result in multiple fatalities more harshly than the multiple accidents, which causes fewer fatalities per accident. In view of this fact, the Societal Risk has also been assessed. In absence of any Societal Risk Criteria specified by Indian Regulatory Authorities in the form of F-N curves, Societal Risk Criteria as suggested by H.S.C., U.K has been used. This has been illustrated in **Fig. 25**

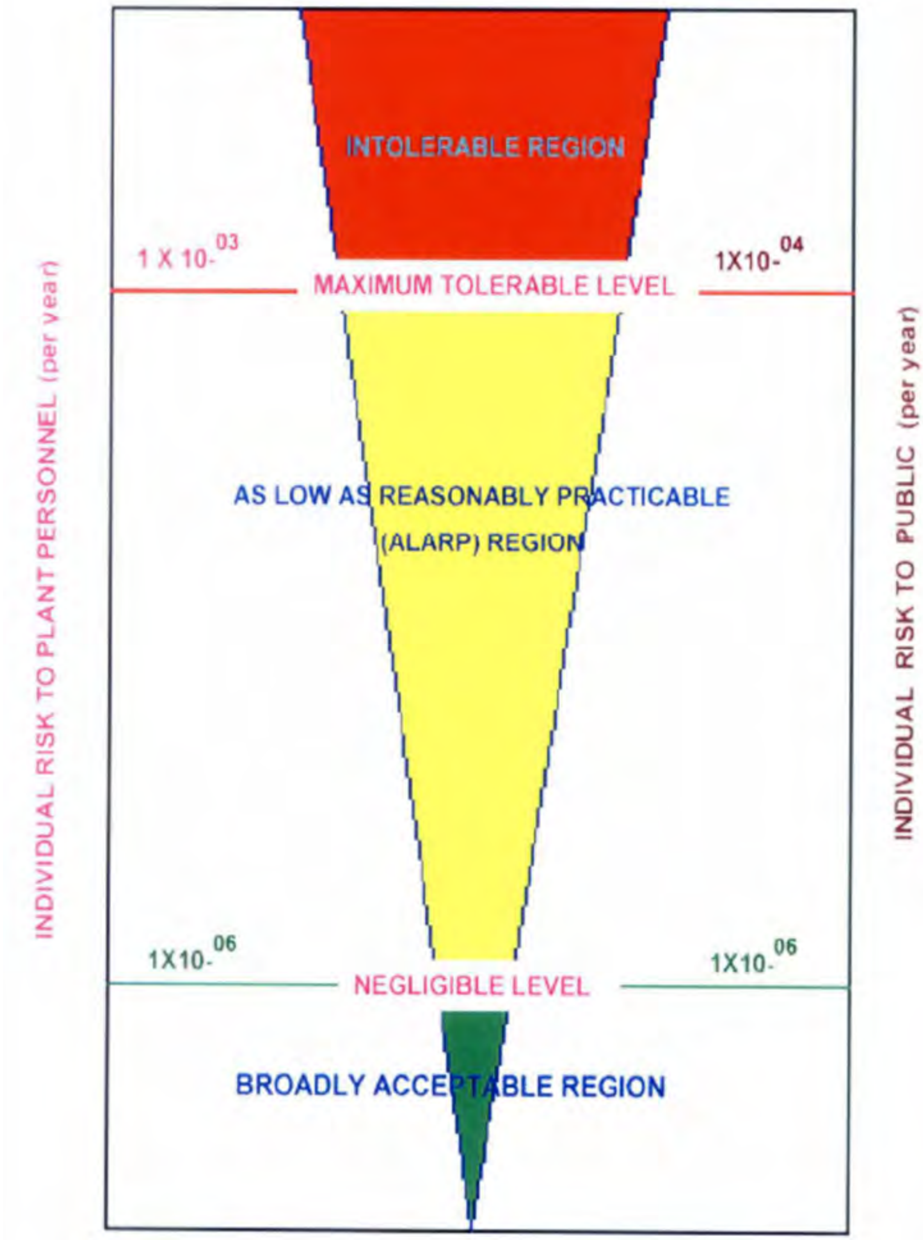

Fig. 25 : Onshore Individual Risk Criteria (Suggested by H.S.E. U.K.)

1.10 CONCLUSION ON RISK ASSESSMENT

It is important to note that since risk analysis being a predictive science, a lot of uncertainties exist in frequency estimation and consequence modelling, as most of the data used are generic in nature and their applicability to a particular type of operations and company is subjective. In view of this, risk levels may best be taken as an aid to decision-making rather than as strict quantitative numbers to prove or disprove safe/unsafe risk levels. It should be noted that any deviation / modification of the installation may change/nullify the conclusions drawn and hence review of risk analysis will be essential.

Based on the risk estimations carried out in above, the conclusions drawn are elaborated below:

- The results of MCA analysis indicates a maximum hazard distance for causing significant damage (@12.5 Kw/m^2 thermal radiation) is extending up to 47.13 m in the release of LPG due to catastrophic rupture of inlet or outlet line connected to the Mounded bullets and subsequently being ignited during worst meteorological conditions resulting in a Jetfire. However, t*he hazard extent will be contained within the plant premises and will not extend beyond plant boundary into any nearby settlement in the area. Also, fire resistant dyke walls will be created, so no cumulative effect of one tank on fire to create fire on other tank farm is foreseen.*

- As per ISO-risk contours the Individual risk contours for plant personnel in Mounded Bullet area are in ALARP (As Low As Reasonably Practicable) region (which extends from 1 x 10^{-3} per year to 1 x 10^{-6} per year). Individual risk contours are not extending far off distances and are confined around the proposed mounded bullet area. Risk is in ALARP Risk region. In relation to the Overall Uran plant layout, Individual Risk is limited to mounded bullet area only. None of the contour is going outside the Uran plant boundary. Therefore, Maximum risk contours for Plant personnel and for general public is confined inside the plant boundary.

- The most dangerous situation of triggered events has also been considered, under the analysis of Domino effect, to assess the risks associated with the proposed Mounded Bullet storage of LPG and it was found that even in the situation of multiple failure events, the total increased Individual and Societal risks associated with the Mounded Bullet storage was within the ALARP region.

1.11 RECOMMENDED RISK REDUCTION MEASURES

Based on the conclusions drawn above, following remedial measures have been recommended for Mounded LPG Bullet storage area of ONGCö Uran plant:

- As high pressure fuel gas is handled in the unit, an adequate Gas detection system should be provided covering the Fuel gas system for quick detection of any leakage of the gas. Means of quick isolation should be provided in the fuel gas system to limit the leaked inventory and duration of fire. The Isolation system should be interlocked with the F&G system.

- The major risk contributors in group risk are associated with large leak in fuel gas piping system. The failure cases from this piping may contribute more than 99% of the total group risk. Therefore, it is recommended that frequent inspection and monitoring of wall thickness of fuel gas piping system, conditions of valves and flanges/gaskets etc. should be carried out and record be maintained. This will help in ascertaining the integrity of the fuel gas piping system and consequently reduce the likelihood of a leak.

- Ignition control goes a long way in reducing the chances of fire. It is recommended that electrical items should be selected and installed as per hazardous area classification OISD-STD-113 and distances of flammable zone from the facility.

- Shutdown valve should be provided at the gas entry point to the turbine hall to limit the gas leaked quantity if any major leak happens. This Shutdown valve should be interlocked with the Fire and gas detection system provided in the turbine hall/enclosure.
- The fire water network should be extended to cover the new Mounded LPG Bullet storage area.
- It is recommended that risk analysis study should be carried out again In the event of any major modification/ addition of new facilities or change in offsite inhabitation to assess the changed risk profile of the installation.

1.12 NATURAL DISASTERS

The project is located in Seismic Zone III. The project area being located on the coast of the Arabian Sea also receives very heavy rains during the monsoons.

The following measures will be undertaken to reduce damage due to earthquakes:

- Crisis Management Group will activate the Emergency Control Centre.
- Crisis Management Group will initiate onsite management as per Crisis management and Disaster Preparedness Plan Manual
- Incident Controller will initiate Emergency Operations at site and report to Chief Incident Controller.
- Evacuate the affected zones with the help of Warden Team.
- The Chief Incident Controller will assess the situation and report to the Chief Emergency Controller (Executive Director, ONGC, Uran).
- Chief Emergency Controller (Executive Director, ONGC, Uran) will seek assistance of District Authorities if required.

The project site may receive very heavy rainfall during the monsoons. Prior to the monsoons, the entire storm water system will be inspected and cleared of all accumulated debris; mechanical equipment (pumps) will be rigorously serviced. Civil structures will also be inspected for integrity and necessary repairs will be carried out. Concerned emergency personnel and equipment will be kept ready at the plant when very heavy rains are forecast. Depending on the weather forecast, if necessary the plant may operate at a reduced capacity. During the period of the stormy weather, the Chief Emergency Controller will be present at the Control Room to constantly monitor the situation and may direct personnel to undertake emergency repairs as deemed necessary.