RISK ASSESSMENT & HAZARD ANALYSIS

Risk Assessment is a systematic process aimed at removing or minimizing hazards at work place to make it safer and healthier. Although the purpose of risk assessment includes the prevention of occupational risks, and this should always be goal, it will not always be achievable in practice. Where elimination of risks is not possible, the risks should be reduced and the residual risk controlled.

Hazard analysis involves the identification and quantification of various probable hazards (unsafe conditions) that may occur at the airport. On the other hand, risk analysis deals with the identification and quantification of risks, the airport equipment/facilities and personnel exposed to, due to accidents resulting from the hazards present at the airport.

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Hazard occurrence may result in on-site implications like:

- Fire and/or explosion;
- Leakage of flammable material;
- Crash landing;
- Bomb threat; and
- Natural calamities like earthquake, cyclone etc.

Other incidents, which can also result in a disaster, are:

- Air raids; and
- Crashing of aircrafts i.e. while landing or take-off.
- Agitation/forced entry by external group of people;
- Sabotage; and
- Hijacking.

In the sections below, the identification of various hazards, probable risks in the airport operation, maximum credible accident analysis and consequence analysis are addressed either qualitatively or quantitatively, which gives a broad identification of risks involved in the airport operation. Based on the risk assessment of various hazards, disaster management plan has been formulated and presented here.

Fuel storage area has been one of the prime concerns as far as airport risk and hazards are concerned. All the fuels are being stored in the fuel yard located within the airport premises. The fuel yard comprises of storages of HSD and ATF fuel. It is proposed that the oil company which will supply the fuel for the airport will bring oil tankers inside and provide the necessary arrangements for filling. Any accident the tanker meets during filling inside airport will cause accidental spillage on concrete surface and related risks as mentioned in following sections.

As the details of storage and handling facilities of ATF has remained the same, as was done by the Vimta Labs in 2016 for obtaining the EC for the proposed extension of Runway at Vijayawada Airport, we have retained the same input data and simulation of each identified hazardous chemical for consequence analysis has been done by using ALOHA. ALOHA (Areal Locations of Hazardous Atmospheres) is a computer program designed to model chemical releases for emergency responders and planners. It can estimate how a toxic cloud might disperse after a chemical release-as well as several fires and explosions scenarios.

Risk Modelling

For quantitative risk assessment, mathematical modellings are needed. ATF and HSD are hazardous chemicals used in the project. For the project, two models are used – ALOHA as developed by US EPA for ATF and F&EI for HSD as developed by DOW Chemicals as ALOHA does not cover HSD in its library. ALOHA is designed to produce reasonable results quickly enough to be of use to responders during a real emergency or can be used as a predictive model. Therefore, ALOHA's calculations represent a compromise between accuracy and speed. Many of ALOHA's features were developed to quickly assist the responder. In the present case, a prediction has been done assuming most unfavourable meteorological condition like low wind speed of 1 m/s and depending on the extent of solar radiation, the model selects the stability class. The airport has storage for HSD but does not have storage of ATF and the fuel filling is done by tankers.

The details of storage capacity and tanker capacity are given in **Table 1**.

Table 1: Capacity of Fuel Storages

Fuel Type	Total Storage Capacity
HSD	3 x 990 L
ATF	Tank diameter/length: 0.75 m/3.5 m arranged by IOCL/HP/Reliance

For ATF: For generating a hazardous scenario, it is assumed that the ATF tanker meets with an accident and the aviation fuel spill on concrete ground. It may cause toxic fume dispersion, may catch fire and cause thermal radiation or the vapor cloud may travel and meeting an ignition source, may explode causing pressure waves and damaging structures. For modelling, the following situations are considered:

A. Leaking Tank, Chemical is not burning & forms an evaporating puddle

B. Leaking Tank, Chemical is burning & forms a pool fire

C. BLEVE, tank explodes & chemical burns in a fireball

N-Heptane and Iso-octane are major constituents of Aviation Fuel. The modelling has been done for both.

For developing a conservative scenario, the results are predicted for both of these constituents of ATF, for all the 3 situations A, B and C and predicted for 3 conditions vis-a-vis their spread distances:

(Red): Zone of highest impact

(Orange): Zone between highest and lowest impact

(Yellow): Zone of lowest impact

Input Used for ALOHA Modelling

ATMOSPHERIC DATA: (MANUAL INPUT OF DATA)

Wind: 1 m/s

Ground Roughness: Open Country

Air Temperature: 30° C

Stability Class: F

Relative Humidity: 50%

SOURCE STRENGTH:

Tank Diameter/Length: 0.75 m/3.5 m

Source State: Liquid

Source Temperature: 30 Degree Celsius

The results are presented for 3 scenarios

Consequences Analysis for Failure Scenarios of Aviation Turbine Fuel (ATF)

N-Heptane and Iso-octane are major constituents of Aviation Fuel. The modelling has been done for both.

N-Heptane:

CAS Number: 142-82-5	PAC-1: 500 ppm	PAC-2: 830 ppm	PAC-3: 5000 ppm
Molecular Weight: 100.20 g/mol.	IDLH: 750 ppm	LEL: 10500 ppm	UEL: 67000 ppm
Ambient Boiling Point: 98.3° C	Vapor Pressure at Ambient Temperature: 0.011 atm.	Freezing Point: -90.6° C	

A. Leaking Tank, Chemical is not burning & forms an evaporating puddle

Case 1: Toxic Area of Vapor Cloud

Model Run: Heavy Gas

Red: 23 meters --- (5000 ppm = PAC-3)

Note: Threat zone was not drawn because effects of near-field patchiness make dispersion predictions less reliable for short distances.

Orange: 62 meters --- (830 ppm = PAC-2)

Yellow: 80 meters --- (500 ppm = PAC-1)

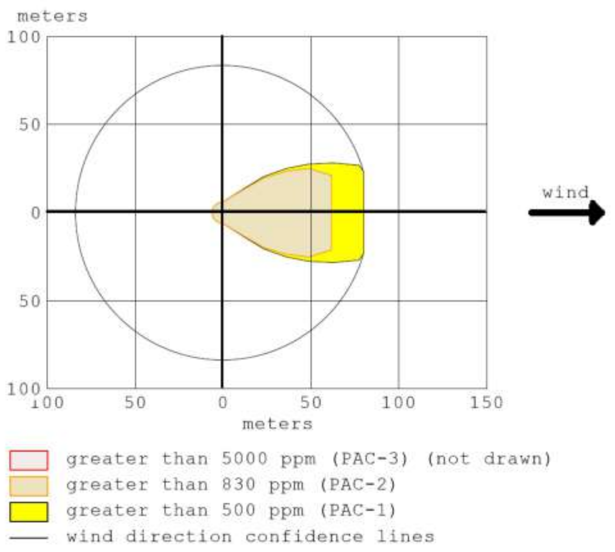

Figure 1: Toxic Release threat zone for N-Heptane

Case 2: Flammable Area of Vapor Cloud

Model Run: Heavy Gas

Red: 23 meters --- (5000 ppm = PAC-3)

Note: Threat zone was not drawn because effects of near-field patchiness make dispersion predictions less reliable for short distances.

Orange: 62 meters --- (830 ppm = PAC-2)

Yellow: 80 meters --- (500 ppm = PAC-1)

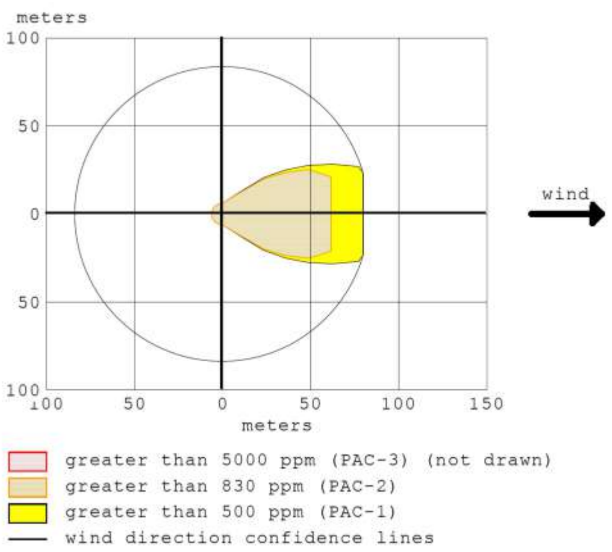

Figure 2: Flammable area of Vapor Cloud for N-Heptane

Case 3: Blast: Vapor Cloud Explosion

Threat Modeled: Overpressure (blast force) from vapor cloud explosion

Type of Ignition: ignited by spark or flame

Level of Congestion: congested

Model Run: Heavy Gas

Red: LOC was never exceeded --- (8.0 psi = destruction of buildings)

Orange: 16 meters --- (3.5 psi = serious injury likely)

Yellow: 28 meters --- (1.0 psi = shatters glass)

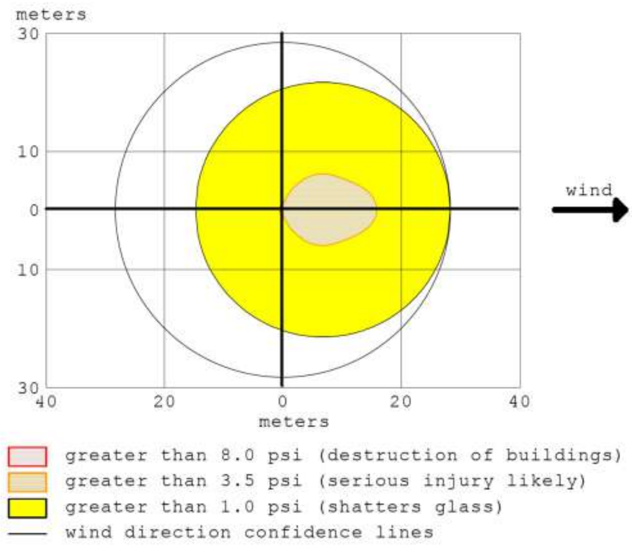

Figure 3: Blast Vapor Cloud Explosion for N-Heptane

B. Leaking Tank, Chemical is burning & forms a pool fire

Threat Modeled: Thermal radiation from pool fire

Red: less than 10 meters (10.9 yards) --- (10.0 kW/(sq m) = potentially lethal within 60 sec)

Orange: less than 10 meters (10.9 yards) --- (5.0 kW/(sq m) = 2nd degree burns within 60 sec)

Yellow: 13 meters --- (2.0 kW/(sq m) = pain within 60 sec)

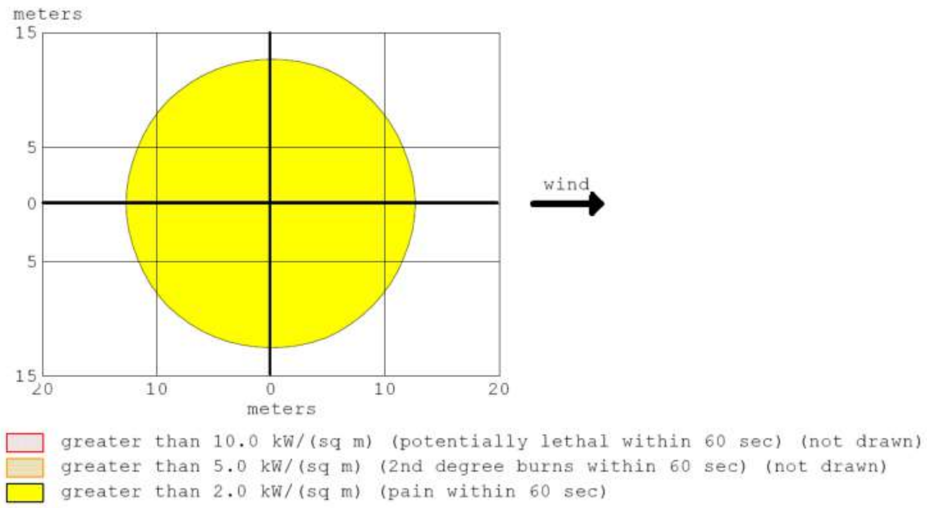

Figure 4: Thermal Radiation from Pool Fire for N-Heptane

C. BLEVE, tank explodes & chemical burns in a fireball (*This is the most appropriate situation for the tanker meeting with an accident***)**

Threat Modeled: Thermal radiation from fireball

Red: 134 meters --- (10.0 kW/(sq m) = potentially lethal within 60 sec)

Orange: 190 meters --- (5.0 kW/(sq m) = 2nd degree burns within 60 sec)

Yellow: 296 meters --- (2.0 kW/(sq m) = pain within 60 sec)

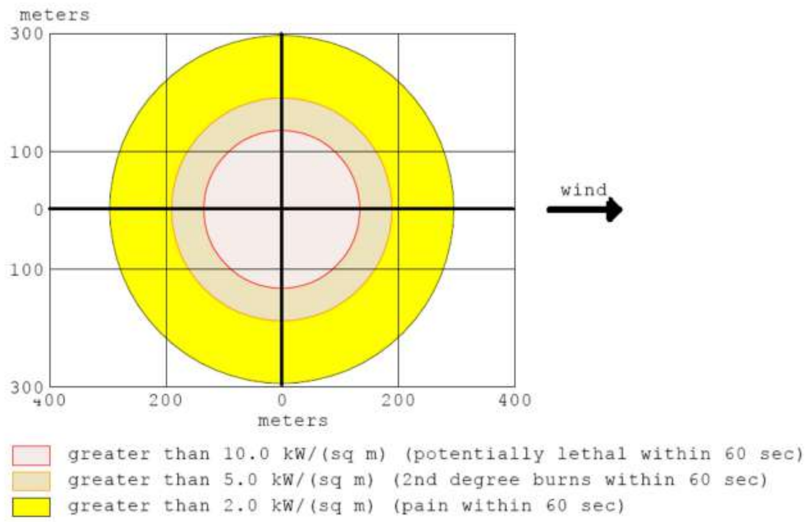

Figure 5: BLEVE, Thermal Radiation from Fireball for N-Heptane

Iso-octane:

CAS Number: 540-84-1	PAC-1: 230 ppm	PAC-2: 830 ppm	PAC-3: 5000 ppm
Molecular Weight: 114.23 g/mol.	LEL: 9500 ppm		UEL: 60000 ppm
Ambient Boiling Point: 99.2° C	Vapor Pressure at Ambient Temperature: 0.082 atm.	Ambient saturation concentration: 82,386 ppm or 8.24%	

A. Leaking Tank, Chemical is not burning & forms an evaporating puddle

Case 1: Toxic Area of Vapor Cloud

Model Run: Heavy Gas

Red: 24 meters --- (5000 ppm = PAC-3)

Note: Threat zone was not drawn because effects of near-field patchiness make dispersion predictions less reliable for short distances.

Orange: 62 meters --- (830 ppm = PAC-2)

Yellow: 124 meters --- (230 ppm = PAC-1)

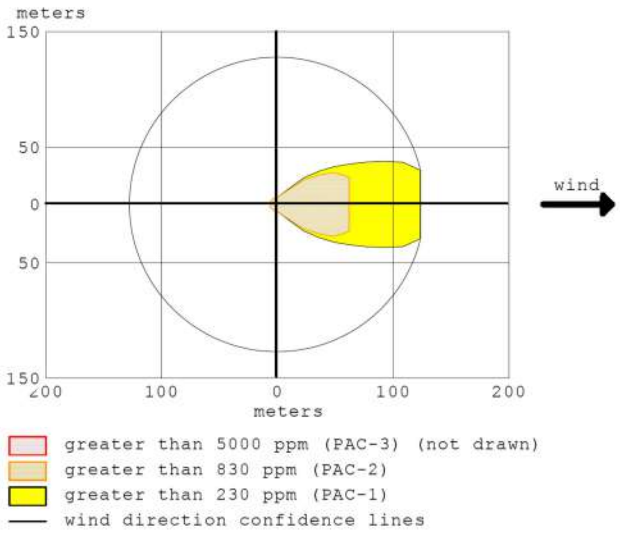

Figure 6: Toxic area of Vapor cloud for Iso-octane

Case 2: Flammable Area of Vapor Cloud

Model Run: Heavy Gas

Red: 24 meters --- (5000 ppm = PAC-3)

Note: Threat zone was not drawn because effects of near-field patchiness make dispersion predictions less reliable for short distances.

Orange: 62 meters --- (830 ppm = PAC-2)

Yellow: 124 meters --- (230 ppm = PAC-1)

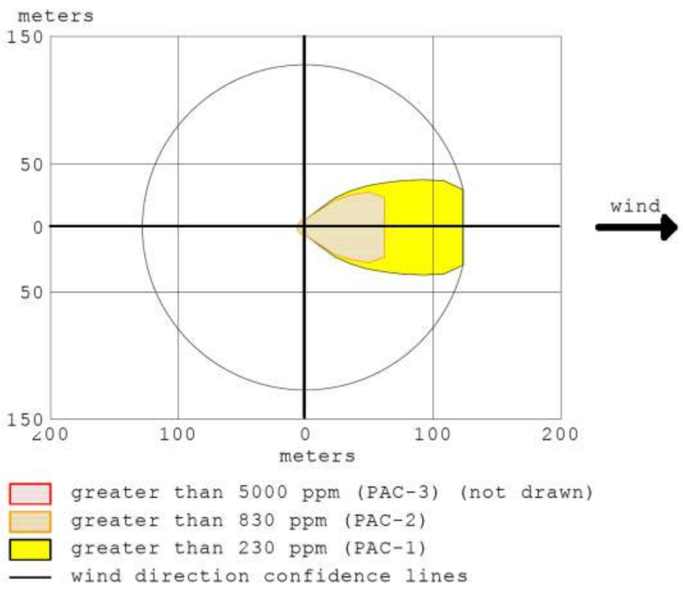

Figure 7: Flammable area of Vapor cloud for Iso-octane

Case 3: Vapor Cloud Explosion

Threat Modeled: Overpressure (blast force) from vapor cloud explosion

Type of Ignition: ignited by spark or flame

Level of Congestion: congested

Model Run: Heavy Gas

Red: LOC was never exceeded --- (8.0 psi = destruction of buildings)

Orange: 17 meters --- (3.5 psi = serious injury likely)

Yellow: 32 meters --- (1.0 psi = shatters glass)

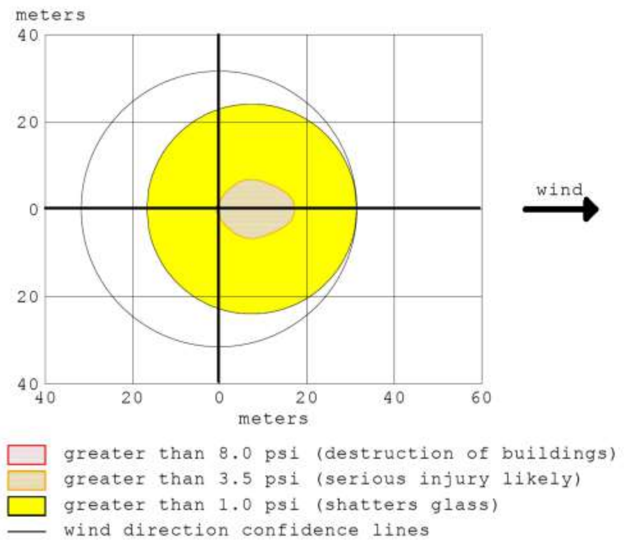

Figure 8: Thermal Radiation from Fireball for Iso-octane

B. Leaking Tank, Chemical is burning & forms a pool fire

Threat Modeled: Thermal radiation from pool fire

Red: less than 10 meters (10.9 yards) --- (10.0 kW/(sq m) = potentially lethal within 60 sec)

Orange: less than 10 meters (10.9 yards) --- (5.0 kW/(sq m) = 2nd degree burns within 60 sec)

Yellow: 13 meters --- (2.0 kW/(sq m) = pain within 60 sec)

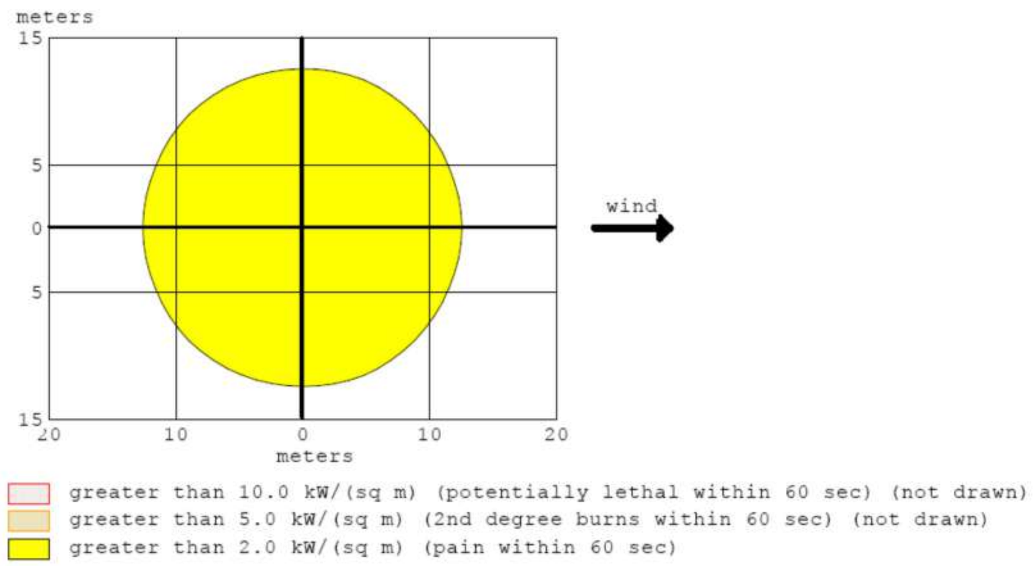

Figure 9: Thermal Radiation from Pool Fire for Iso-octane

C. BLEVE, tank explodes & chemical burns in a fireball (This is the most appropriate situation for the tanker meeting with an accident**)**

Threat Modeled: Thermal radiation from fireball

Red: 135 meters --- (10.0 kW/(sq m) = potentially lethal within 60 sec)
Orange: 190 meters --- (5.0 kW/(sq m) = 2nd degree burns within 60 sec)
Yellow: 297 meters --- (2.0 kW/(sq m) = pain within 60 sec)

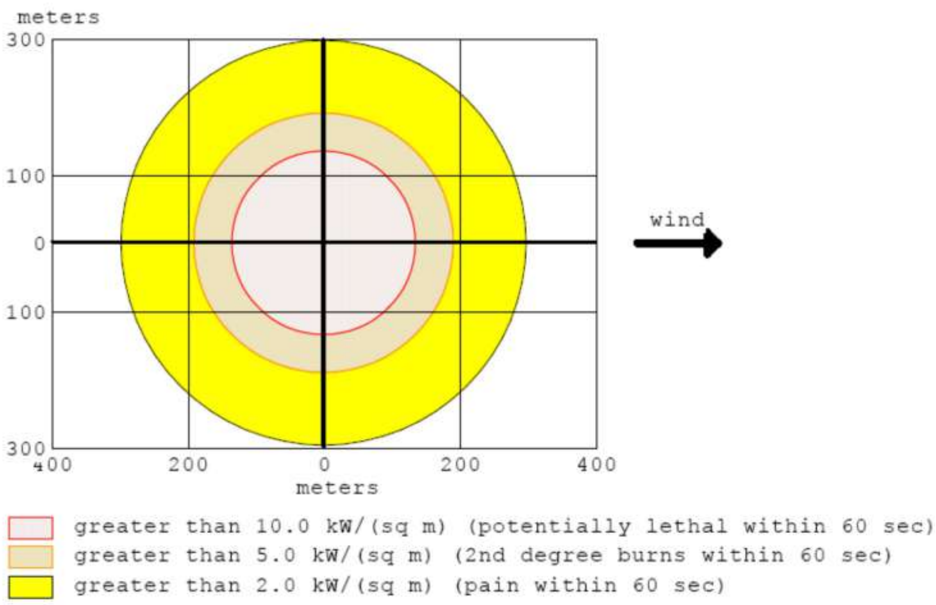

Figure 10: BLEVE, Thermal Radiation from Pool Fire for Iso-octane

Summary of ALOHA Results

The summarization of the results obtained from Risk Modelling Assessment if given in **Table 2.**

Table 2: Summarization of ALOHA Results

Situation		Affected Distance (m)		
		Red	**Orange**	**Yellow**
N- HEPTANE				
Leaking Tank, Chemical is not burning &forms an evaporating puddle	**Toxic Area of Vapor Cloud**	23	62	80
	Flammable Area of Vapor Cloud	23	62	80
	Blast: Vapor Cloud Explosion	0	16	28
Leaking Tank, Chemical is burning & forms a pool fire.	**Thermal radiation**	<10	<10	13
BLEVE, tank explodes & Chemical burns in a fireball.	**Thermal radiation**	134	190	296
ISO-OCTANE				
Leaking Tank, Chemical is not burning & forms an evaporating puddle	**Toxic Area of Vapor Cloud**	24	62	124
	Flammable Area of Vapor Cloud	24	62	124
	Blast: Vapor Cloud Explosion	0	17	32
Leaking Tank, Chemical is burning & forms a pool fire	**Thermal radiation**	<10	<10	13
BLEVE, tank explodes& Chemical burns in a fireball.	**Thermal radiation**	135	190	297

Conclusion: As per the result obtained from ALOHA, it has been interpreted that the worst case scenario will be an accident scenario causing *explosion of tank and the chemical will burn in a fireball (BLEVE).* The effect of this scenario will be up to a distance of *297 m (say 300 m from the place of accident)*. Therefore it requires immediate evacuation of population say up to 300 m and provides immediate medical facilities for injured persons as mentioned in Disaster Management Plan.

Consequences Analysis for Failure Scenarios of High Speed Diesel Storage (HSD)

The Vijayawada Airport has an existing diesel storage facility of capacity 3x990 litres which will cater to the need of expansion. It has been envisaged that risk may arise from handling and storage of HSD and the extent of risk involved has been worked out in the report by calculating the Fire and Explosion Index and the distance to be affected in case of fire due to heat radiation. DOW Fire and Explosion

Index was calculated for the proposed project to access the affected distance and following assumptions are kept in mind:

- The three tanks, at full capacity, store 2471 kg of HSD having heat value of 19300 BTU/lb.
- Since HSD is liquid at room temperature, the operating pressure has been considered to be 1 atm (14.6959 psig).
- The location of the tanks is well accessible for the authorities.
- In case of accident, the tanks may rupture causing discharge of flammable substances, spreading into a pool and the pool catching fire.
- There will be black soot at the top of flame and hence only the bottom portion of flame will cause heat radiation
- The tank is well accessible. However, for conservative scenario, it is assumed that it can face material handling related leaks and spills take place.
- The MF, Nf and Nr are obtained from list of Material Factors and Properties as per NFPA Classification.

The material factor has been determined as follows

MATERIAL FACTOR DETERMINATION GUIDE

Liquids & Gases Flammability or Combustibility[1]	NFPA 325M or 49	Reactivity or Instability				
		$N_R = 0$	$N_R = 1$	$N_R = 2$	$N_R = 3$	$N_R = 4$
Non-combustible[2]	$N_F = 0$	1	14	24	29	40
F.P. > 200 °F (> 93.3 °C)	$N_F = 1$	4	14	24	29	40
F.P. > 100 °F (> 37.8 °C) ≤ 200 °F (≤ 93.3 °C)	$N_F = 2$	10	14	24	29	40
F.P. ≥ 73 °F (≥ 22.8 °C) < 100 °F (< 37.8 °C) or F.P. < 73 °F (< 22.8 °C) & BP. ≥ 100 °F (≥ 37.8 °C)	$N_F = 3$	16	16	24	29	40
F.P. < 73 °F (< 22.8 °C) & B.P. < 100 °F (< 37.8 °C)	$N_F = 4$	21	21	24	29	40
Combustible Dust or Mist[3]						
St-1 (K_{St} ≤ 200 bar m/sec)		16	16	24	29	40
St-2 (K_{St} = 201-300 bar m/sec)		21	21	24	29	40
St-3 (K_{St} > 300 bar m/sec)		24	24	24	29	40
Combustible Solids						
Dense > 40 mm thick[4]	$N_F = 1$	4	14	24	29	40
Open < 40 mm thick[5]	$N_F = 2$	10	14	24	29	40
Foam, fiber, powder, etc.[6]	$N_F = 3$	16	16	24	29	40

F.P. = Flash Point, closed cup B.P. = Boiling Point at Standard Temperatures and Pressure (STP)

After this the Fire & Safety Index has been calculated from the following:

FIRE & EXPLOSION INDEX

AREA / COUNTRY: India	DIVISION: Disaster Mgmt	LOCATION: Vijayawada	DATE: 11.9.2019
SITE: Airport	MANUFACTURING UNIT	PROCESS UNIT	
PREPARED BY: GCPL	APPROVED BY: (Superintendent)	BUILDING	
REVIEWED BY: (Management)	REVIEWED BY: (Technology Center)	REVIEWED BY: (Safety & Loss Prevention)	
MATERIALS IN PROCESS UNIT			
STATE OF OPERATION: __ DESIGN __ START UP ✓ NORMAL OPERATION __ SHUTDOWN	BASIC MATERIAL(S) FOR MATERIAL FACTOR: Diesel (HSD)		

	Penalty Factor Range	Penalty Factor Used(1)
MATERIAL FACTOR (See Table 1 or Appendices A or B) Note requirements when unit temperature over 140 °F (60 °C)		
1. General Process Hazards		
Base Factor	1.00	1.00
A. Exothermic Chemical Reactions	0.30 to 1.25	0
B. Endothermic Processes	0.20 to 0.40	0
C. Material Handling and Transfer	0.25 to 1.05	1.0
D. Enclosed or Indoor Process Units	0.25 to 0.90	0
E. Access	0.20 to 0.35	0.2
F. Drainage and Spill Control ______ gal or cu.m.	0.25 to 0.50	0.5
General Process Hazards Factor (F_1)		1.7
2. Special Process Hazards		
Base Factor	1.00	1.00
A. Toxic Material(s)	0.20 to 0.80	0
B. Sub-Atmospheric Pressure (< 500 mm Hg)	0.50	0.5
C. Operation In or Near Flammable Range ___ Inerted ___ Not Inerted		
1. Tank Farms Storage Flammable Liquids	0.50	0.5
2. Process Upset or Purge Failure	0.30	0
3. Always in Flammable Range	0.80	0
D. Dust Explosion (See Table 3)	0.25 to 2.00	0
E. Pressure (See Figure 2) Operating Pressure 14.69 psig or ~~kPa~~ gauge; Relief Setting ______ psig or kPa gauge		0.18
F. Low Temperature	0.20 to 0.30	0
G. Quantity of Flammable/Unstable Material: Quantity 2471 lb or kg; H_C = 19300 BTU/lb or kcal/kg		
1. Liquids or Gases in Process (See Figure 3)		0
2. Liquids or Gases in Storage (See Figure 4)		0.16
3. Combustible Solids in Storage, Dust in Process (See Figure 5)		0
H. Corrosion and Erosion	0.10 to 0.75	0.2
I. Leakage – Joints and Packing	0.10 to 1.50	0.2
J. Use of Fired Equipment (See Figure 6)		0
K. Hot Oil Heat Exchange System (See Table 5)	0.15 to 1.15	0
L. Rotating Equipment	0.50	0
Special Process Hazards Factor (F_2)		2.74
Process Unit Hazards Factor ($F_1 \times F_2$) = F_3		4.658
Fire and Explosion Index ($F_3 \times MF$ = F&EI) 4.658X16		74.5

(1) For no penalty use 0.00.

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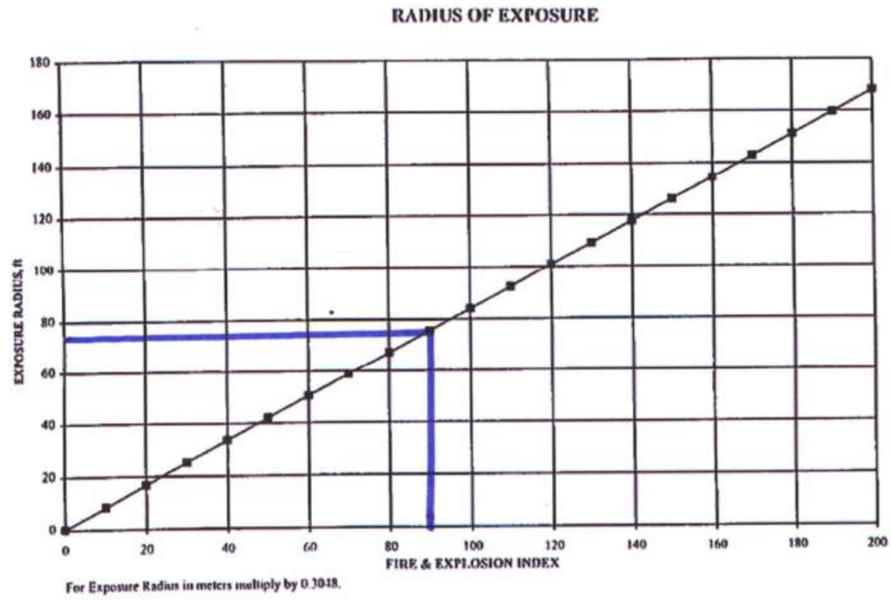
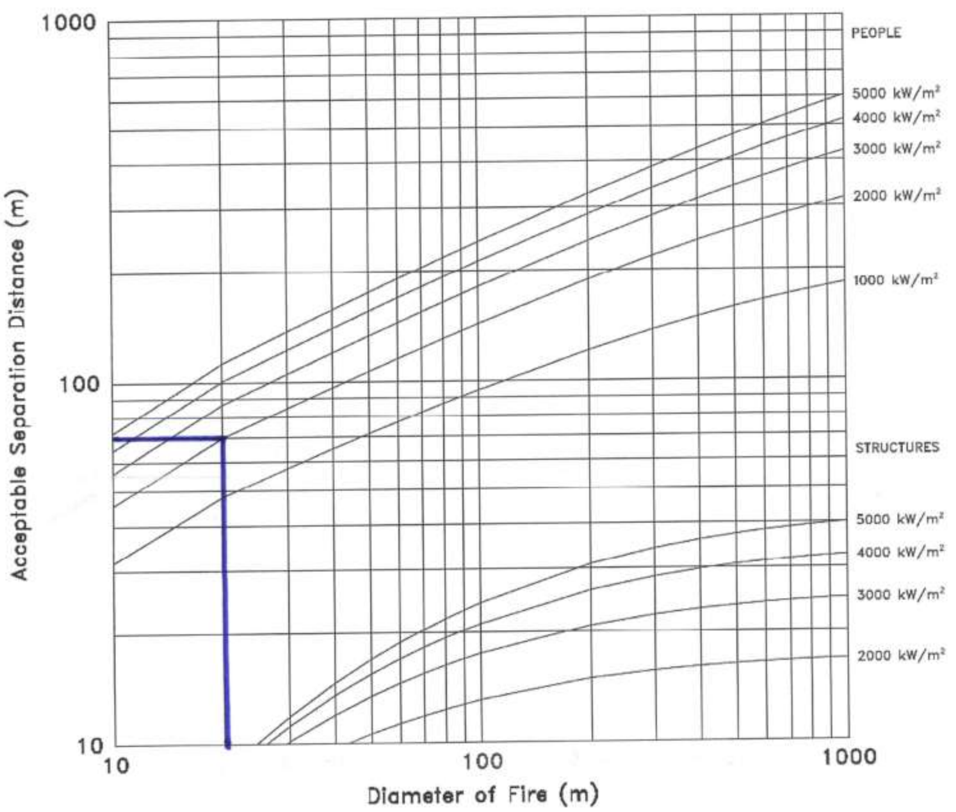
The F& I index value came out to be 75 and produces an area of exposure up to 65 feet i.e. 19.8 m (say 20 m) as shown in **Figure** below.



From a heat radiation model, the acceptable separation distance of 70 m has been worked out as given in figure below:



Heat Radiation index of 1500 kW/m^2 is used for HSD. F&EI of 75 is considered as moderate damage as given below:

F & E INDEX Range	Degree of Hazard
1-60	Light
61-96	Moderate
97-127	Intermediate
128-158	Heavy
159-up	Severe

This indicates that people residing in area up to 70 m from the periphery of fire, i.e. 80 m from centre of tank will be exposed to unacceptable heat radiation and must be evacuated in case of a fire.