Quantitative Risk Assessment for

Guru Gobind Singh Refinery, HMEL Bathinda

1. Scope and Objective of the Study

The objective of this QRA study is:

- The consequence analysis of the worst case scenarios
- Individual and societal risk quantification and contour mapping.
- Evaluation of risk against the risk Acceptance Criteria
- Suggest risk reduction and mitigation measures for prevention and control of accidents to reduce the Risk.

2. QRA Methodology

The QRA is carried out by identifying the hazards, using both installation specific and industry standard data to estimate the likelihood of hazardous events and using mathematical models to calculate the consequences (in terms of fire size, explosion overpressure etc.) of the scenarios.

Risk Assessment Study will comprise of the following steps/ activities:

System Description

This step deals with defining the system under consideration. In order to achieve the desired capacity of 11.25MMTPA the existing process units, utilities & off sites need to be augmented / debottlenecked. In addition, some new facilities are being added to improve the profitability of the refinery. Facilities that are planned to be modified/debottlenecked are provided below along with proposed new facilities.

A.) Process units in which critical equipment modification will occur. These include process units, viz, CDU/VDU, NHT, DHDT, VGO- HDT, DCU, ARU & SWS-I, II

B.) A new Sulphur Recovery Unit (1 X300TPD)

C.) Proposed storage facilities

D.) A new Bitumen Blowing Unit (1x0.5 MMTPA)

Hazard Identification

This step deals with identification of possible hazards. The potential Loss of Containment scenarios has been considered for the following facilities:

A.) Process units in which critical equipment modification will occur. These include process units, viz, CDU/VDU, NHT, DHDT, VGO- HDT, DCU, ARU & SWS-I, II

B.) A new Sulphur Recovery Unit (1 X300TPD)

C.) Proposed storage facilities

Since Bitumen is a complex black solid consisting of high molecular weight organic compounds with carbon numbers greater than C25 and high carbon to hydrogen ratios, it is relatively stable and unlikely to react in a hazardous manner. As bitumen is a solid at ambient temperature, it is normally handled and stored at temperatures above 100 ^{o}C. Therefore, contact with hot bitumen is a potential burn hazard. Bitumen's normal boiling point and flash point are both above 250^{o}C, hence the possibility of fire hazard is relatively low & only localized impact will occur. Consequentially, the risk level posed by bitumen blowing unit will have insignificant contribution in the overall risk level of the proposed project. Hence, no credible scenario or major accident event associated with handling of residues has been identified at the BBU facility.

Consequence Analysis

Consequence assessment is conducted to understand the impact of identified scenarios in terms of Thermal radiation (Jet fire, Pool Fire), Explosion (vapor cloud explosion). Software model PHAST RISK Micro V 6.7 developed by DNV is used in this step. The following models for thermal radiation, explosion will be considered:

a. Flash Fire
b. Vapour cloud explosion (VCE)
c. BLEVE

Impact Assessments

This step deals with calculating the impacts of potential fire and explosion hazards associated with the scenarios. Software model PHAST RISK Micro V 6.7, developed by DNV, will be used to calculate the impacts of fire and explosion hazards. It enables the user to assess the physical effects of accidental releases of toxic or flammable chemicals.

Frequency Analysis

This step deals with determining how often – in terms of frequency per year – fire, explosion & toxic hazards can likely to occur. The likelihood of occurrence of the identified hazardous scenarios is assessed by reviewing historical industry accident data.

In this study the historical data available in international renowned databases will be used. The same are listed below:

1. Reference Manual Bevi Risk Assessments version 3.2, Netherlands
2. CPR 18E – Committee for Prevention of Disasters, Netherlands

Risk Calculation

This step involves calculating risk considering both severity of the consequences of an identified hazard and the probability of its occurrence.

Risk = Likelihood of Occurrences X Severity of Consequences

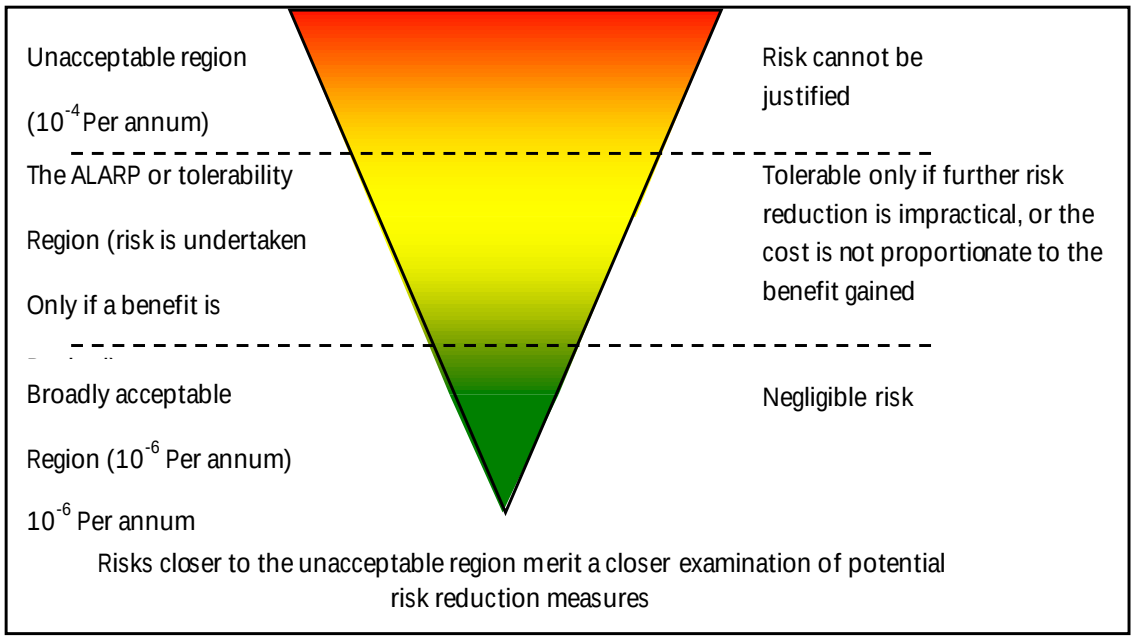
Risk will be calculated using software PHAST RISK Micro V 6.7 by DNV. This software will receive input from the Frequency Analysis and Impact Assessment Tasks. Risk is measured in various ways and presented numerically and graphically.

Risk Assessment

This step deals with comparing the calculated risk with the standard values. For this project UK HSE risk acceptance criteria will be followed which is as below:

Authority and Application	Maximum Tolerable Risk (Per Year)	Negligible Risk (Per Year)
VROM, The Netherlands (New)	1.0E-06	1.0E-08
VROM, The Netherlands (existing)	1.0E-05	1.0E-08
HSE, UK (existing hazardous industry)	1.0E-04	1.0E-06
HSE, UK (New nuclear power station)	1.0E-05	1.0E-06
HSE, UK (Substance transport)	1.0E-04	1.0E-06
HSE, UK (New housing near plants)	3 x 1.0E-06	3 x 1.0E-07
Hong Kong Government (New plants)	1.0E-05	Not used

HSE, UK for existing hazardous industry highlighted in the above table is used for the study.



Note: People inside industry will have 10 times higher Risk than Social people

Risk Tolerable

Risk mitigation is a decision making process based on the comparison of the risk calculated and predefined risk criteria. This comparative analysis would results in outcomes:

- The risk is below as low as reasonably practicable (ALARP) level, then the risk is tolerable and no further actions are required,
- The risk falls in the ALARP region, which requires efforts to reduce further, (it would not be economically feasible to reduce the risk further), and
- The risk is above the ALARP region, which requires design modifications to reduce the risk to, at minimum, to the ALARP region.

Findings

This step deals with reporting the findings of QRA study. If the risk calculated is not tolerable, the final report will provide specific technical recommendations to bring down the risk level or if the risk calculated is in ALARP zone, recommendations will be provided the further bring sown the risk level.

Presentation of risk results

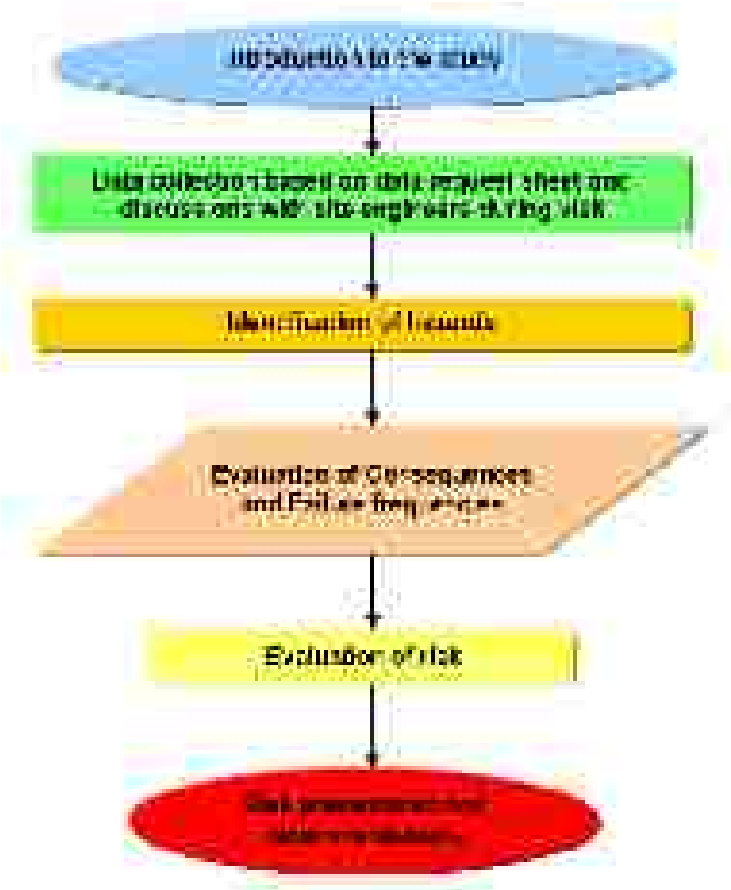
In the present study, risks to people are expressed in two complementary forms:

Individual Risk – the risk experienced by an individual person.

Societal Risk – the risk experienced by the whole group of people exposed to the hazard.

The individual risk and societal risks are calculated based on the consequence, base event frequency, ignition probability, population density in the area, weather conditions etc.

Overview of Risk Assessment Methodology



3. Data used and Assumptions made for the study

a. Scenarios

As per CPR 18E - Guidelines for Quantitative Risk Assessment, developed by the Committee for the Prevention of Disasters, Netherlands, for each of scenario two leak sizes i.e., hole sizes are considered for analysis,

For Pipelines

- Leak – Leak size 10% of the pipeline diameter
- Rupture – Actual diameter of the Pipe

For storage tanks

- Leak – Leak size 10 mm
- Catastrophic Rupture

The following table present the potential initiating events and credible accident scenarios identified and quantitatively analysed:

Table 1 – List of Hazardous Scenario Identified

S No	Scenario	Leak Size	Pressure (Kg/cm2 g)	Temp (^{0} C)
(A) PROCESS UNITS IN WHICH CRITICAL EQUIPMENT MODIFICATION WILL OCCUR				
CDU(Crude Distillation Unit)/ VDU (Vacuum Distillation Unit)				
1.	Release from discharge line of Pre- flashed Crude pump(501-P-104)	10	31.1	159.9
		CR	31.1	159.9
NHT Unit (Naphtha Hydro treating Unit)				
2.	Release from Second Hydro-treating Reactor (502-R-002)	10	30	263
		CR	30	263
3.	Release from Stripper Reflux Drum (502-V-004)	CR	17.7	40
DHDT(Diesel Hydro treating Unit)				
4.	Release from Hot HP Separator (507-V-003)	10	62.6	270
		CR	62.6	270
FCC - PC Unit				
5.	Release from Reactor (510-R-001)	10	1.69	104
		CR	1.69	104
VGO- HDT Unit				
6.	Release from discharge line of Hydrogen Compressors (509-K-002)	10	94.7	118.3
		CR	94.7	118.3
Delayed Coker Unit (DCU)				
7.	Release from discharge line of LPG product pump (508-P-028 A/B)	10	25.9	41.6
		CR	25.9	41.6
Amine Regeneration unit (ARU)				
8.	Release from Amine Regenerator Reflux Drum (522-V-102)	10	1.7	55.01
		CR	1.7	55.01
Sour Water Separator (SWS - I & II)				
9.	Release from Sour Water Surge drum (520-V-101)	CR	6.03	48
(B) A NEW SULPHUR RECOVERY UNIT (1 X300TPD)				
10.	Release from ARU Acid Gas KO Drum (524-V-001)	10	0.7	55
		CR	0.7	55
11.	Release from fuel gas line to Incinerator burner (524-LZ-004)	10	1.5	30
		CR	1.5	30
12.	Release from Hydrogen make up line to Hydrogenation heater (524-E-101)	10	0.7	40
		CR	0.7	40
(C) PROPOSED STORAGE FACILITIES				
Crude storage tanks				
13.	Release from Crude Storage Tank	CR	Atmospheric	Ambient
Intermediate feed tanks				
14.	Release from Sour diesel Tank	CR	Atmospheric	Ambient
Finished product storage tanks				
15.	Release from MS-III Tank	CR	Atmospheric	Ambient

16.	Release from Naphtha Tank	CR	Atmospheric	Ambient
17.	Release from HSD Tank	CR	Atmospheric	Ambient
18.	Release from Sweet SKO Tank	CR	Atmospheric	Ambient
LPG Mounded Bullets				
19.	Release from LPG mounded bullet	CR	7	Ambient
CFBC & BBU (Bitumen Blowing Unit)				
20.	Release from BBU	CR	Atmospheric	100

Since Bitumen is a complex black solid consisting of high molecular weight organic compounds with carbon numbers greater than C25 and high carbon to hydrogen ratios, it is relatively stable and unlikely to react in a hazardous manner. As bitumen is a solid at ambient temperature, it is normally handled and stored at temperatures above 100 ^{o}C. Therefore, contact with hot bitumen is a potential burn hazard. Bitumen's normal boiling point and flash point are both above 250^{o}C, hence the possibility of fire hazard is relatively low & only localized impact will occur. Consequentially, the risk level posed by bitumen blowing unit will have insignificant contribution in the overall risk level of the proposed project. Hence, no credible scenario or major accident event associated with handling of residues has been identified at the BBU facility.

b. Metrological Data

Ambient Temperature: 30 deg C

Humidity: 70%

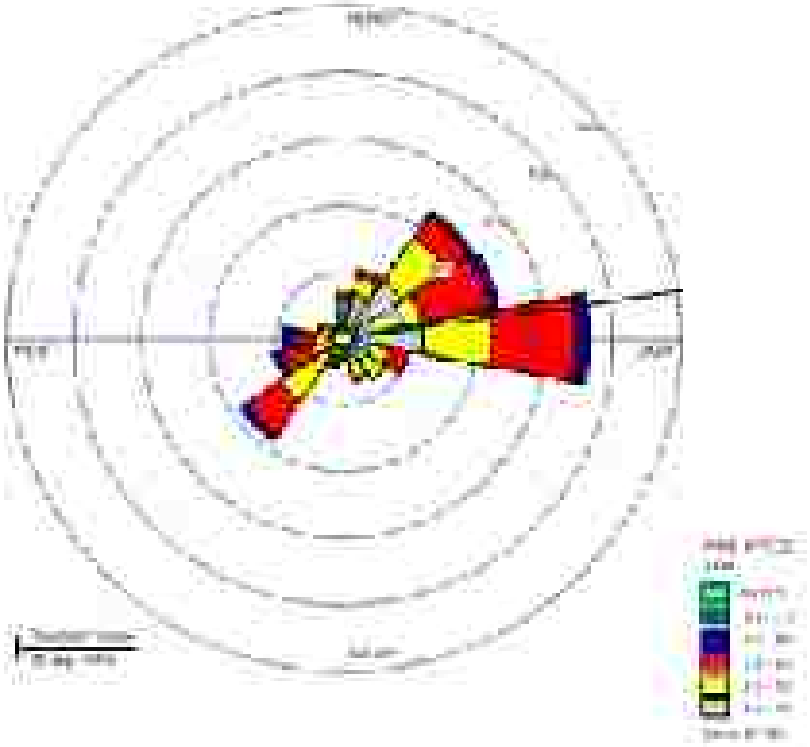
Surface Roughness: 30 mm

Solar Radiation: 0.5 kW/m^2

The following wind speed and stability class are considered for the study

Wind Speed (m/s)	Stability Class	Description
1.5	F	This is typical of during night time with low wind speed.
5	D	This is typical of day time situation, with moderate wind fluctuations

Location-specific Wind Rose Diagram



c. Failure Frequencies

For this study the failure data is taken from CPR 18E – Guidelines for Quantitative Risk Assessment, developed by the Committee for the Prevention of Disasters, Netherlands.

Internal domino effects are not explicitly covered in QRA. An internal domino needs to be considered only in case of a situation in which the failure of one component clearly leads to the failure of another component. In Such cases contents of the biggest vessel / tank needs to be taken for Instantaneous failure.

Table 2 – Failure Frequency

S.No	Scenarios	Leak Size	Failure Frequency (per year)
(A)	PROCESS UNITS IN WHICH CRITICAL EQUIPMENT MODIFICATION WILL OCCUR		
CDU (Crude Distillation Unit)/ VDU (Vacuum Distillation Unit)			
1.	Release from discharge line of Pre- flashed Crude pump(501-P-104)	10	3.5E-05
		CR	7.0E-06
NHT Unit (Naphtha Hydrotreating Unit)			
2.	Release from Second Hydro-treating Reactor (502-R-002)	10	1.0E-04
		CR	5.0E-06

3.	Release from Stripper Reflux Drum (502-V-004)	CR	5.0E-06
DHDT(Diesel Hydro treating Unit)			
4.	Release from Hot HP Separator (507-V-003)	10	1.0E-04
		CR	5.0E-06
FCC - PC Unit			
5.	Release from Reactor (510-R-001)	10	1.0E-04
		CR	5.0E-06
VGO- HDT Unit			
6.	Release from discharge line of Hydrogen Compressors (509-K-002)	10	4.1E-05
		CR	8.1E-06
Delayed Coker Unit			
7.	Release from discharge line of LPG product pump (508-P-028 A/B)	10	1.8E-04
		CR	2.7E-05
Amine Regeneration unit			
8.	Release from Amine Regenerator Reflux Drum (522-V-102)	10	1.0E-04
		CR	5.0E-06
Sour Water Separator (SWS - I & II)			
9.	Release from Sour Water Surge drum (520-V-101)	CR	5.0E-06
(B)	A NEW SULPHUR RECOVERY UNIT (1 X300TPD)		
10.	Release from ARU Acid Gas KO Drum (524-V-001)	10	1.0E-04
		CR	5.0E-06
11.	Release from fuel gas line to Incinerator burner (524-LZ-004)	10	2.5E-04
		CR	5.0E-05
12.	Release from Hydrogen make up line to Hydrogenation heater (524-E-101)	10	7.6E-04
		CR	1.5E-04
(C)	PROPOSED STORAGE FACILITIES		
Crude storage tanks			
13.	Release from Crude Storage Tank	CR	5.00E-06
Intermediate feed tanks			
14.	Release from Sour diesel Tank	CR	5.00E-06
Finished product storage tanks			
15.	Release from MS-III Tank	CR	5.00E-06
16.	Release from Naphtha Tank	CR	5.00E-06
17.	Release from HSD Tank	CR	5.00E-06
18.	Release from Sweet SKO Tank	CR	5.00E-06
LPG Mounded Bullets			
19.	Release from LPG mounded bullet	CR	5.00E-07

Legends: CR – Catastrophic Rupture

d. Immediate Ignition Probability

Considering chemical category, immediate ignition probability are used for study

Substance category	Source term Continuous	Source term Instantaneous	Probability of direct ignition
Category 0 average/high reactivity	< 10 kg/s 10 – 100 kg/s > 100 kg/s	< 1000 kg 1000 – 10,000 kg > 10,000 kg	0.2 0.5 0.7
Category 0 low reactivity	< 10 kg/s 10 – 100 kg/s > 100 kg/s	< 1000 kg 1000 – 10,000 kg > 10,000 kg	0.02 0.04 0.09
Category 1	All flow rates	All quantities	0.065
Category 2	All flow rates	All quantities	0.01
Category 3, 4	All flow rates	All quantities	0

Category 0 : Extremely Flammable

Category 1 : Highly Flammable

Category 2 : Flammable

Category 3, 4 : Combustible

LPG, Propane: 0.7

HSD, SKO, Naphtha and Heavy cut: 0.065

e. Delayed Ignition Probability

Delayed Ignition is considered due to plant persons and due to adjacent process facility.

Source type	Ignition source	Probability of ignition
Point source	Adjacent process installation Flare Oven (outside) Oven (inside) Boiler (outside) Boiler (inside)	0.5 1.0 0.9 0.45 0.45 0.23
Line source	high-voltage cable (per 100 m) Motor vehicle, train Ship	0.2 see note 0.5
Population source	Households (per person) Offices (per person)	0.01 0.01

f. Explosion Probability

The ignition of a free gas cloud, an incident occurs demonstrating characteristics of both a flash fire and an explosion. This is modelled as two separate events: as a pure flash fire and a pure explosion. The fraction that is modelled as an explosion is equal to 0.4.

g. Population Data

Population within the facility:

Onsite Population Details		
Sr. No.	Unit	Population
1	PPU	7
2	PPU Warehouse	53
3	Security Gate	3
4	Fire water station	13
5	Workshop	160
6	CPP	55
7	Nitrogen plant +cooling tower	6
8	Coke Yard	31
9	HGU	10
10	Admin. Building	120
11	Water Block(RWTP+RO+Solar Pond)	45
12	Treater Unit	5
13	RACR	1
14	ROCR	1
15	PCR	1
16	OMSCR+Related tankages	13
17	ETP	5
18	Main Control Room(MCR)	30
19	Lab Building	57
20	Training	5
21	Canteen	64
23	Warehouse	70
24	Y-shaped office building (Site office)	15
25	Crude Receiving Terminal	6
	Refinery Main Gate	25
27	Gate -2 (G2)	5
28	Gate -3 (G3)	5
29	Gate -4 (G4)	5
30	Gate -5 (G5)	5
31	Main Gate	25
32	Welfare centre	10
33	Security Command Control	5
34	Marketing Time Office	18
35	SRU/ SWS/ ARU complex	6
36	MS Block	9
37	CDU/ VDU Unit	5
38	DHDT	3
39	VGO- HDT	4
40	FCC-PC	13
41	DCU	9
43	Road Day Tanks- Tank Farm 33	20

Population around the facility

S. No.	Village Name	No. of People
1.	HMEL Township Population	1334
2	Naurang ~1.0 km in W	2217
3	Kanakwal	500

h. Blocking systems:

The blocking systems are used to limit the released quantity following a LOC. A blocking system consists of a detection system (ex; gas detection, hydrocarbon detection, etc) combined with shut-off valves. The shut-off valves can be closed automatically or manually. Blocking systems are further classified into Automatic, semi-automatic & non-automated (Manual) system.

For this study Semi Automatic blocking system is assumed. Considering the leak detection takes place using DCS system automatically and leads to an alarm signal in a continuously staffed control room and the operator closes the MOVs by actuating a switch in the control room. The probability of failure per operation is equal to 0.01; the time required for closing the blocking valves is equal to 10 minutes.

Consequence Assessment:

Accidental release of flammable liquids / gases and toxic gases can result in severe consequences. Delayed ignition of flammable gases can result in blast overpressures covering large areas. This may lead to extensive loss of life and property. In contrast, fires have localized consequences. Fires can be put out or contained in most cases; there are few mitigating actions one can take once a flammable gas or a vapour cloud gets released. Major accident hazards arise, therefore, consequent upon the release of flammable gases.

The effect of fire on a human being is in the form of burns. There are three categories of burn such as first degree, second degree and third degree burns. The consequences caused by exposure to heat radiation are a function of:

- The radiation energy onto the human body [kW/m2];
- The exposure duration [sec];
- The protection of the skin tissue (clothed or naked body).
- The lethality of a pool fire is assumed to be 100% for the people who are caught in the flame. Outside the flame area, the lethality depends on the heat radiation distances.

The limits for 1% of the exposed people to be killed due to heat radiation, and for second-degree burns are given in the table below (Reference from Guidelines for Hazard Evaluation Procedures, Centre for Chemical Process Safety, American Institute of Chemical Engineers)

Exposure Duration	Radiation energy (1% lethality, kW/m^2	Radiation energy for 2^{nd} degree burns, kW/m^2	Radiation energy for first degree burns, kW/m^2
10 Sec	21.2	16	12.5
30 Sec	9.3	7.0	4.0

Table 3 – Damages to Human Life Due to Heat Radiation

Incident Radiation (kW/m^2)	Type of Damage
0.25-0.7	Equivalent to Solar Radiation
1.6	No discomfort for long exposure
4.0	Sufficient to cause pain within 20 sec. Blistering of skin (first degree burns are likely)
9.5	Pain threshold reached after 8 sec. second degree burns after 20 sec.
12.5	Minimum energy required for piloted ignition of wood, melting plastic tubing etc.
37.5	Heavy Damage to process equipments

Table 4 – Effects Due To Incident Radiation Intensity

Consequence Analysis:

Inventory Used for the Risk Assessment study is as below.

S.No	Scenarios	Leak Size	Inventory (m3)
A.	PROCESS UNITS IN WHICH CRITICAL EQUIPMENT MODIFICATION WILL OCCUR		
CDU (Crude Distillation Unit)/ VDU (Vacuum Distillation Unit)			
1.	Release from discharge line of Pre- flashed Crude pump(501-P-104)	10	101
		CR	6836
NHT Unit (Naphtha Hydrotreating Unit)			
2.	Release from Second Hydro-treating Reactor (502-R-002)	10	455
		CR	4553
3.	Release from Stripper Reflux Drum (502-V-004)	CR	148
DHDT(Diesel Hydro treating Unit)			
4.	Release from Hot HP Separator (507-V-003)	10	8
		CR	82
FCC - PC Unit			
5.	Release from Reactor (510-R-001)	10	193
		CR	1927
VGO- HDT Unit			
6.	Release from discharge line of Hydrogen Compressors (509-K-002)	10	87
		CR	4299
Delayed Coker Unit			
7.	Release from discharge line of LPG product pump (508-P-028 A/B)	10	2
		CR	52
Amine Regeneration unit			
8.	Release from Amine Regenerator Reflux Drum (522-V-102)	10	0.52
		CR	5.2
Sour Water Separator (SWS - I & II)			
9.	Release from Sour Water Surge drum (520-V-101)	CR	335.25
B.	A NEW SULPHUR RECOVERY UNIT (1 X300TPD)		
10.	Release from ARU Acid Gas KO Drum (524-V-001)	10	2.22
		CR	22.2
11.	Release from fuel gas line to Incinerator burner (524-LZ-004)	10	36
		CR	453
12.	Release from Hydrogen make up line to Hydrogenation heater (524-E-101)	10	37
		CR	453

C.	PROPOSED OFFSITE STORAGE FACILITIES		
Crude storage tanks			
13.	Release from Crude Storage Tank	CR	60000
Intermediate feed tanks			
14.	Release from Sour diesel Tank	CR	20000
Finished product storage tanks			
15.	Release from MS-III Tank	CR	9000
16.	Release from Naphtha Tank	CR	9000
17.	Release from HSD Tank	CR	55000
18.	Release from Sweet SKO Tank	CR	4500
LPG Mounded Bullets			
19.	Release from LPG mounded bullet	CR	2900

Table 5 – Inventory Details

Consequence Results for Jet Fire:

S.No	Scenarios	Leak Size	Downwind Damage Distances in m					
			1.5F Weather Condition			5D Weather Condition		
			4 kW/m2	12.5 kW/m2	37.5 kW/m2	4 kW/m2	12.5 kW/m2	37.5 kW/m2
(A) PROCESS UNITS IN WHICH CRITICAL EQUIPMENT MODIFICATION WILL OCCUR								
CDU (Crude Distillation Unit)/ VDU (Vacuum Distillation Unit)								
1.	Release from discharge line of Pre- flashed Crude pump(501-P-104)	10	152.4	119.4	99.8	127.6	96.5	78.3
		CR	964.8	765.8	645.7	768.3	595.3	491.2
NHT Unit (Naphtha Hydrotreating Unit)								
2.	Release from Second Hydro-treating Reactor (502-R-002)	10	13.6	10.5	NR	13.8	11.0	NR
VGO- HDT Unit								
3.	Release from discharge line of Hydrogen Compressors (509-K-002)	10	24.7	18.1	8.5	25.8	21.7	18.2
		CR	151.4	104.6	76.5	140.0	111.2	92.5
Delayed Coker Unit								
4.	Release from discharge line of LPG product pump (508-P-028 A/B)	10	31.5	25.1	21.3	28.0	21.2	17.2
		CR	151.4	119.3	100.2	136.3	102.0	81.9

Table 6 – Consequence Distance for Jet Fire

Analysis of Results

Maximum damage due to jet fire radiations will be caused by Rupture in discharge line of Pre-flashed Crude pump (501-P-104) in CDU (Crude Distillation Unit)/ VDU (Vacuum Distillation Unit), at a weather condition of 1.5F. The jet fire radiation of 37.5 kW/m^2 (corresponding to 100% fatality) will reach up to a distance of 645.7 m at 1.5F weather condition. The jet fire radiation of 12.5 kW/m2 will reach up to a distance of 765.8 m at 1.5F weather condition. The equipments within a distance of 765.8 m will be subjected to major damage or piloted ignition of wood, melting of plastics tubings etc is possible within this distance. The jet fire radiation of 4 kW/m2 will reach up to a distance of 964 m at 1.5F weather condition. First degree burns may be caused for persons who are within 964m distance.

Consequence Results for Flash Fire:

S.No	Scenarios	Leak Size	Downwind Damage Distances in m					
			1.5F Weather Condition			5D Weather Condition		
			UFL	LFL	50%LFL	UFL	LFL	50%LFL
(A) PROCESS UNITS IN WHICH CRITICAL EQUIPMENT MODIFICATION WILL OCCUR								
CDU (Crude Distillation Unit)/ VDU (Vacuum Distillation Unit)								
1.	Release from discharge line of Pre- flashed Crude pump(501-P-104)	10	13.3	145.9	315.1	12.3	154.3	261.8
		CR	156.6	1209.9	1926.4	156.6	1507.5	2145.6
NHT Unit (Naphtha Hydro treating Unit)								
2.	Release from Second Hydro-treating Reactor (502-R-002)	10	1.0	6.1	11.7	1.0	5.0	8.2
		CR	70.5	155.6	255.9	72.7	215.1	390.7
3.	Release from Stripper Reflux Drum (502-V-004)	CR	231.2	477.6	583.1	124.4	287.1	423.6
DHDT(Diesel Hydro treating Unit)								
4.	Release from Hot HP Separator (507-V-003)	10	6.0	13.8	18.0	6.0	16.1	24.4
		CR	13.3	30.9	41.2	13.3	37.1	58.6
FCC - PC Unit								
5.	Release from Reactor (510-R-001)	10	0.4	2.0	3.6	0.4	1.7	2.7
		CR	20.1	70.6	202.9	23.0	143.2	329.8
VGO- HDT Unit								
6.	Release from discharge line of Hydrogen Compressors (509-K-002)	10	0.4	25.3	34.0	0.4	20.5	28.9
		CR	3.7	79.4	192.1	3.3	83.3	120.4
Delayed Coker Unit								
7.	Release from discharge line of LPG product pump (508-P-028 A/B)	10	3.3	17.3	55.0	3.0	11.4	28.3
		CR	22.0	217.0	379.8	19.8	149.4	209.6
Amine Regeneration unit								
8.	Release from Amine Regenerator Reflux Drum (522-V-102)	10	0.08	1.07	2.05	0.08	0.9	1.7
		CR	1.2	3.3	10	1.2	5	1.6
(B) A NEW SULPHUR RECOVERY UNIT (1 X 300TPD)								
9	Release from ARU Acid Gas KO Drum (524-V-001)	10	0.07	0.9	1.7	0.07	0.8	1.4
		CR	1.8	10	28	1.8	20	39
(C) PROPOSED OFFSITE STORAGE FACILITIES								
Crude storage tanks								
10	Release from Crude Storage Tank	CR	590.4	1717.2	2088.6	535.2	1184.1	1492.0
Finished product storage tanks								
11	Release from MS-III Tank	CR	525.2	1152.2	1401.5	413.6	831.4	1099.1

12	Release from Naphtha Tank	CR	436.6	1087.2	1331.6	362.7	765.1	998.0
13	Release from HSD Tank	CR	182.5	760.3	1150.7	219.4	686.4	989.5
14	Release from Sweet SKO Tank	CR	55.8	166.0	283.3	67.7	159.8	252.6
LPG Mounded Bullets								
15	Release from LPG mounded bullet	CR	85.1	484.3	1064.2	122.2	719.2	1143.2

Table 7 – Consequence Distance for Flash Fire

Analysis of Results

Process units

In case of Rupture of Rupture in discharge line of Pre- flashed Crude pump (501-P-104) in CDU (Crude Distillation Unit)/ VDU (Vacuum Distillation Unit), the LEL concentration is present up to a maximum downwind distance of 1209 m and UEL concentration is present up to a maximum distance of 156 m. Presence of an ignition source may lead to flash fire in this zone.

Storage Tanks

In case of Rupture of Crude Storage tank, the LEL concentration is present up to a maximum downwind distance of 1717 m and UEL concentration is present up to a maximum distance of 590 m. Presence of an ignition source may lead to flash fire in this zone.

Consequence Results for Fireball:

S.No	Scenarios	Leak Size	Downwind Damage Distances in m					
			1.5F Weather Condition			5D Weather Condition		
			4 kW/m2	12.5 kW/m2	37.5 kW/m2	4 kW/m2	12.5 kW/m2	37.5 kW/m2
(A) PROCESS UNITS IN WHICH CRITICAL EQUIPMENT MODIFICATION WILL OCCUR								
NHT Unit (Naphtha Hydrotreating Unit)								
1.	Release from Second Hydro-treating Reactor (502-R-002)	10	NR	NR	NR	NR	NR	NR
		CR	1,289	705.1	270.4	1,289.0	705.1	270.4
2.	Release from Stripper Reflux Drum (502-V-004)	CR	640.4	345.5	128.4	640.4	345.5	128.4
DHDT(Diesel Hydro treating Unit)								
3.	Release from Hot HP Separator (507-V-003)	10	162.8	88.4	37.6	162.8	88.4	37.6
		CR	345.0	189.4	83.2	345.0	189.4	83.2
FCC - PC Unit								
4.	Release from Reactor (510-R-001)	10	NR	NR	NR	NR	NR	NR
		CR	273.3	126.6	NR	273.3	126.6	NR

VGO- HDT Unit								
5.	Release from discharge line of Hydrogen Compressors (509-K-002)	10	NR	NR	NR	NR	NR	NR
		CR	252.7	NR	NR	252.7	NR	NR
Amine Regeneration unit								
9.	Release from Amine Regenerator Reflux Drum (522-V-102)	NR	NR	NR	NR	NR	NR	NR
		11.91	NR	NR	11.91	NR	NR	11.91
(B) A NEW SULPHUR RECOVERY UNIT (1 X300TPD)								
9	Release from ARU Acid Gas KO Drum (524-V-001)	NR	NR	NR	NR	NR	NR	NR
		14.59	NR	NR	14.59	NR	NR	14.59
(C) PROPOSED OFFSITE STORAGE FACILITIES								
LPG Mounded Bullets								
6.	Release from LPG mounded bullet	CR	1,173.6	632.8	214.9	1,173.6	632.8	214.9

Table 8 – Consequence Distance for Fireball

Analysis of Results

Process units

Maximum damage due to fire ball radiations will be caused Rupture of Second Hydro-treating Reactor (502-R-002) in NHT Unit (Naphtha Hydro treating Unit). The fire ball radiation of 37.5 kW/m^2 (corresponding to 100% fatality) will reach up to a distance of 270.4 m. The fire ball radiation of 12.5 kW/m2 will reach up to a distance of 705.1m. The equipments within a distance of 705.1m will be subjected to major damage or piloted ignition of wood, melting of plastics tubings etc is possible within this distance. The fire ball radiation of 4 kW/m2 will reach up to a distance of 1289 m at 1.5F weather condition. First degree burns may be caused for persons who are within 1289 m distance.

Storage Tanks

Maximum damage due to fire ball radiations will be caused Rupture of LPG mounded bullet. The fire ball radiation of 37.5 kW/m^2 (corresponding to 100% fatality) will reach up to a distance of 214 m. The fire ball radiation of 12.5 kW/m2 will reach up to a distance of 632.8m. The equipments within a distance of 632.8 will be subjected to major damage or piloted ignition of wood, melting of plastics tubings etc is possible within this distance. The fire ball radiation of 4 kW/m2 will reach up to a distance of 1173.6 m at 1.5F weather condition. First degree burns may be caused for persons who are within 1173.6 m distance.

Consequence Results for Explosion:

S.No	Scenarios	Leak Size	Downwind Damage Distances in m					
			1.5F Weather Condition			5D Weather Condition		
			0.03 bar	0.1 bar	0.2 bar	0.03 bar	0.1 bar	0.2 bar
(A) PROCESS UNITS IN WHICH CRITICAL EQUIPMENT MODIFICATION WILL OCCUR								
CDU (Crude Distillation Unit)/ VDU (Vacuum Distillation Unit)								
1.	Release from discharge line of Pre- flashed Crude pump(501-P-104)	10	482.5	383.6	346.7	413.6	325.5	292.7
		CR	2794.5	2066.5	1797.9	3085.6	2322.8	2056.0
NHT Unit (Naphtha Hydrotreating Unit)								
2.	Release from Second Hydro-treating Reactor (502-R-002)	10	19.6	14.1	12.0	NR	NR	NR
		CR	1795.7	851.8	505.1	1805.8	867.5	518.6
3.	Release from Stripper Reflux Drum (502-V-004)	CR	1347.4	896.8	735.5	879.3	539.3	454.0
DHDT(Diesel Hydro treating Unit)								
4.	Release from Hot HP Separator (507-V-003)	10	135.8	63.7	36.8	161.4	80.3	50.1
		CR	403.8	189.4	109.6	398.7	188.0	113.9
FCC - PC Unit								
5.	Release from Reactor (510-R-001)	10	NR	NR	NR	NR	NR	NR
		CR	489.7	237.5	143.6	510.8	252.2	209.2
VGO- HDT Unit								
6.	Release from discharge line of Hydrogen Compressors (509-K-002)	10	71.7	47.8	38.9	54.5	34.7	27.3
		CR	405.8	282.0	236.0	309.9	201.0	160.4
Delayed Coker Unit								
7.	Release from discharge line of LPG product pump (508-P-028 A/B)	10	74.5	60.5	55.2	38.4	27.9	23.9
		CR	634.4	482.8	426.3	377.4	275.6	237.8
(B) PROPOSED OFFSITE STORAGE FACILITIES								
Crude storage tanks								
8.	Release from Crude Storage Tank	CR	4244.8	2972.8	2522.5	3510.9	2236.7	1801.5
Finished product storage tanks								
9.	Release from MS-III Tank	CR	3032.3	2069.7	1722.8	2519.1	1571.2	1267.9
10.	Release from Naphtha Tank	CR	2855.7	1953.5	1636.3	2348.3	1465.8	1177.6
11.	Release from HSD Tank	CR	1891.9	1408.5	1259.4	1767.5	1197.6	1032.6
12.	Release from Sweet SKO Tank	CR	550.4	370.9	316.2	549.8	331.6	268.1
LPG Mounded Bullets								
13.	Release from LPG mounded bullet	CR	1789.6	1015.6	923.5	1838.6	1211.9	1117.4

Table 9 – Consequence Distance for Explosion

Analysis of Results

Process units

The maximum damage can be felt in case of Rupture of discharge line of Pre- flashed Crude pump (501-P-104) in CDU (Crude Distillation Unit)/ VDU (Vacuum Distillation Unit). An overpressure of 0.3 bar can be felt up to a distance of 1797.9 m, equipment within this distance can suffer permanent damage, and it can also cause a lethality of around 50% for persons who are within this distance. An overpressure of 0.10 bar can be felt up to a distance of 2066.5 m; equipment within this range can suffer repairable damages.

An overpressure of 0.03 bars can be felt up to a distance of 2794.5 m which leads to shattering of glass etc.

Storage Tanks

The maximum damage can be felt in case of Rupture of crude storage tank. An overpressure of 0.3 bar can be felt up to a distance of 2522.5 m, equipment within this distance can suffer permanent damage, and it can also cause a lethality of around 50% for persons who are within this distance. An overpressure of 0.10 bar can be felt up to a distance of 2972.8m; equipment within this range can suffer repairable damages.

An overpressure of 0.03 bars can be felt up to a distance of 4244.8 m which leads to shattering of glass etc.

Consequence Results for Pool Fire:

S.No	Scenarios	Leak Size	Downwind Damage Distances in m					
			1.5F Weather Condition			5D Weather Condition		
			4 kW/m2	12.5 kW/m2	37.5 kW/m2	4 kW/m2	12.5 kW/m2	37.5 kW/m2
(A) PROCESS UNITS IN WHICH CRITICAL EQUIPMENT MODIFICATION WILL OCCUR								
1.	Release from Stripper Reflux Drum (502-V-004)	CR	139.4	69.1	NR	178.1	68.2	NR
(B) PROPOSED OFFSITE STORAGE FACILITIES								
Crude storage tanks								
2.	Release from crude storage tank	CR	596.4	369.2	221.4	608.7	390.9	258.4
Finished product storage tanks								
3.	Release from MS-III Tank	CR	141.4	69.9	NR	184.9	70.5	NR
4.	Release from Naphtha Tank	CR	550.3	339.4	201.0	562.9	361.0	237.7
5.	Release from HSD Tank	CR	151.2	77.8	NR	300.4	189.5	NR
6.	Release from Sweet SKO Tank	CR	146.4	75.5	NR	181.5	76.2	NR

Table 10 – Consequence Distance due to Pool Fire

Analysis of Results

Maximum damage due to pool fire radiations will be caused by Rupture of crude storage tank, at a weather condition of 5D. The pool fire radiation of 37.5 kW/m^2 (corresponding to 100% fatality) will reach up to a distance of 258.4 m at 5D weather condition. The pool fire radiation of 12.5 kW/m^2 will reach up to a distance of 390.9 m at 1.5F weather condition. The equipments within a distance of 390.9 m will be subjected to major damage or piloted ignition of wood, melting of plastics tubings etc is possible within this distance. The pool fire radiation of 4 kW/m^2 will reach up to a distance of 608.7 m at 1.5F weather condition. First degree burns may be caused for persons who are within 608.7 m distance.

Consequence Results for Toxic Dispersion:

S.No	Scenarios	Leak Size	IDLH Conc.(ppm)	Downwind Damage Distances in m	
				1.5F Weather Condition	5D Weather Condition
(A) PROCESS UNITS IN WHICH CRITICAL EQUIPMENT MODIFICATION WILL OCCUR					
NHT Unit (Naphtha Hydro treating Unit)					
1.	Release from Second Hydro-treating Reactor (502-R-002)	10	Toluene=500 ppm	NR	NR
		CR	Toluene=500 ppm	449.9	293.9
DHDT(Diesel Hydro treating Unit)					
2.	Release from Hot HP Separator (507-V-003)	10	H2S= 100 ppm	40.7	24.0
		CR	H2S= 100 ppm	99.8	58.1
Amine Regeneration unit					
3.	Release from Amine Regenerator Reflux Drum (522-V-102)	10	H2S= 100 ppm	192	46
		CR	H2S= 100 ppm	682	283
Sour Water Separator (SWS - I & II)					
4.	Release from Sour Water Surge drum (520-V-101)	CR	H2S= 100 ppm	2526.8	1298.2
(B) A NEW SULPHUR RECOVERY UNIT (1 X300TPD)					
5.	Release from ARU Acid Gas KO Drum (524-V-001)	10	H2S= 100 ppm	139	30
		CR	H2S= 100 ppm	956	420

Table 11 – Consequence Distance due to Toxic Dispersion

Analysis of Results

Sour water separator

Release from sour water surge drum will have the maximum downwind distance of H_2S dispersion. The 100 ppm of H_2S at the weather conditions of 1.5 F & 5D will reach as far as 2526.8 m & 1298.2 m respectively.

Risk Assessment:

Individual Risk and Societal Risk:

The Individual Risk per annum (IRPA) measure expresses the risk exposure to any Individual who is continuously present in a particular area for the whole year. The risk exposure is calculated for all relevant hazards and summed to give the overall risks for area of the installation.

The table given below presents the Individual Risk & Societal Risk arising from the major accident events identified for the study.

S.No	Scenarios	Leak Size	Individual Risk per avg. year	Societal Risk per avg. year
(A)	PROCESS UNITS IN WHICH CRITICAL EQUIPMENT MODIFICATION WILL OCCUR			
CDU (Crude Distillation Unit)/ VDU (Vacuum Distillation Unit)				
1.	Release from discharge line of Pre- flashed Crude pump(501-P-104)	10	3.00E-06	2.90E-06
		CR	3.81E-05	3.74E-05
NHT Unit (Naphtha Hydro treating Unit)				
2.	Release from Second Hydro-treating Reactor (502-R-002)	10	2.22E-09	1.59E-09
		CR	9.56E-06	7.93E-06
3.	Release from Stripper Reflux Drum (502-V-004)	CR	5.11E-06	6.73E-06
DHDT(Diesel Hydro treating Unit)				
4.	Release from Hot HP Separator (507-V-003)	10	7.42E-07	7.29E-07
		CR	2.97E-06	2.97E-06
FCC - PC Unit				
5.	Release from Reactor (510-R-001)	10	Negligible	Negligible
		CR	5.97E-07	5.31E-07
VGO- HDT Unit				
6.	Release from discharge line of Hydrogen Compressors (509-K-002)	10	2.30E-08	1.61E-08
		CR	4.90E-07	4.30E-07
Delayed Coker Unit				
7.	Release from discharge line of LPG product pump (508-P-028 A/B)	10	5.64E-07	5.03E-07
		CR	6.90E-06	8.57E-06
Amine Regeneration unit				
8.	Release from Amine Regenerator Reflux Drum (522-V-102)	10	Negligible	Negligible
		CR	Negligible	Negligible
Sour Water Separator (SWS - I & II)				
9.	Release from Sour Water Surge drum (520-V-101)	CR	1.05E-05	9.96E-06
(B)	A NEW SULPHUR RECOVERY UNIT (1 X300TPD)			
10.	Release from ARU Acid Gas KO Drum (524-V-001)	10	Negligible	Negligible
		CR	Negligible	Negligible
11.	Release from fuel gas line to Incinerator burner (524-LZ-004)	10	1.61E-06	1.61E-06
		CR	2.11E-07	2.11E-07

12.	Release from Hydrogen make up line to Hydrogenation heater (524-E-101)	10	Negligible	Negligible
		CR	Negligible	Negligible
(C) PROPOSED OFFSITE STORAGE FACILITIES				
Crude storage tanks				
13.	Release from Crude Storage Tank	CR	2.63E-04	2.29E-04
Finished product storage tanks				
14.	Release from MS-III Tank	CR	2.38E-05	3.26E-05
15.	Release from Naphtha Tank	CR	1.29E-04	1.15E-04
16.	Release from HSD Tank	CR	9.55E-06	1.27E-05
17.	Release from Sweet SKO Tank	CR	4.36E-07	4.71E-07
LPG Mounded Bullets				
18.	Release from LPG mounded bullet	CR	1.62E-05	1.66E-05

Table 12 – Risk Values

Over all Individual Risk and Societal Risk:

S.NO	Scenarios	Individual Risk per avg. year	Societal Risk per avg. year
1	Proposed offsite storage facilities	4.42E-04	4.06E-04
2	Process units in which critical equipment modification will occur	7.86E-05	7.86E-05
3	New Sulphur recovery unit	1.82E-06	1.82E-06

Legends:

Unacceptable	ALARP	Acceptable

Risk Presentation

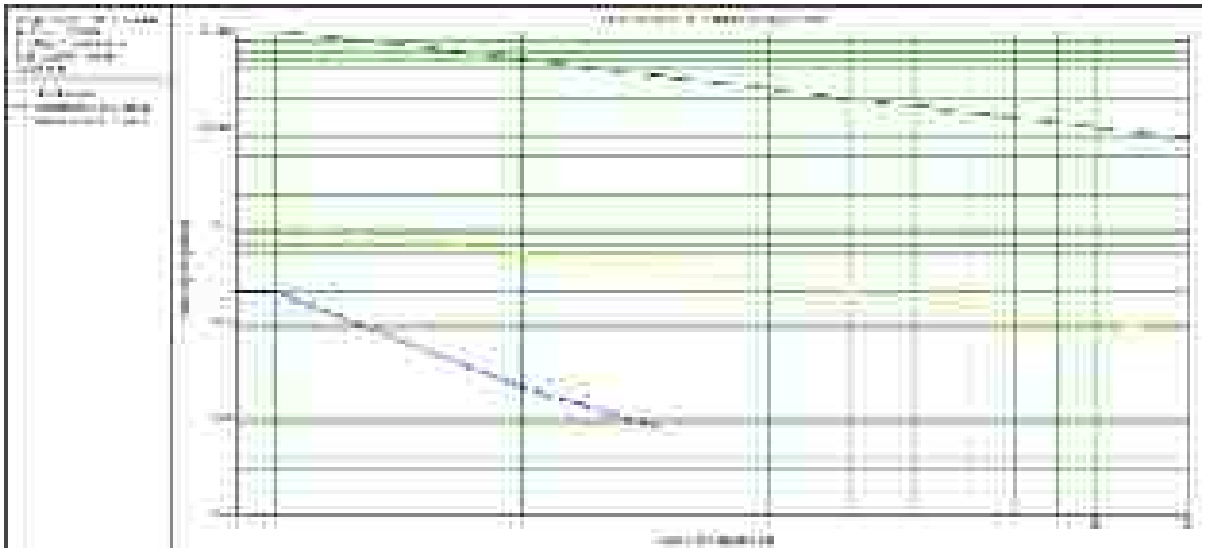
The individual & societal risks worked out for the various scenarios are given below in the form of IR contour & F- N Curve respectively.

(A). Process Units In Which Critical Equipment Modification Will Occur

CDU (Crude Distillation Unit)/ VDU (Vacuum Distillation Unit)

1. Leak in discharge line of Pre- flashed Crude pump (501-P-104)

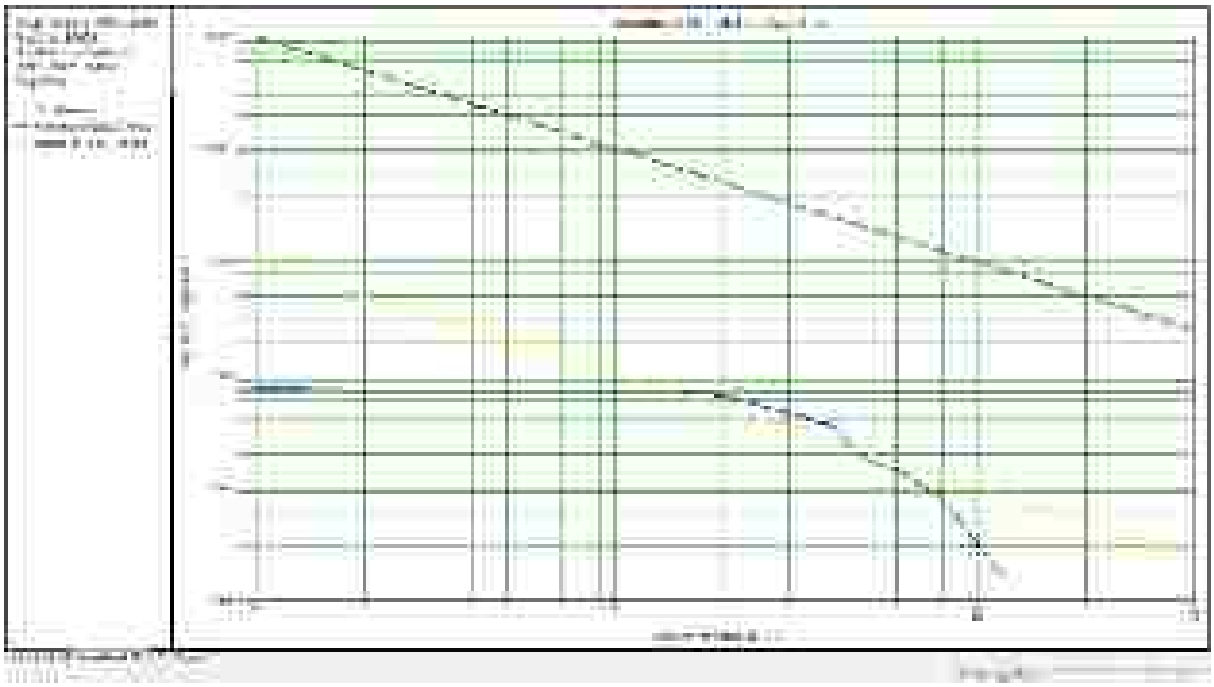
Individual Risk: 3.00E-006 per avg year



Societal Risk: 2.9E-06 per avg year

2. Rupture in discharge line of Pre- flashed Crude pump (501-P-104)

Individual Risk: 3.81E-05 per avg year

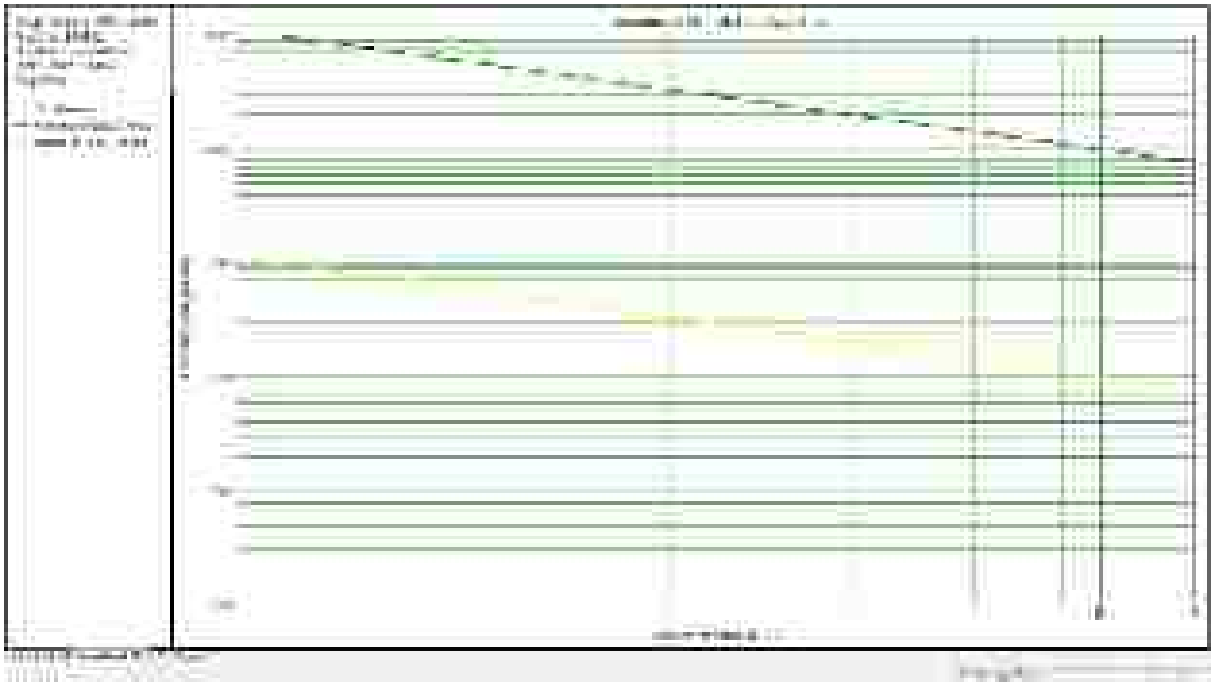


Societal Risk: 3.74E-05 per avg year

NHT Unit (Naphtha Hydro treating Unit)

3. Leak in Second Hydro-treating Reactor (502-R-002)

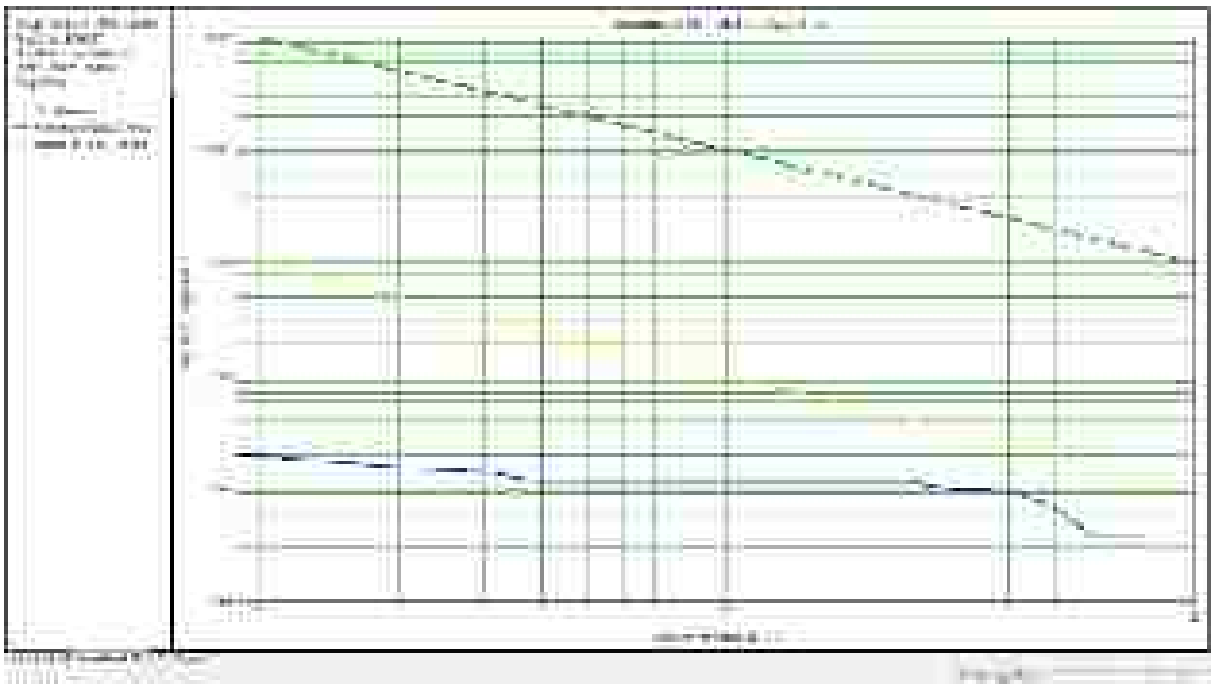
Individual Risk: 2.22E-09 per avg year



Societal Risk: 1.59E-09 per avg year

4. Rupture in Second Hydro-treating Reactor (502-R-002)

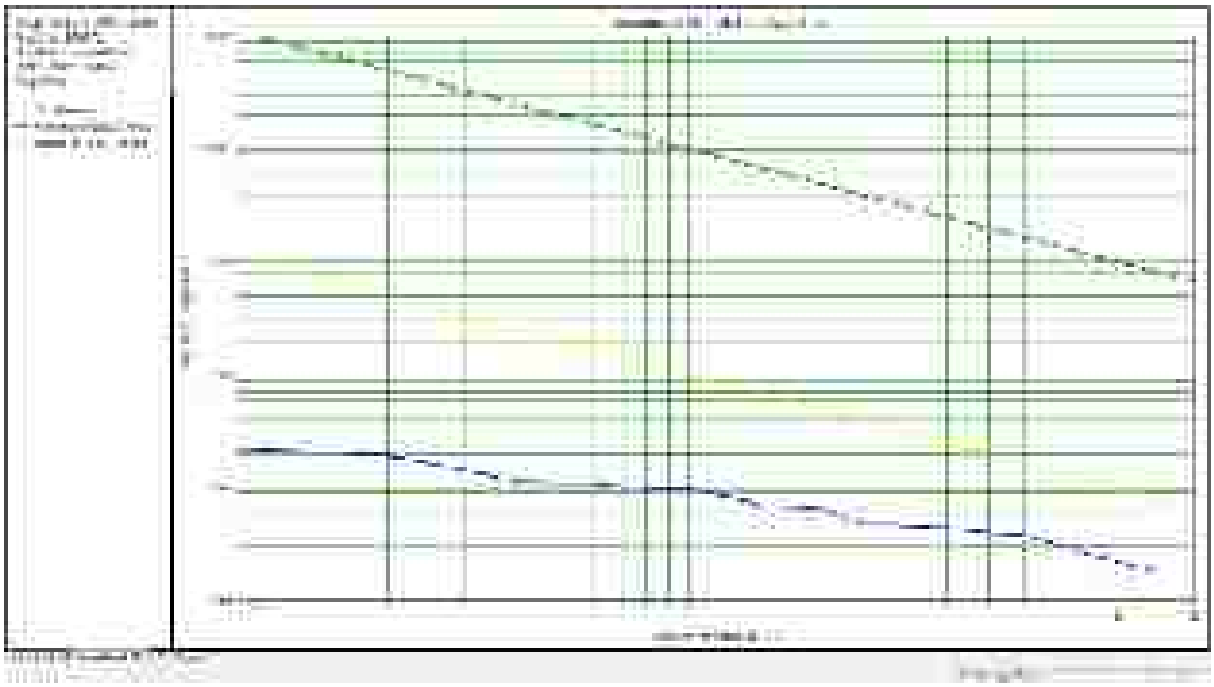
Individual Risk: 9.56E-06 per avg year



Societal Risk: 7.93E-06 per avg year

5. Rupture in Stripper Reflux Drum (502-V-004)

Individual Risk: 5.11E-06 per avg year

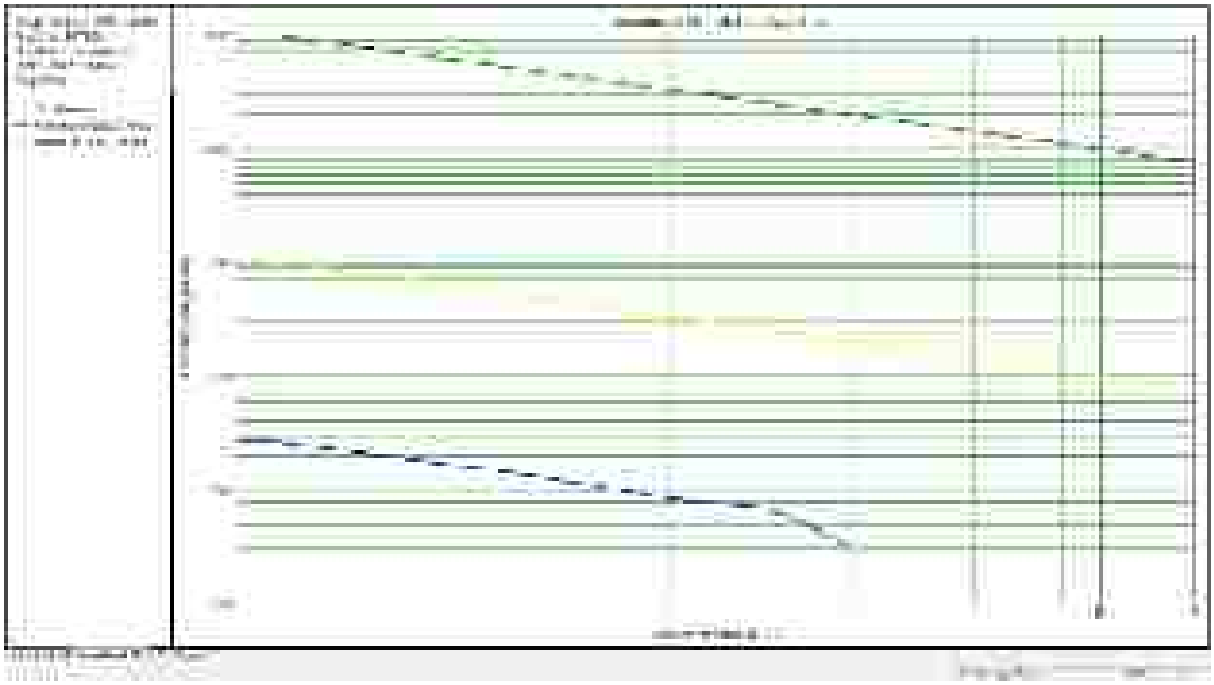


Societal Risk: 6.73E-06 per avg year

DHDT (Diesel Hydro treating Unit)

6. Leak in Hot HP Separator (507-V-003)

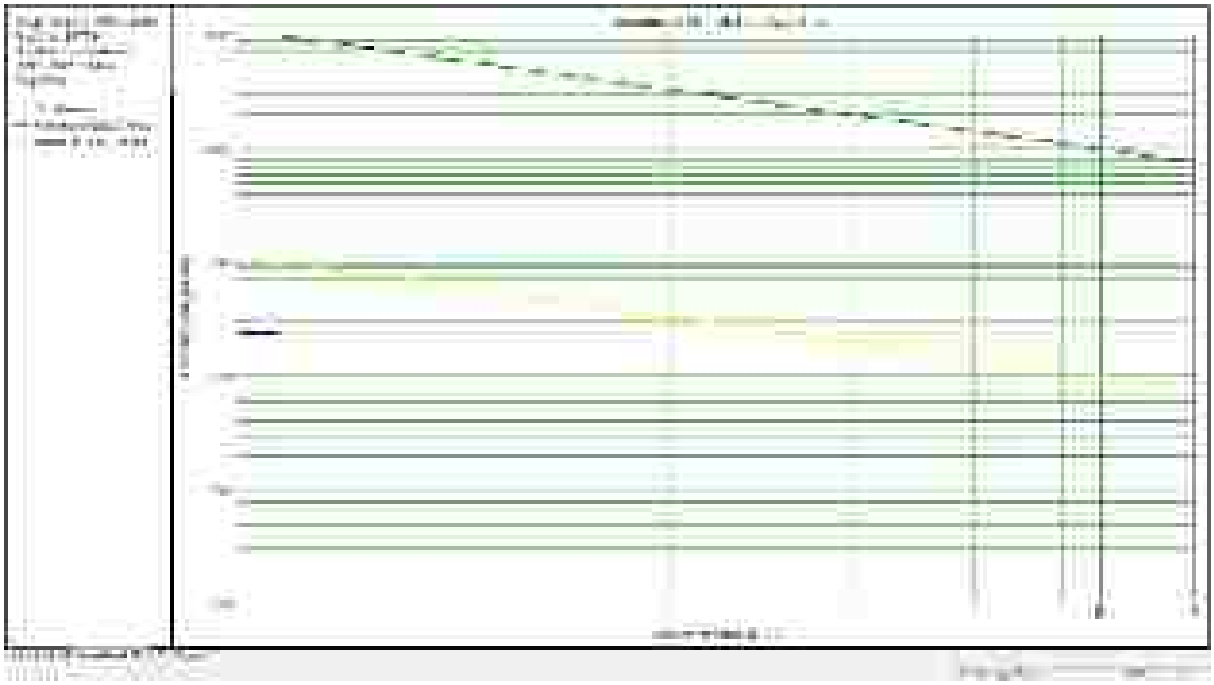
Individual Risk: 7.42E-07per avg year



Societal Risk: 7.29E-07 per avg year

7. Rupture in Hot HP Separator (507-V-003)

Individual Risk: 2.97E-06per avg year



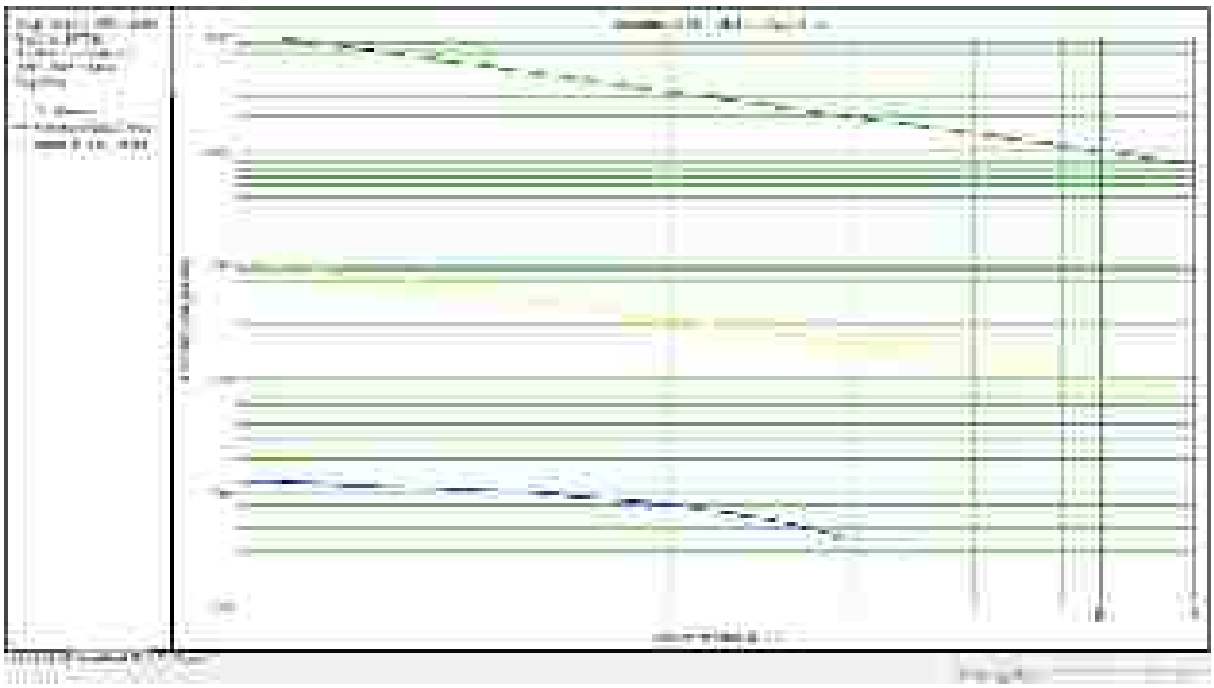
Societal Risk: 2.97E-06 per avg year

8. Leak in the Reactor (510-R-001)

Considering the quantity of release, population distribution, weather condition & other process parameters, Individual risk & Societal risk values for this scenario are negligible. Hence no Individual Risk Contours & FN curves are found.

9. Rupture in the Reactor (510-R-001)

Individual Risk: 5.97E-07 per avg year

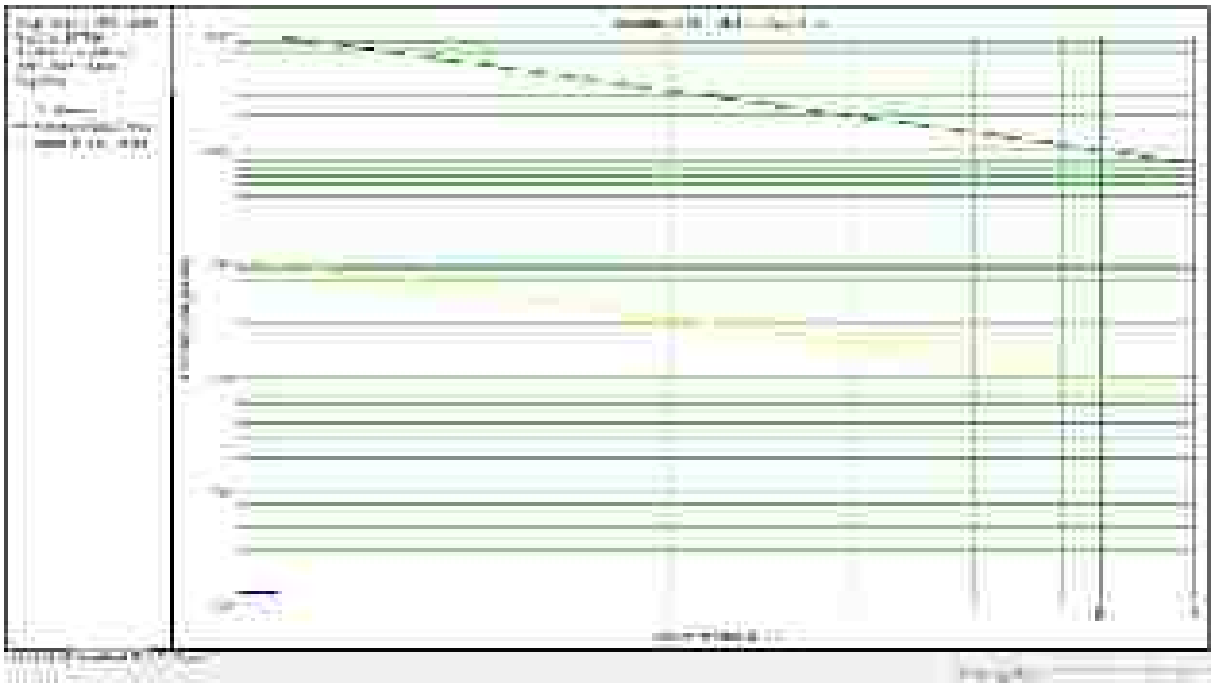


Societal Risk: 5.31E-07per avg year

VGO- HDT Unit

10. Leak in discharge line of Hydrogen Compressors (509-K-002)

Individual Risk: 2.30E-08 per avg year



Societal Risk: 1.61E-08 per avg year