RISK ASSESSMENT

1.0 OBJECTIVE

The objective of carrying out Risk Assessment Study for CCPP is to study the risks involving hazardous materials and their consequences. In this endeavor, the study objectives are outlined here under.
RA will include a number of steps:
Hazard Identification
Release Assessment
Exposure Assessment
Consequence Assessment
Risk Estimation
Institute of Engineering and Ocean Technology (IEOT), ONGC, Panvel was entrusted with job of QRA Study of Combine Cycle Power Plant (CCPP) at Hazira Plant. The principle aim of this study is to carry out Quantitative Risk Assessment of CCPP at Hazira. Consequence analysis has been done to evaluate various consequence analysis has been done to evaluate various consequence by major hydrocarbon facilities and risk estimation has been done for the plant personal. IEOT has exercised all reasonable engineering judgement, skill, care and diligence in carrying out this study. IEOT, ONGC has utilized onshore Risk Analysis software tool called "SAFETI Professional Version-6.7" for carrying out QRA Study. Based on the Risk Assessment few conclusions have been drawn which are mentioned at 1.10.

CONSEQUENCE ANALYSIS

1.1 GENERAL

Consequence analysis involves the application of mathematical, analytical and computer models for calculation of effects and damages subsequent to a hydrocarbon release accident. Consequence models are used to predict the physical behavior of hazardous incidents. The techniques used to model the consequences of hydrocarbon and other hazardous material releases cover the following:

- Modeling of Discharge Rates when holes develop in process equipment/piping/pipeline.
- Modeling of the size and shape of flammable and toxic gas clouds from releases in the atmosphere.
- Modeling of the flame and radiation field of the releases that are ignited and burn as jet fire, pool fire, flash fire and BLEVE/Fire ball.
- Modeling of the explosion fields of releases which are ignited away from the plant of release.

Flammable material to be used at site is High pressure Fuel Gas. Therefore, Jet fire, Flash, Fire ball and explosion have been considered as credible events on ignition of leaked inventory. Therefore, the following modeling is relevant to the present Risk Analysis Study and their computer outputs for major risk contributors are placed at Appendix-I of this report.

- Dispersion modeling
- Jet fire/Flash fire and Explosion Modeling

1.2 DISCHARGE AND DISPERSION MODELLING

1.2 .1 DISCHARGE RATE MODELLING

The initial rate of release of hydrocarbon through a leak depends mainly on the pressure inside the equipment, size of the hole and phase of the release (liquid, gas or two-phase). The release rate decreases with time as the equipment depressurizes. This reduction depends mainly on the hydrocarbon inventory and the action taken to isolate the leak and blow-down the equipment.

1.2.2 **GAS DISPERSION MODELLING**

Releases of gas (or gas flashed from liquid releases) into the open-air form clouds whose dispersion is governed by the wind, by turbulence around the site, the density of the gas and initial momentum of the release. The sizes of these gas clouds above their Lower Flammable Limit (LFL) are important in determining whether the release will ignite.

1.3 FIRE AND EXPLOSION MODELLING

1.3.1 JET FIRE

Jet fires are burning jets of gas or atomized liquid whose shape is dominated by the momentum of the release. The jet flame stabilizes on or close to the point of release and continues until the release is stopped. The effect of jet flame impingement is severe as it may cut through equipment, pipeline or structure. The surface heat flux level is of the order of 200-300 kw/m2 as against 100-110 kw/m2 heat flux at the flame surface of a pool fire. The damage effect of thermal radiation is dependent on both the level of thermal radiation and duration of exposure. Jet fire is a credible scenario in this installation.

1.3.2 POOL FIRES

Pool fires are burning pools of liquid, which has collected on a horizontal surface.
The size and spread of the pool will gradually increase with time but will reach an equilibrium size shortly after ignition; the pool size is then determined from the burning rate and the release rate. Thermal radiation levels are estimated for this equilibrium size pool fire. If the liquid release is stopped, the size of the burning pool will gradually diminish. Pool fire is not a credible scenario for this CCPP.

1.3.3 FLASH FIRE

A flash fire occurs when a cloud of gas burns without generating any significant overpressure. The cloud is typically ignited on its edge remote from the leak source the combustion zone moves through the cloud away from the ignition point. The duration of the flash fire is relatively short but it may stabilize as a continuous jet fire from the leak source. For flash fires, an approximate estimate for the extent of the total effect zone is the area over which the cloud is above the LFL It is assumed that this area is not increased by cloud expansion during burning.

1.3.4 BLEVE/FIRE BALL

Under certain circumstances, vessels/spheres containing liquefied flammable gases under pressure and immersed in a fire can undergo Boiling Liquid Expanding Vapour Explosion (BLEVE). This occurs when pressure in the vessel builds up to such a level that the fire-weakened vessel bursts. Once it bursts and ignites a fire ball ensues. A fireball is an intense spherical fire resulting from a sudden release of pressurized liquid or gas which is immediately ignited, burning as it expand forming a ball of fire, rising in the air. BLEVE is not a credible scenario in this installation.

1.4 DAMAGE CRITERIA

Different accident scenarios result into different damaging effects. The damage criteria considered for this analysis are as follows:
(i) Hydrocarbon vapours released accidentally will normally disperse in the direction of wind. If the dispersed gas finds an ignition source before being diluted below its LFL, a flash fire is likely to occur and the flame may travel back to source of leak. Any person trapped in the flash fire is likely to suffer fatal burn injury. Escalation of fire may also take place if combustible materials are trapped in the flash fire. Depletion of oxygen is also a possibility in the vicinity of hydrocarbon leakage source.
(ii) Thermal radiations due to pool fire, jet fire or dike fire may result into different degrees of burn on human bodies. Thermal radiation also causes damage to the inanimate objects like equipment, piping, buildings etc. The damage caused due to various thermal radiation levels are summarized in the following table.

Table No. 1.4.1
Thermal Radiation Damage due to Incident Radiation Intensity
(Source: Guidelines for Chemical Process by CCPS of the AIChE,1989)

Incident Radiation	Incident Radiation
37.1	Sufficient to cause damage to process equipment.
21	Minimum energy required to ignite wood at infinitely long exposure (non piloted)
12.1	Minimum energy required for piloted ignition of wood, melting of plastic tubing.
9.1	Pain threshold reached after 7 s, second degree burns after 20 s.

4.1	Sufficient to cause pain to personnel if unable to reach cover within 20 sec., however, blistering of skin (2nd degree burns) is likely, 0% lethality.
1.6	Will cause no discomfort on long exposure

The level of damage caused is a function of duration of exposure, as well as of heat flux. This is true both for the effect on buildings and plant equipment and for the effect on personnel. However, the variation of likely exposure times is much more marked with personnel, due to the possibility of finding shelter.

The variation of effects on humans with changes in heat flux and duration of exposure have been expressed in the form of probit equation:

Probit = -14.9 + 2.16 Ln (t*I 4/3*10 - 4)

Where,

t = duration of exposure in seconds;

I = thermal radiation intensity in watts/sq.m.

For 10% fatality level, Probit = 1.0

For the analysis of fatal effects due to thermal radiation, the radiation intensity of 12.1 kw/m2 is calculated from the above Probit equation as it is assumed that persons will require about 80 seconds to move away from the accident area to a "shelter" area.

Based on the above equations, the fatal effects on humans due to various levels of thermal radiation and duration of exposure have been calculated and summarized below in Table No. 1.4.2.

Table No. 1.4.2

Fatal Radiation Exposure Levels

(Source: WHAZAN – World Bank Hazard Analysis, 1998)

Radiation level (KW/m2)	**Fatality Level**		
	1% 10% 99%	**1% 10% 99%**	**1% 10% 99%**
	Exposure in seconds		
1.6	100	1300	3200
4.1	110	370	930
12.1	30	80	200
37.1	8	20	10

(iii) For transient fires like fireball, Probit equation as described above is used to arrive at the fatal radiation level considering the duration of the fireball. Further, fire fatalities need to be considered for people in the open (i.e. working on the site, or walking outside the site) and people inside working in office, or inside houses). For this study, the following Fatality

Probabilities have been considered.

Table No. 1.4.3

Fire Fatality Probability

(Source: Risk Analysis Training Course Manual

prepared for IEOT, ONGC by DNV Technica, 1996)

Fire Type	**Fatality Probability**	
	Outdoors Indoors	Outdoors Indoors
Flash fire	1.0	0.1
Jet, Pool fire	0.7	0.1
Fireball	0.7	0.2

In the event of an explosion-taking place within the complex, due to hydrocarbon and air mixing and catching fire, the resultant blast wave may have damaging effect. The tanks, buildings, structures etc., can only tolerate low level of overpressure. Human body by comparison can with stand higher overpressure but injury or fatality can be inflicted by collapse of buildings or structures or by being thrown over. The damage effect of blast overpressure for residential type building is given in Table 1.4.4.

Table No. 1.4.4
Damage Effect of Blast Overpressure
(Source: Guidelines for Chemical Process
by CCPS of the AIChE,1989)

Blast Over Pressure		Damage Level
(barg)	(psig)	
0.35	5	Heavy Building Damage
0.16	2.3	Lower limit of serious structural damage
0.10	1.5	Repairable Building Damage
0.05	0.7	Glass Damage to Buildings
0.02	0.3	Safe distance, 10% of Window Glass Broken

Overpressure duration is important for determining effects on structures. The positive pressure phase of the blast wave can last from 10 to 100 ms for typical UVCE. The same overpressure level can have different effects depending on the duration.
The interpretation of these data is clear with respect to structural damage but subject to debate with respect to human casualties. The Rijnmond (1972) study equates heavy building damage i.e. 0.31 barg to a fatal effect, as those inside buildings would likely to be killed by the collapsing structure. For the present study, the following Explosion Fatality Probabilities have been adopted:

Overpressure (barg)	Fatality Probability	
	Outside	Inside
0.35	0.3	1.0
0.10	0.1	0.3

1.1 Consequence Effect Distances
The operation, maintenance and safety requirement of an installation generally determine the minimum distance between facilities. From risk point of view, the distance in between facilities is important primarily to avoid any cascading effect (Domino) subsequent to a failure/fire. Further, minimum distance between process area and plant boundary is given mainly to reduce damage effect on outside people. Therefore it is important to maintain minimum safe distance in order to reduce overall risk of an installation.

1.1.1 HEAT RADIATION EFFECT
Jet Fire Scenario
Lift gas Header is handling gas at high pressure. It may result jet fire for continuous release and flash fire/ fireball for instantaneous release (catastrophic rupture). Release duration will depend on leak detection and isolation time.
Catastrophic rupture may result a short duration Flash Fire. Direct exposure of personnel to flash fire may result serious injury or fatality **Generally it can be assumed that steel equipment will not fail when exposed to a radiation level of 12.1kw/m2 or less. At that radiation level the metals temperature stabilizes at about 300deg C, which will not endanger its integrity. But the same radiation level could be fatal for human being as per Table 1.4.2. However, at radiation level of 37.1 kw/m2 steel equipment may loose its integrity depending on exposure duration as per Table 1.4.1. The radiation intensity of 37.1 kw/m2 for a duration of 20 minutes can cause damage/yield to steel plates.**
Following table gives the consequence effect distance of leaks from different facilities.
S= Small Leak (1mm), M=Medium leak (21mm) & L= Large (100mm).

A- FUEL GAS SCRUBBER AND ASSOCIATED PIPING

TABLE 1.1.1 Fuel Gas Scrubber -Jet fire (distance in meters)

Leak Size	Release duration (s)	4kw/m2	12.5 kw/m2	37.5kw/m2
Small leak – 5mm	3274	5.0	-	-
Medium Leak -25mm	131	31	25	21
Large Leak -100mm	9	117	91	72

TABLE 1.1.2 Fuel Gas Scrubber – Flash Fire

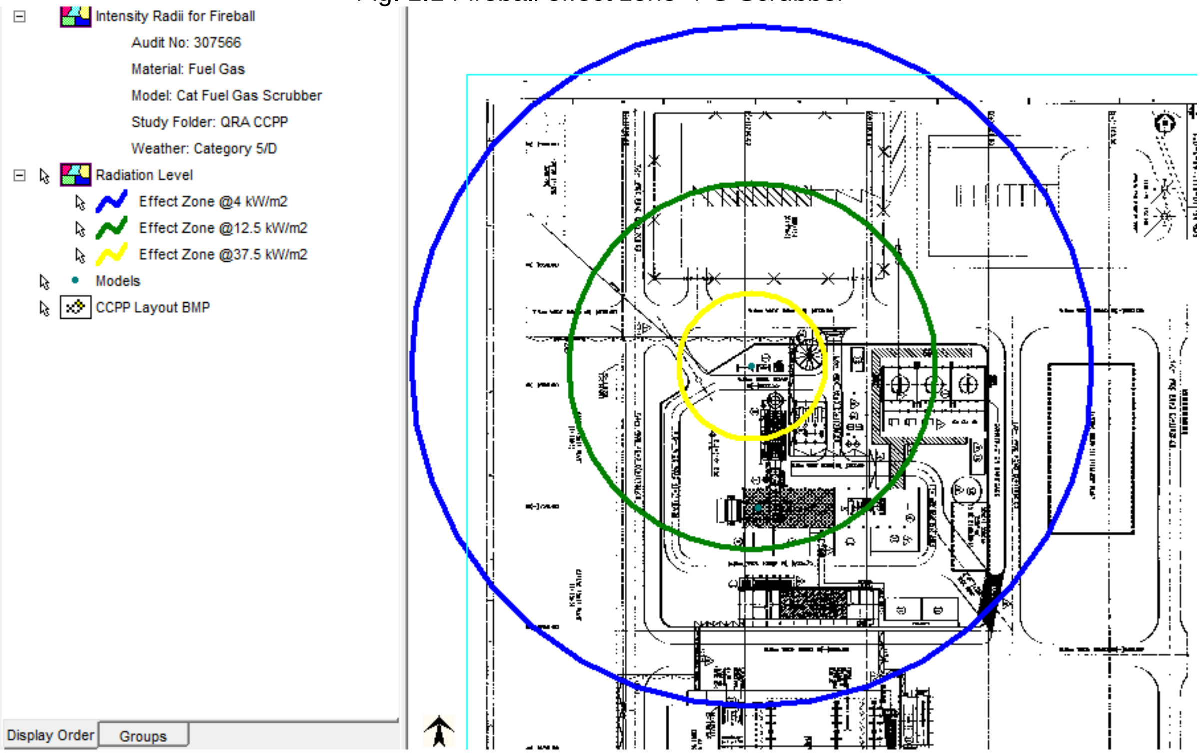
Hazard distance Fuel gas Scrubber (in meters)

Facility	LFL	½ LFL
Small leak	3	6
Medium Leak	14	37
Large Leak	93	202
Catastrophic rupture	15	25

TABLE 1.1.3 Fuel Gas Scrubber -Fireball (distance in meters)

Leak Size	4kw/m2	12.5 kw/m2	37.5kw/m2
Catastrophic Rupture	148	80	32

Fig. 1.1 Fireball effect zone- FG Scrubber



Radiation effect zone of 37.1kw/m2 is limited around the Scrubber. Since fire ball duration is 17second, equipment damage not expected.

B- GAS TURBINE AND ASSOCIATED PIPING

TABLE 1.1.4 Consequence Effect Distances- Jet fire (meters)

Facility	Release duration (s)	4kw/m2	12.5kw/m2	37.5kw/m2
Small leak	2456	5.0	-	-
Medium Leak	100	31	25	21
Large Leak	6	117	91	72

Gas turbine is housed in a Hall and large leak will fill the enclosure and consequence effect and its distance may be different. In such case flash fire or explosion may occur.

TABLE 1.1.1 Gas Turbine – Flash Fire

Hazard distance Gas turbine (in meters)

Facility	LFL	½ LFL
Small leak	3	6
Medium Leak	14	37
Large Leak	93	202
Catastrophic rupture	15	25

Gas turbine is housed in a Hall and large leak will fill the enclosure and consequence effect and its distance may be different. In such case flash fire or explosion may occur.

1.6 EXPLOSION ANALYSIS

Facilities in CCPP are placed in existing plant. In such scenario there is some degree of confinement. In case of Fuel gas conditioning skid and Scrubber, Large gas cloud buildup is not expected, however, in case of catastrophic release, explosion may take place in confined spaces, involving small amount of flammable mass. Fuel gas is mainly Methane and after the release it will rise above and disperse faster. Explosion in unconfined or unobstructed region is not expected. However, in case of gas turbine, a large leak or catastrophic rupture in gas turbine enclosure, may get ignition in form of spark or hot surface in the gas turbine. In such case explosion may result.

Table1.6.1 FG Scrubber - Explosion Overpressure Distances (meters

Leak size	Explosion Overpressure			
	1.5psi	2.3psi	3psi	5psi
Medium	34	33	-	-
Large Leak	39	25	-	-
Catastrophic	46	37	-	-

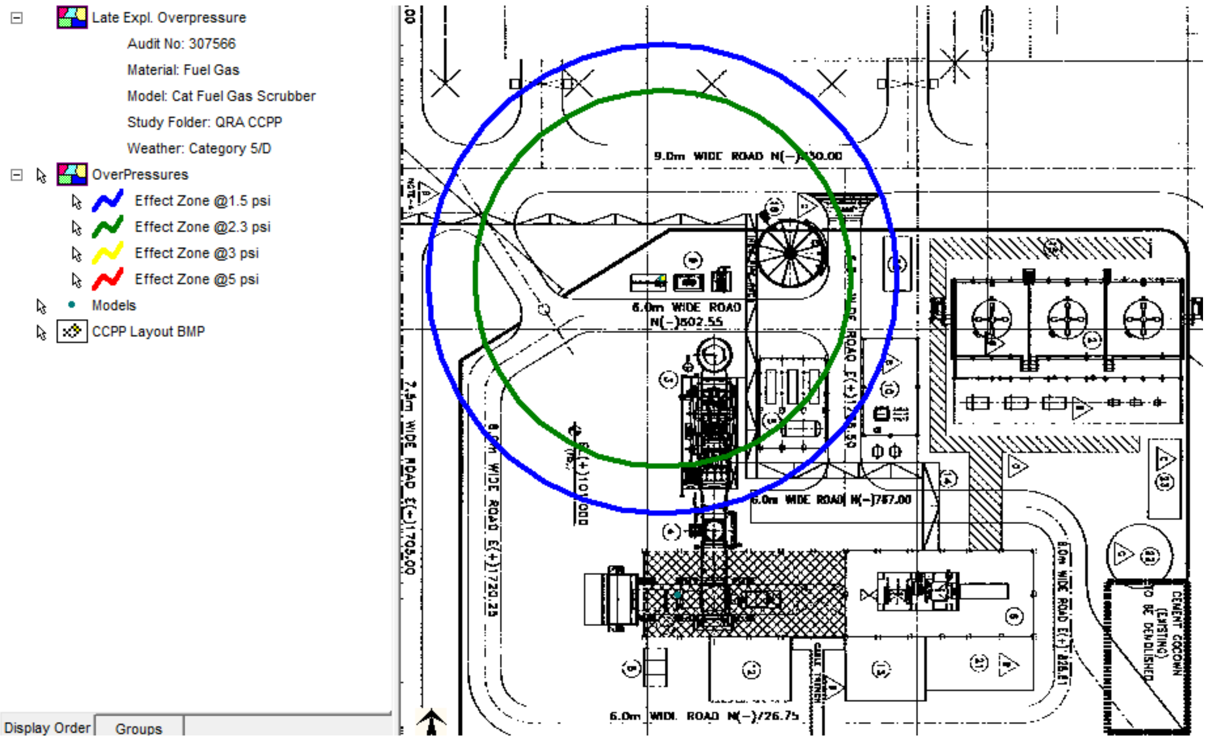


Fig. 1.2 Explosion overpressure – catastrophic Rupture in FG Scrubber

Around the FG Scrubber, there is not much confinement and hence, high explosion overpressure is not resulted.

Table 1.6.2 Gas Turbine - Explosion Overpressure Distances (meters)

Leak Size	Explosion overpressure			
	1.5psi	2.3psi	3psi	5psi
Medium	48	34	-	-
Large Leak	39	25	-	-
Catastrophic rupture	48	34	27	17

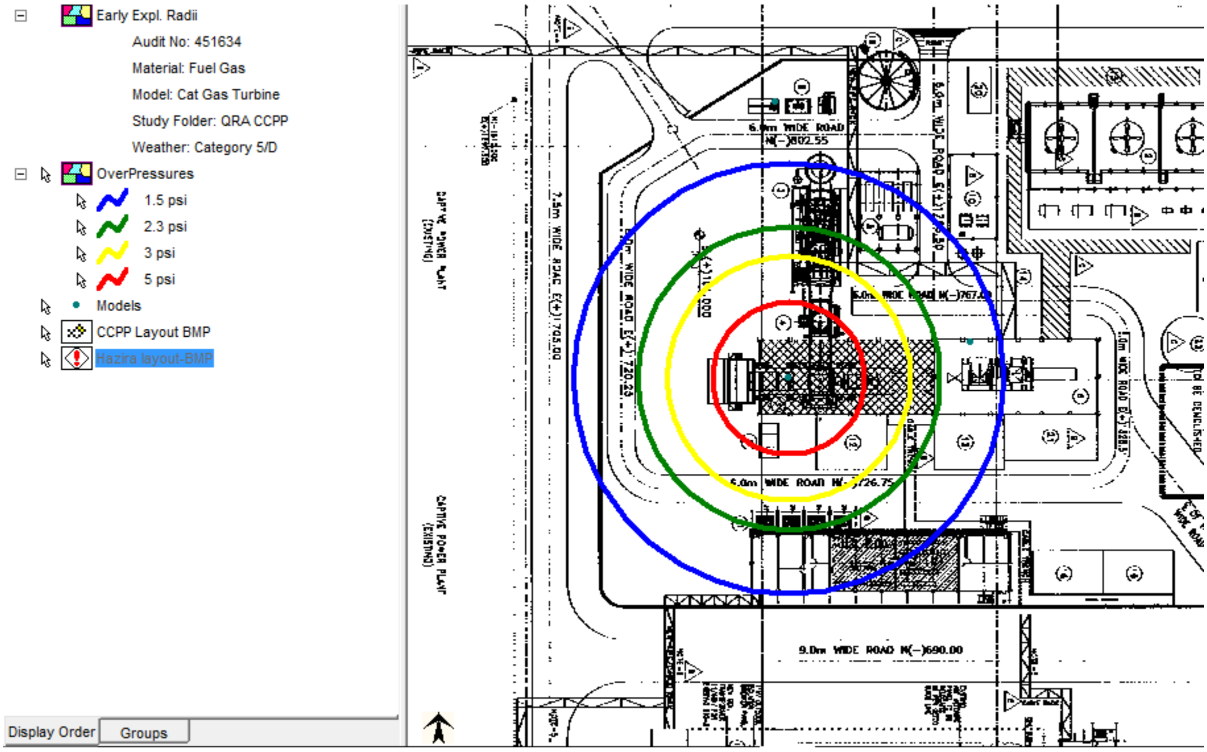


Fig. 1.3 Early Explosion Overpressure- Gas Turbine Enclosure.

As gas turbine will be installed in the enclosure, there is around 200m3 of confinement volume. Also, obstruction is present in form of gas turbine. In this case higher degree of explosion overpressure may result as shown above. Upto 3psi overpressure is limited to smaller area in the CCPP layout.

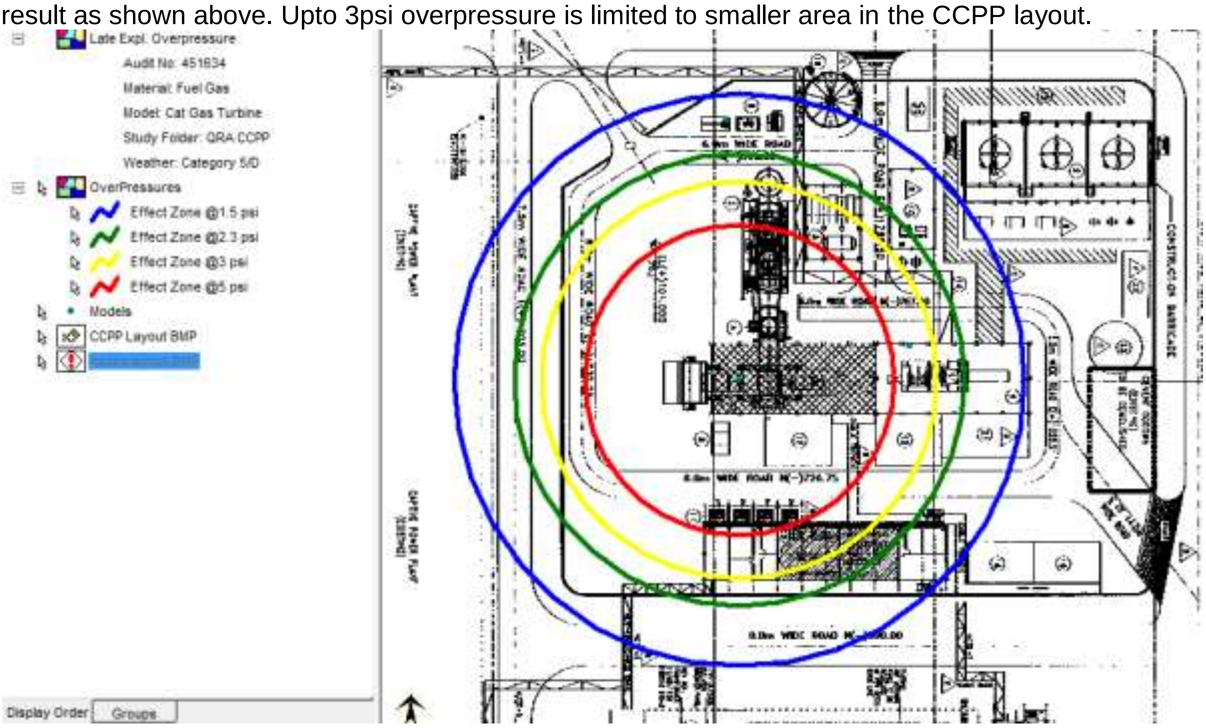


Fig. 1.4 Late Explosion Overpressure- Gas Turbine enclosure

Explosion overpressure of 1 psi is limited to gas turbine but 3psi overpressure may reach upto control room.

1.7 FREQUENCY ESTIMATION

1.7.1. GENERAL

Frequency analysis involves estimating the likelihood of each of the selected failure cases, which were defined in the hazard identification stage. Typical requirements are frequencies of pipe leaks, flange/valve/small bore fitting leaks, heat exchanger leaks, vessel leaks, pump leaks etc.
Frequency is the expected number of occurrences of the event per unit time, usually a year. The frequency is usually presented in scientific notation, e.g. 6.1 x 10-3 yr-1.

1.7.2 APPROACH TO FREQUENCY ANALYSIS

For establishing a failure rate for a release scenario two approaches are used.

1.7.3 GENERIC PROCESS EQUIPMENT LEAK FREQUENCIES

1.7.3.1 GENERAL APPROACH

The failure rate for a certain item is then broken down with the correct proportions for required release rate bands basis. The overall frequency for a particular set of equipment is then calculated by,
FT = Fi *N i
Where, FT= Total Failure Frequency /per year/per unit
Fi = Individual item Frequency /per year N i = Number of items i or length of piping

1.7.3.1.2 DATA SOURCE

For this study leak frequency has been taken from “Failure Frequency Guidance – Process Equipment Leak frequency Data for use in QRA”. This failure frequency database is prepared by DNV on the basis of LEAK Software output.

REPRESENTATIVE FAILURE CASE FREQUENCIES ESTIMATION:

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 No. 1.7.6.1.

ONSHORE IGNITION PROBABILITIES

There are two main types of ignition, which may occur in case a release of flammable gas or liquid takes place in process plant.

- **IMMEDIATE IGNITION**

This takes place due to the incident causing the release. This is only really relevant for impact events, which may generate sparks before the fire occurs.

- **DELAYED IGNITION**

This takes place due to the gas cloud drifting over an ignition source under the influence of wind either onsite or offsite. Depending on the ignition delay, this may allow personnel to escape before the fire occurs.
The following factors affect the delayed ignition probability;

- Material released
- Cloud size:
- Release duration:
- Cloud location:
- Number and strength of ignition sources:
- Location of ignition source: This is important to ascertain whether a
- release could reach the ignition sources.

1.7.4. IGNITION THEORY

The probability of causing ignition has two components
Presence factor: This is defined as the probability that the source will actually be present i.e. active/operating when the flammable cloud or liquid passes over it. This is simply in the range of 0 to 1.
Ignition Factor: This is defined as the probability that, given it is present, it will actually ignite the cloud in a given time interval e.g. 0.1 probability in 60 seconds.

Generally, the flammable material released in a process plant contains the following two types of phases:

- Gas
- Liquid

Ignition probabilities for various ignition sources present inside the CCPP have been adopted from Risk Analysis Training Document, 1996- prepared by M/S DNV-Technica, UK for IEOT,ONGC, Panvel.

Table No. 1.7.6.1 LIST OF FAILURE CASES FOR CCPP

Sl. No	Case ID No.	Case Description	Sizes	Failure Frequency
1.	FG Scrubber	Small Leak	< 10 mm	3.50E-03
		Medium Leak	10-50 mm	1.20E-03
		Large Leak	50-150 mm	2.86E-04
		Catas. Rupture	> 150 mm	1.21E-04
2.	Gas turbine	Small Leak	< 10 mm	1.83E-03
		Medium Leak	10-50 mm	9.60E-04
		Large Leak	50-150 mm	1.24E-04
		Catas. Rupture	> 150 mm	0.00E+00

1.8 RISK ESTIMATION

1.8.1 RISK PRESENTATION

Once the frequencies and consequences of each modeled accident scenario have been estimated, they have to be combined to form measures of overall risk. In this study, Event Tree Analysis (ETA) in-built within SAFETI software has been used to estimate the risk. Risk is usually presented in the forms elaborated below:

1.8.1.1 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 Contour*s, which are also commonly known as *Iso- Risk Curve*s. SAFETI software presents Individual risk in this form. 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 361 days a year. It is the standard output from a risk analysis.

1.8.1.2 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 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. Theterm "societal risk" is the group risk of the members of the general public/nearby community. It is expressed in the form of following risk measures:-

F-N Curve - It is 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. SAFETI software presents group risk in this form as well as ranks the societal risk results in descending order of fatalities for easy identification of the accident scenarios contributing maximum to the societal (or group) risk.

1.8.2 RISK ESTIMATION

SAFETI software generates the risk estimates using the in-built Event Tree Analysis incorporated in it and presents the risk results.

1.8.2.1 FATALITY RISK RESULTS

1.8.2.1.1 INDIVIDUAL RISK ESTIMATES

The overall Individual risk contours (ISO-risk curves) for CCPP is generated by “SAFETI” software are placed at Appendix-II of the report. After examination and evaluation of the contours and taking into account presence factor the individual risk levels at a few normally manned locations inside the plant have been estimated and placed as follows in Table No.9.2.1.

Table No.8.2.1 Individual Risk Levels for CCPP

LOCATION	LSIR (per year)	ISIR (per year)
Control Room	1.24×10^{-4}	3.1×10^{-5}
Local GTG Control Room	5.47×10^{-4}	1.37×10^{-4}
N-W Entry Gate	5.09×10^{-4}	1.25×10^{-4}
Workshop	4.58×10^{-4}	1.4×10^{-4}

Therefore risk to most of the continuously manned location is in broadly acceptable region.

1.8.2.1.2 SOCIETAL (GROUP) RISK ESTIMATES

The overall Societal (Group) risk F-N curve plotted by “SAFETI” software forCCPP is placed at Appendix-III of the report. 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 No 1.8.2.2.

Table No.1.8.2.2 Societal (Group) Risk computed for CCPP

Estimated number of fatalities (N)	Cumulative frequency (F) of “N” or more fatalities (per year)
N=3	2.3×10^{-4}
N=5	2.3×10^{-4}
N=10	6.0×10^{-5}

The group of people is for the persons working in CCPP. Risk is limited to the CCPP plant area. On perusal of the Societal Risk Ranking results presented at Appendix-III of the report it can be summarized that the following are the major risk contributing scenarios.

Sl. No.	Name of the facility	Leak category	Leak size	% Contribution
1.	Fuel Gas Scrubber	Large leak	100mm	52.63
2.	Gas Turbine	Large Leak	100mm	35.45
3.	Fuel Gas Scrubber	Catastrophic Rupture	-	8.91
4.	Gas Turbine	Medium Leak	25mm	2.39

Fuel gas scrubber and associated piping are the major contributor of risk in Combined cycle Power Plant (CCPP).

1.9 RISK ASSESSMENT

1.9.1 RISK CRITERIA

Indian Regulatory Authorities have not specified any formal regulation/guideline regarding risk criteria to be adopted. In absence of it, in this study, Individual Risk Acceptance Criteria (RAC) as suggested by Health & Safety Executive (HSE), of the Government of United Kingdom, for onshore hazardous industry has been used to assess the individual risk to public and plant personnel.

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. Societal Risk Criteria as suggested by H.S.E., U.K has been used.

Health & Safety Executive, U.K suggested a flexible framework, for risk criteria. This form of criteria usually specifies a level, often known as the *maximum tolerable criterion,* above which the risk is regarded as intolerable whatever the benefit may be, and must be reduced. Below this level, the risks should also be made *as low as reasonably practicable* (ALARP). This means that when deciding whether or not to implement risk reduction measures, their cost may be taken into account, using cost-benefit analysis. In this region, the higher the risks, the more it is worth spending to reduce them. If the risks are low enough, it may not be worth spending anything, and the risks are then regarded as negligible.

This approach can be interpreted as dividing risks into three tiers, as is illustrated in Fig.10.1.1. These tiers are described in the following page:

- An intolerable region, within which the risk is generally intolerable whatever the benefit may be. Risk reduction measures or design changes are considered essential.

- A middle band (or ALARP region) where the risk is considered to be tolerable only when it has been made ALARP. This requires risk reduction measures to be implemented if they are reasonably practicable, as evaluated by cost- benefit analysis.

- A negligible region, within which the risk is generally tolerable, and no risk reduction measures are needed.

Figure No.10.1.1 Risk Criteria Framework Suggested by H.S.E. U.K.

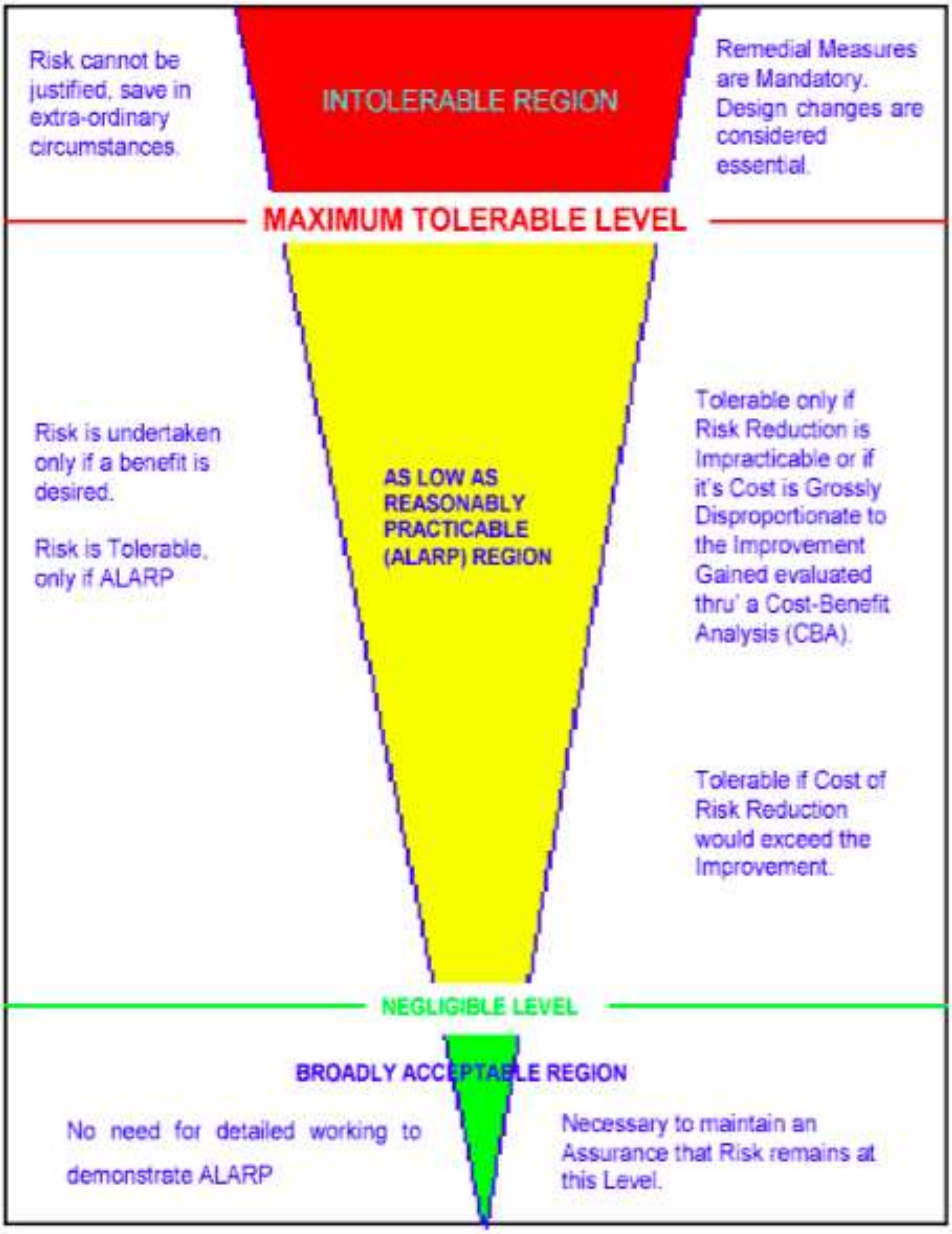
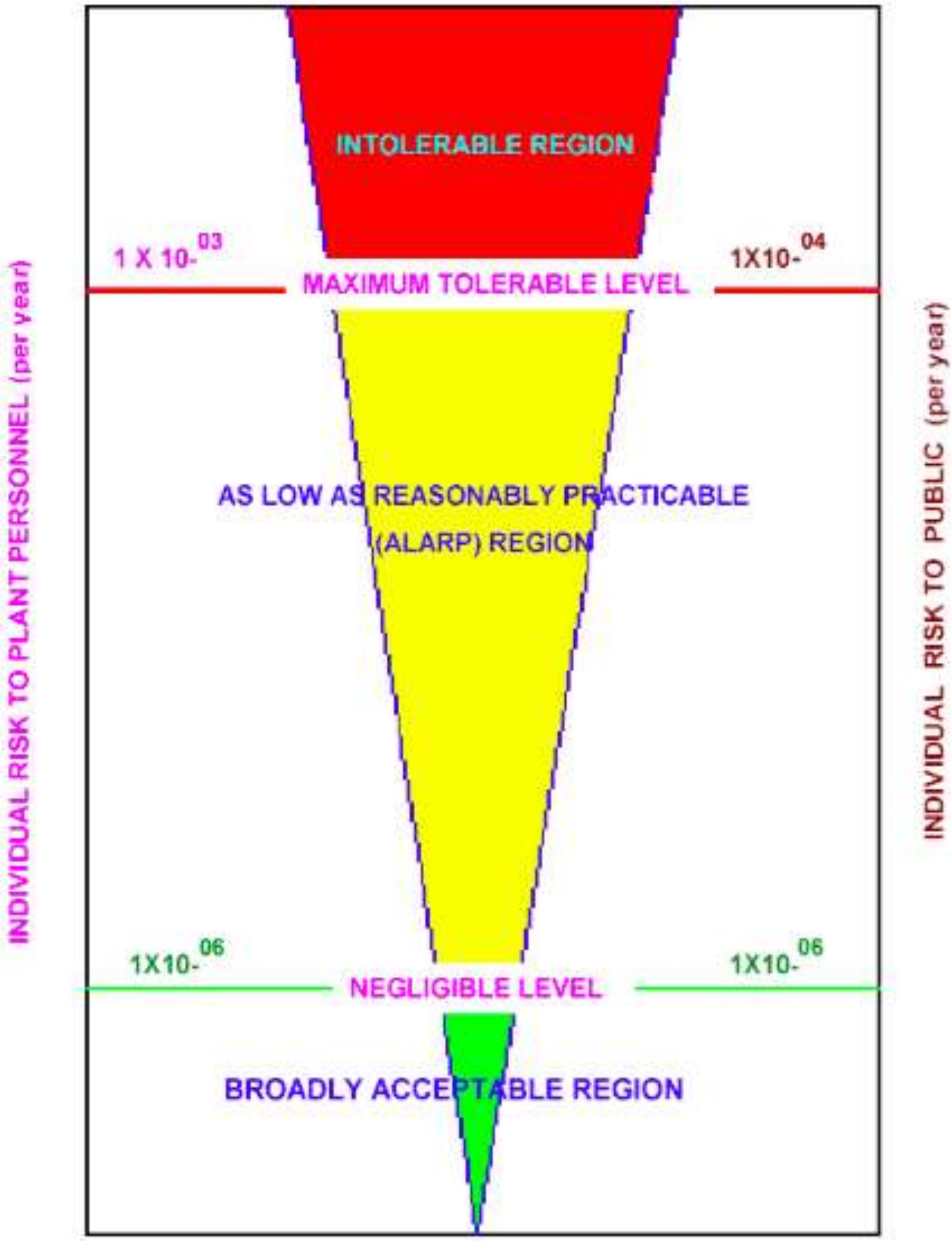


Figure 10.1.2 : ONSHORE INDIVIDUAL RISK CRITERIA
(Suggested by H.S.E. U.K.)



Also the risk levels suggested for plant personnel and general public are placed in the Table given below & in Fig 10.1.2 in the previous page:

Table No. 1.9.1.1: INDIVIDUAL RISK CRITERIA
(Suggested by Health & Safety Executive, U.K)

RISK LEVELS	PUBLIC (per year)	PLANT PERSONNEL (per year)
Maximum Tolerable	$1x\ 10^{-4}$	$1x\ 10^{-3}$
Negligible	$1x\ 10^{-6}$	$1x\ 10^{-6}$

Table No. 1.9.1.2: SOCIETAL RISK CRITERIA
(Suggested by Health & Safety Commission, UK)

RISK LEVELS	N	F
Maximum Tolerable	1	$1x10^{-1}$
	10	$1x10^{-2}$
	100	$1x10^{-3}$
	1000	$1X10^{-4}$
Negligible	1	$1X10^{-4}$
	10	$1X10^{-5}$
	100	$1X10^{-6}$
	1000	$1X10^{-7}$

Note:
1 N is the Number of Fatalities
2 F is the frequency of N or more fatalities per year

Further, risks can be categorized as involuntary or voluntary, depending on the benefit gained from the activity by an individual undertaking the risks, arising out of the activity.
Risk to an individual member of the Public may generally be treated as involuntary. For the sake of comparison, the following involuntary risks undertaken by individuals may be of interest:

		Chances of Death
Road Accidents in India (risk in Urban areas is much more)	:	5 x 10^{-5} per year
Lightning (in India)	:	2 x 10^{-6} per year
Railway Accidents (in India)	:	1.5 x 10^{-5} per year
Drowning (India)	:	3 x 10^{-5} per year

Risks to an individual Plant Personnel are usually being treated as voluntary. For the sake of comparison, the following voluntary risks undertaken by individuals may be of interest:

		Chances of Death (U.K. figures)
Cigarette Smoking (20 cigarettes per day)	:	5 x 10^{-3} per year
Playing Football	:	4 x 10^{-5} per year
Motor Vehicle Accidents (Car Racing)	:	1.06 x 10^{-4} per year
Rock Climbing	:	4 x 10^{-5} per year

1.9.2 RISK ASSESSMENT:-

1.9.2.1: INDIVIDUAL RISK TO PLANT PERSONNEL & GENERAL PUBLIC:-

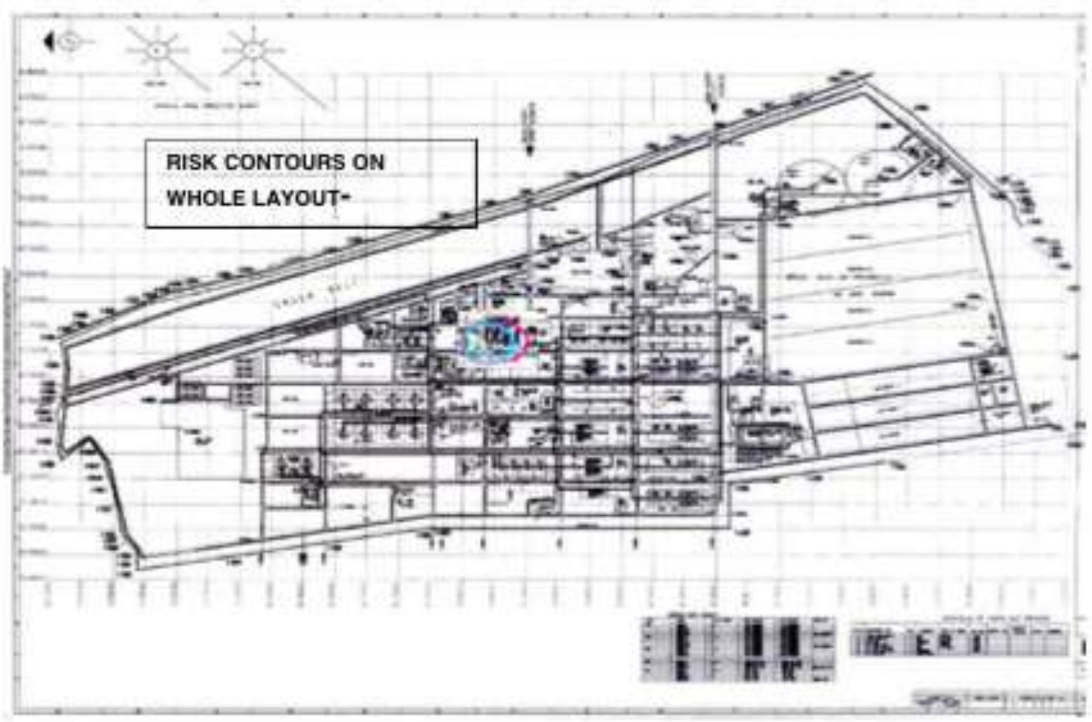
- **Individual Risk to Plant Personnel inside CCPP**:-

It may be observed from the individual risk contours for CCPP placed at Appendix-II of the report and risk pictures tabulated under Table 1.9.2.1 and also, taking into account the presence factor of the plant personnel (assuming that a plant person is present inside the plant area for an average of 8 hours a day) the individual specific individual risk (ISIR) to the plant personnel inside plant is in ALARP risk region.

LOCATION	LSIR (per year)	ISIR (per year)
Control Room	1.24×10^{-4}	3.1×10^{-5}
Local GTG Control Room	5.47×10^{-4}	1.37×10^{-4}
N-W Entry Gate	5.09×10^{-4}	1.25×10^{-4}
Workshop	4.58×10^{-4}	1.4×10^{-4}

- **Individual Risk to General Public around CCPP: -**

All the ISO risk contours from 1X10-4 /year to 1X10-6 /year are limited to the CCPP and FGH area. None of the contour is going outside the Hazira plant boundary. Because of CCPP in the existing plant, no risk is caused to outside inhabitation as depicted below.



1.9.2.2 SOCIETAL (GROUP) RISK

On perusal of the F-N Curve generated for CCPP and the Societal (Group) Risk figures tabulated under Table No. 1.9.2.2 as given below, it can be concluded that the societal risk is in the ALARP risk region.

1.10 Conclusion:

- Individual risk contour are not extending far off distances and are confined around the CCPP. Risk is in ALARP Risk region. Maximum individual risk is covering GT and fuel Scrubber (KOD) area. In relation to the Overall Hazira plant layout, Individual Risk is limited to a small area.
- ISO risk contours from $1x10^{-4}$/year to $1x10^{-6}$/year are limited to the CCPP and FGH area. None of the contour is going outside the Hazira plant boundary. Therefore, Maximum risk contour for Plant personnel and for general public is confined inside the plant boundary.
- Maximum working persons are expected to be available on site during day time and hence Group (Societal) risk considering this case is in ALARP Risk Region. In Night time less person are present at site so group risk for night will reduce further.

- Jet fire is the most credible scenario in case of leakage from the Fuel gas system. Small leak from fuel gas scrubber etc. is expected to disperse easily, if ignited, will have local effect limited to the facility. Medium leak if ignited may have local effect limited to the facility. Medium leak if ignited may give small duration jet fire. Jet fire may result damage to facility. Timely isolation of the leak may reduce the consequences considerably. Jet fire from medium leak may last for about 130seconds. Radiation level of 37.1 Kw/m2 have potential to result facility damage.
- Facilities are situated in well-ventilated area, however, Worst case Scenario are analyzed for large leak/catastrophic rupture. Large leak or catastrophic rupture in the fuel gas system or gas turbine, if ignited immediately may give rise to small duration jet fire and for delayed ignition can result flash fire, fireball or explosion. Gas detection and ignition control will help in minimizing the consequences.
- Catastrophic rupture followed by delayed ignition may result flash fire. Flash fire effects are localized. Facility damage not expected but major injury or fatality may result for the person trapped in the flash fire.
- Gas Turbine Generator is to be housed in a well –ventilated Hall. Small leaks are expected to disperse easily. Worst case scenario of catastrophic rupture ignited by high temperature on gas turbine may give rise to fireball/explosion.
- In case of early Explosion in gas turbine enclosure, Gas Turbine Control room is falling under 3psi overpressure zone and Control Room is beyond 3psi Pressure zone. In case of late explosion, 3 psi overpressure is reaching up to Control Room.
- In relation to the overall plant, the consequence effect are broadly limited to the CCPP area.

1.11 Major Recommendation & Action:

Based on the conclusion drawn above, following are the major recommendation for improvement of Safety.

1. As high fuel gas handled in the CCPP, an adequate Gas detection system should be provided covering the Fuel gas system for quick detection of any leakage of the gas.
   Action: adequate Gas detection system is in place.

2. 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. A long duration jet fire, because of medium or large leak, may damage the pipe rack passing near the FG System and may escalate the consequences.

   Action: Onsite & off site emergency Plan is Available. Proper exit system is provided.
3. Adequate ventilation should be insured in the Gas Turbine Hall. The gas turbine hall should adequately be covered by gas detection system so that any leak can be detected and control measure can be activated accordingly.
   Action: Available

4. In Case of explosion in the Gas turbine enclosure, the Gas Turbine Control room and Control room is falling in 3 psi explosion overpressure zone. Therefore it is recommended that Gas Turbine Control Room and Control room should be made to withstand 3 psi explosion overpressure or be shifted beyond the 3 psi explosion overpressure zone.

5. 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.

1.12 Detailed safety precautions to be taken for handling of natural gas

Process Safety Management

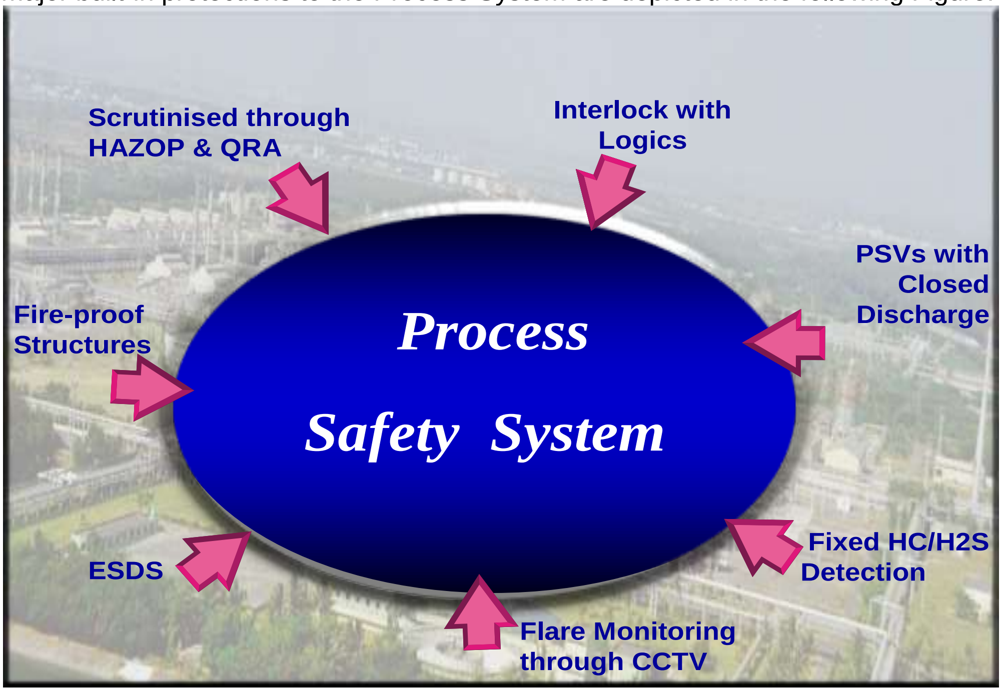
Incidents continue to occur in various industries worldwide that use highly hazardous chemicals in processes which exhibit toxic, reactive, flammable, or even explosive properties, or may exhibit a combination of these properties. The occurrence of process upsets in terms of parameters e.g. Temperature, Pressure, level, composition etc.

The Process Safety Management is intended to prevent process related hazardous event e.g. unexpected release of toxic, reactive, or flammable liquids and gases in processes involving highly hazardous chemicals. deals with which contains requirements for the management of hazards associated with processes using highly hazardous chemicals.

The process Safety System deals with several aspects in the Hazira Plant, which is categorized below:

1. Process Interlocks with logics
2. Basic Process Design has been scrutinized through Hazard & Operability Studies and Quantitative Risk Assessment(QRA) studies
3. All PSVs have closed discharge to the flare.
4. Process units are provided with fixed Hydrocarbon and Hydrogen Sulphide Detectors at strategic locations.
5. Continuous Flare monitoring is done through CCTV at Main Control Room.
6. Emergency Shut Down Systems (ESDS) are provided to affect shut down of individual units and also the whole plant in case of an emergency that necessitates shutdown.
7. All the process vessels are provided with Fire proofing of their skirts upto a height of 1 meter to protect vessels containing hydrocarbons from any outside fire engulfment.

   The major built-in protections to the Process System are depicted in the following Figure:



Other Measures are:

1. Availability of Standard Operating Procedures(SOPs)
2. Availability of Material Safety Data Sheets (MSDS) for each hazardous chemical.
3. Availability of safe Work Procedures for each critical job.
4. Management of Change Procedures
5. Pre-start up safety Reviews.
6. Availability of plant specific HSE information
7. Availability of Disaster Management Plan
8. Accident / Incident reporting, investigation & analysis system
9. HSE Auditing system
10. HSE Training
11. Occupational Health & Hygiene
12. Personal Protecting Equipments and many others