IndianOil

GUWAHATI REFINERY

Risk Assessment

For 80 TPH Circulating Fluidized Bed Combustion (CFBC) Pet Coke Boiler Project at IOC Guwahati Refinery, Noonmati, ASSAM

By

FS Academy Of Excellence

Simplify Safety & Success

www.trainerandsafetyconsultant.in

#32, A-1, Janapriya Apartment, Phase-5, Miyapur

Hyderabad

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03 March 2017	0	Initial Issue	F S Academy Team	Awadhesh Shah	C SubbaRao
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ACKNOWLEDGEMENT

At the outset, M/S F S Academy of Excellence – Hyderabad wish to express their deepest Gratitude to M/S Indian Oil Corporation GUWAHATI Unit One of the best Public Sector Undertaking for giving an opportunity for the Risk Assessment for 80 TPH Circulating Fluidized Bed Combustion (CFBC) Pet Coke Boiler Project.

We acknowledge the valuable assistance provided by Shri A K Kalita Manager – HSE, Boiler Dept. & other Dept. officers & staff who facilitated information flow in spite of their busy schedule.

Smt. Monika Das Chief Manager HSE Head of the Department & Shri Mayur Goswami Chief Manager – HSE & their staff deserve special thanks for providing all necessary documents for this Risk Assessment.

We wish M/S Indian Oil Corporation GUWAHATI Unit every success in all its endeavours.

Hanumanth Rao

Competent Person

for FS Academy Of Excellence
Simplify Safety & Success

FORWORD

All Industrial Accidents are predictable & Preventable. As a preventive measure of minimizing the chance of accidents to occur in hazardous installations and thereby reducing the possibility of injury, loss of material and degradation of the environment, it is necessary to use more searching and systematic methods for risk control to supplement the existing procedures. The inherent property of material used in the process and the processes themselves pose the potential hazard in any hazardous installation and hence a comprehensive risk assessment is needed for effective management of risk, which needs to be identified, assessed and eliminated or controlled.

Guwahati Refinery propose to install 80 TPH (net) Circulating Fluidized Bed Combustion (CFBC) Pet Coke Boiler Project under compliance of statutory requirement. IOC management offered M/S F S Academy of Excellence to prepare Risk Assessment Report as part of Accident prevention program.

In line with the provision of The Environment (Protection) Act 1986, these guidelines have been prepared with a view to assist employers to conduct an effective Risk assessment at the workplace. Risk assessment is an important tool for the prevention of occupational accidents and diseases and forms an integral part of the occupational safety and health management system. The guidelines provide simple steps which are required to be taken to identify the hazards the place of work, to determine the severity of any such risks and to implement control measures to eliminate and/or control the risks accordingly.

This will lead to a safe and healthy workplace which will not only benefit the workers but also improve productivity and competitiveness of the enterprise.

ABBREVIATIONS

LEL	:	Lower Explosion Limit
LFL	:	Lower Flammability Limit
UEL	:	Upper Explosion Limit
PHA	:	Preliminary Hazard Analysis
MCACA	:	Maximum Credible Accident and Consequence Analysis
HAZOP	:	Hazard Operability Studies
OISD	:	Oil Industry Safety Directorate
BLEVE	:	Boiling Liquid Expanding Vapor Explosion
SAFETI	:	Software for Assessment of Fire Explosion and Toxicity Index
DIPPR	:	Design Institute for Physical Property Data
AIChE		American Institute of Chemical Engineers
VOC		Volatile Organic Compound
ROV		Remotely Operated Valve
API		American Petroleum Institute
ALARP	:	As Low As Reasonably Practicable
LDO		Light Diesel oil
MoE&F		Ministry of Environment & Forest
ETP		Effluent Treatment Plant
ESP		Electro Static Precipitation
DCU		Delayed Coker Unit
SCADA		Supervisory Control and data acquisition
F & EI		Fire and Explosion Index

Proposed Project Details:-

<table>
<tr><td>1..Report Date</td><td>May 2017</td></tr>
<tr><td>2. Title & Subtitle</td><td>Risk Assessment for 80 TPH(net) Circulating Fluidized Bed Combustion (CFBC) Pet Coke Boiler Project at Guwahati Refinery, Noonmati, Assam.</td></tr>
<tr><td>3.Organization Name & Address</td><td>INDIANOIL COPRORATION LIMIED
GUWAHATI REFINERY
NOOONMATI GUWAHATI-781020</td></tr>
<tr><td>4.Reporting Organization Name & Address</td><td>FS Academy Of Excellence
Simplify Safety & Success
#32, A-1, Janapriya Apartment, Phase-5, Miyapur, Hyderabad.
www.trainerandsafetyconsultant.in
email:ashah@trainerandsafetyconsultant.in
hrsafeinfo@gmail.com
Phone/Fax:040-23046664</td></tr>
<tr><td>5. Nos of pages</td><td>95</td></tr>
<tr><td></td><td></td></tr>
<tr><td colspan="2">1. Risk Assessment studies were carried out for 80 TPH(net) Circulating Fluidized Bed Combustion (CFBC) Pet Coke proposed Boiler Project at Guwahati Refinery, Assam.
2. The exercise has been taken in compliance with MOE&F.
3. The methodology and guidelines given in INDIAN STANDARD HAZARD IDENTIFCATION AND RISK ANALYSIS - CODE OF PRACTICE (IS 15656:2006) were adopted for the analysis.
Risk assessment tools used in the assessment starting from Hazard identification, Analysis, Modeling & finally Risk reduction measures mentioned in Report.
The assessment was based on site visit and design related information provided by the client.
The findings are the result of the application of the best available techniques and practices applicable to the project. The conclusions drawn based on unbiased opinion of the consultant.</td></tr>
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Executive Summary

A Risk Assessment study was undertaken to assess the risk levels to for 80 TPH(net) Circulating Fluidized Bed Combustion (CFBC) Pet Coke Boiler Project.

The main findings are summarized below.

The analyzed outcomes from various potential hazardous scenarios were envisaged for 80 TPH(net) Circulating Fluidized Bed Combustion (CFBC) Pet Coke Boiler Project.

Chapter:1 describes briefly the scope of the assignment and the areas covered in the assignment.

Chapter: 2 & 3 covers the methodology adopted for Hazard Identification of LDO storage and Steam Boiler facilities using the Preliminary Hazard Analysis (PHA) and Maximum Credible Accident Analysis.

Chapter 4 is devoted to Consequence Analysis. The aspects covered in this chapter include accidental release of LDO resulting in jet fires and pool fires, vapor cloud explosion, leading to heat radiation & over pressure effects on the people, environment and assets. The damage distances for all the Maximum Credible Accident Analysis Scenarios are presented in tabular form covering heat radiation effects and overpressure effects. The damage contours for the scenarios due to heat radiation and overpressure effects are drawn to know the impact on the surroundings. Toxic effect of fluegas is also covered.

Remaining Chapters are devoted to Risk Analysis. The study has been done for the maximum credible accident scenarios by taking Individual and societal risk criteria, Release frequencies, Weather probability, Population and Ignition probability into consideration. The Individual risk contours and Societal risk FN curve are presented.

Based on presented observations on the Risk Assessment study we given the recommendations, which will help in enhancement of safety of the LDO and Pet Coke boiler.

The risk was assessed and found to range within permissible limit. This level has been compared with criteria for new hazardous industries given in IS 15656: 2006, and was found to be above the negligible range.

As the risk number is relative, mitigation measures have been given for further reduction in the risk levels.

Boiler emission found as per MoE&F guidelines.

Chapter -1

INRODUCTION:

Risk Assessment is the process of evaluating the risks to safety and health arising from hazards at work. This forms an integral part of the **Occupational Safety, Health** & Environment whereby all hazards are identified and evaluated taking into consideration existing control measures.

The ultimate aim is to eliminate or minimise risks at work through tightening of control measures. The risk assessment process may also identify the training needs of employees and contribute towards the building of a preventive safety and health culture. In this endeavour, the commitment of management, employees and competent persons are important in carrying out a proper risk assessment.

Risk Assessment is an important tool in the creation of safe working conditions thereby increasing productivity and employees' morale while reducing injury, sick leaves and manpower turnover. It also aims at cost reduction as accidents and occupational Health are costly to the injured/diseased person, the close family, the organization as well as the Nation.

1. A : Project Description :

As data given by IOC, the proposed installation will be located at INDIANOIL COPRORATION LIMIED GUWAHATI REFINERY, NOOONMATI GUWAHATI-781020.

1.A .i PROJECT BACKGROUND

Guwahati Refinery is the country's first public sector Refinery as well as Indian Oils first Refinery serving the nation since 1962, built with Rumanian assistance. The crude processing capacity of this Refinery is 1 MMTPA and the Refinery is designed to process a mix of OIL and ONGC crude.

In order to meet the future steam and power demand Indian oil Corporation (IndianOil) Limited, proposes to set up 80TPH (net) CFBC boiler utilizing Pet coke generated in DCU (Delayed Coker Unit). Indian oil corporation limited (IOCL) has appointed STEAG ENERGY SERVICES (India) private limited (SESI) as a Consultant for the installation of 80TPH (net) Petcoke based CFBC boiler at Noonmati, Guwahati refinery , Assam.

1.A. ii. PROCESS OF MIX OF OIL, ONGC & IMPORTED CRUDE: DESCRIPTION:

Guwahati Refinery thermal Power station consists of the following boilers:

Boiler	Installed capacity (MCR), TPH	Make	Yr. of commissioning	Operating pressure, Kg/cm2-g	Operating Temp, Deg C
Boiler 3	20	Rumanian	1962-64	39	450
Boiler 4	20	Rumanian	1962-64	39	450
Boiler 5	40	M/s IJT	1994	39	450
Boiler 6	50	M/s Thermax	2004	39	450
Boiler 7	50	M/s Thermax	2004	39	450

The Rumanian boilers (boiler 3 and boiler4) have been in operation for the past 50 years and have outlived their services and are operating at low efficiency of 71%-74% (against design efficiency of 89%) with a maximum capacity of 15-16 TPH against MCR of 20 TPH. Also, spares of these boilers are not available for carrying out proper maintenance and RLA study of these boilers carried out by external agencies, M/s Energo engineering projects ltd, has declared that these boilers must be condemned.

With the situation as above, the opportunity of utilizing Pet coke generated in DCU, as fuel for boilers for steam generation was explored and it was found that not only it will meet the future steam demand of the refinery, but also provide significant GRM benefit, since the price of Pet coke is about $1/3^{rd}$ the price of fuel oil.

Also with the addition of new units like IndadeptG and revamp of INDMAX for capacity augmentation, power demand of the refinery is going to increase from around 14 MW to around 16.3 MW. Hence 80 TPH capacity is finalized as the capacity keeping in mind future scenario and additional operational cushion. The detail work up of steam power balance and refinery fuel balance, for finalizing 80 TPH capacity. A summary of the work up is presented below:

SUMMARY	CASE 1
CAPACITY, TMTPA	1000
PETCOKE GENERATED, TMTPA	60.4
MAX BOILER CAPACITY WITH AVAILABLE PETCOKE,TPH	78.0
BOILER OPERATING CAPACITY WITH PRESENT REFINERY FUEL BALANCE,TPH	60.1
PROPOSED CAPACITY,TPH	80.0

1.A.iii. SOURCE OF FUEL

Presently Pet coke generated in DCU is being sold to a third party. With the available Pet coke the estimated steam generation capacity will be around 78 TPH at 41 kg/cm^2 (g) and 455 deg C which will be able to meet the projected steam and power demand of the refinery. Hence pet coke is considered as the source of the fuel for proposed project from the point of view of long-term availability.

1.A.iv. SELECTION OF TECHNOLOGY

Alternate proven technologies namely pulverized combustion (CFBC) have been studied along with their relative merits and demerits. One of CFBC's key advantages is its ability to use a wider range of fuels, including pet coke. Another advantage of CFBC is that it does not slag as the combustion temperature in CFBC boilers is low (800C to 900C) and reduces the NOx emissions. To maintain the level of SO_2 emissions, abatement technology such as limestone injection for CFBC boilers are incorporated to keep emissions within statutory limits.

1.A.v UNIT SIZE

Based on the projected steam and power demand, the capacity of the steam generator is as follows:

Steam generation capacity	:	80 TPH (net)
Main steam pressure	:	41 bar
Main steam temperature	:	455^0C (+ 5^0C)

1.A.vi. PLANT LAYOUT

Plant layout has been developed optimizing various facilities including ash disposal to accommodate in approximately 3.04 acres of land. The plant will be located on the north side of the refinery. The boiler is located at a distance of 200 mts from the fuel oil tanks in the line with OISD guidelines.

The finished ground level (FGL) for the proposed project is 75 meters.

1.A.vii BASIC UTILITES

A) WATER

The water requirement for the project shall be met from the existing facilities. 10 m^3/hr. additional make up water will be required in the refinery after the implementation of pet-coke boiler project, which will be sourced from the recycled water. However, post pet-coke boiler project, the fresh water requirement will be reduced with more recycling of the waste water.

B) FUEL

The estimated pet coke requirement for the proposed plant is calculated at main steam parameters, feed water parameters and GCV of pet coke. The pet coke requirement for proposed project is 8.055 TPH which will be sourced from the existing Delayed Coker Unit of Guwahati Refinery.

1. ENVIRONMENTAL ASPECTS

1.1 GENERAL

The environmental impact of the proposed plant covering the following aspects is discussed:

a) Air pollution
b) Water pollution
c) Noise pollution
d) Pollution monitoring system

1.2 AIR POLLUTION

The air pollutants from the proposed units are:

a) Dust particulates from fly ash in flue gas
b) Sulphur dioxide in flue gas
c) Nitrogen oxides in flue gas
d) Pet coke dust particles' during storage/handling
e) Ash dust

For thermal power stations, Indian emission regulations and the environment (protection) rules, 1986 vide gazette notification dated 8thdec 15, stipulate the limits for particulate matter emission, as furnished in the below table and the minimum stack height to be maintained to keep the sulphur dioxide level in the ambient air within the air quality standards is also furnished below.

STANDARD FOR PARTICULATE MATTER EMISSION

Parameter	Standards
TPPs(units <200MW) to be installed from 1st January, 2017	30mg/nm3

STACK HEIGHT REQUIREMENT FOR SULPHER DIOXIDE CONTROL

BOILER SIZE	STACK HEIGHT
Less than 200MW	H=14(Q)0.3
200MW&more to less than 500 MW	220m
500 MW and more	275m

Where Q= sulphur dioxide emission rate in kg/hr
H=stack height in meters
With this, the stack height for the proposed 80 TPH boiler will be 70 meters.
The height of the stack, which disperse the pollutants, has been fixed based on the above guidelines of the Indian emission regulations. The electrostatic precipitator removes most of the fly ash from the flue gas, thereby limiting the quality of fly ash emitted

to atmosphere. The ESP will be designed for outlet dust concentration of maximum 30mg/nm3.

1.3 NO_X & SOX EMISSIONS

By selecting CFBC firing technology for the steam generator, NOx has been limited to 100 mg/Nm^3 and therefore, no additional equipment for NOx control is required.

SO_2 concentration level from this CFBC boiler will be below 100 mg/Nm^3 which is sufficiently below permissible limits based on the sulphur content of the Pet coke. As such there is no requirement for the installing any flue gas de -sulphurising equipment since lime stone will be used for sulphur absorption.

Dust due to Pet coke handling would be minimized by providing suitable dust suppression/extraction systems at crushed house, junction towers etc. for the Pet coke stockyard, dust suppression system is to be provided. Boiler bunkers are to be provided with ventilation system with bag filters to trap the dust in the bunkers.

1.4 a. WATER POLLUTION

The water pollutants from the proposed units are

1)	Boiler blow down
2)	Dust suppression system-pet coke yard run off
3)	Oil handling area runoff water

The water effluents will be duly treated in existing ETP to meet the stipulations of central/state pollution control board.

1.4 b. BOILER BLOW DOWN

The salient characteristics of the blow down water from the point of view of pollution are the pH and temperature of water since suspended solids are negligible. The pH would be in the range of 9.5 to 10.3 and the temperature of the blow down water would be approximately around 3% of steam generated per hour.

1.4 c. DUST SUPPRESSION SYSTEM

Waste water at the Pet coke yard suppression system and leached water will be treated in ETP.

1.4.c. OIL HANDLING AREA RUN OFF

The oil in wastewater will be treated in existing ETP.

1.5 NOISE POLLUTION

The boiler and equipment will be so specified and designed to minimize noise pollution. Major noise producing equipment such as compressors fans, motors will be designed to limit the noise levels to <75 dba at 1m from the equipment and if required it has to be provided with suitable noise abatement enclosures to achieve this. Equipment will be statically and dynamically balanced to eliminate any vibration that can lead to noise generation. Blow off valves; discharge pipes, relief valves and other noise producing static equipment will be equipped with silencers. Pipelines will be suitably sized to avoid excess velocities that can lead to noise generation. Wherever necessary, insulation will be provided for reducing heat loss and noise pollution.

1.6 POLLUTION MONITORING AND SURVEILLANCE SYSTEMS

Air quality monitoring program

The purpose of air quality monitoring is acquisition of data for comparison against prescribed standards, thereby ensuring that the quality of air is maintained within the permissible levels.

It is proposed to monitor the following from the stack emission:

✓ Suspended particulate matter
✓ Sulphur dioxide
✓ Oxides of nitrogen

For this purpose it is proposed to acquire following monitoring equipment's:

a) High volume sampler for monitoring particulate matter
b) Sulphur dioxide monitor
c) NOx monitor

It is also proposed to monitor particulate emission with the continuous stack particulate matter monitoring system. The stack monitoring data would be utilized to keep a continuous check on the performance of ESPs.

1.7 WATER QUALITY MONITORING PROGRAM

The monitoring schedule and parameters to be analysed in the effluent generated from various sources is presented in table below:

Monitoring schedule for effluents in boiler

Source of effluent	frequency of analysis	Parameters for examination
Boiler blow down	Weekly	pH, suspended solids, oil and grease, copper, iron

Qualified persons would be in charge of the system for monitoring of the parameters. Adequate instruments would be provided to monitor the parameters.

1.8 IMPACT OF POLLUTION /ENVIRONMENTAL DISTURBANCE

Since all necessary pollution control measures to maintain the emission levels of dust particles and sulphur dioxide within the permissible limits would be taken and necessary treatment of effluents would be carried out, there would be no adverse impact on either air or water quality in and around the power station site on account of installation of the proposed plant.

1.B : Methodology and Scope of Risk Analysis:

The methodology and approach for the studies are based on Indian Standards **IS 15656: 2006**HAZARD IDENTIFICATION & RISK ANALYSIS – CODE OF PRACTICE. The techniques use safety-related data, practical experience and human factors even while considering scientific based quantitative techniques. The results provide an independent and objective assessment of various types of hazards.

The scope of work includes:

1. Identification of Hazards
2. Credible accidental events.
3. Consequence modeling
4. Consequence Analysis
5. Risk Analysis.

The following procedure has been adopted:-

A) Data Collection
B) Hazard Identification
C) Consequence Analysis
D) Damage contour mapping on the plot plan
C) Recommendations for risk reduction

Visited Guwahati Refinery on Dated 07/02/2017 & collected following the drawings:-

ETGO43-SESI-C-PLOTPLAN-001,REV.06TENTATIVE LOCATION OF PETCOKE BOILER AND PIPECONVEYOR ROUTE AT GR.

* Process Flow diagram
* Metrological Data

The Software Part was conducted by CSIR-IICT using internationally accepted ‘PHAST RISK MICRO 6.7’ software.

The areas covered in this assignment are:

i) LDO Storage tank
ii) Fluegas Pipelines
iii) Steam Boiler

The Risk Analysis report is prepared taking into consideration of LDO storage tank, Fluegas Pipelines and Steam Boiler facilities at Noonmati, Guwahati refinery, Assam.

Pet Coke (Petroleum Coke) Storage, handling, Health& Fire Hazards:

Pet Coke(Petroleum coke)shall be handled by Conveyor up to Firing & it is a co-product of several distillation processes used in refinery heavy crude oil. It is black –colored solid composed primary of carbon, sulfur, metals & nonvolatile inorganic compounds.

It is chemically inert but pose human health & environment Risks including release of common pollutants, hazardous substances & high level of Green house gas carbon dioxide.

It does not vaporize in to atmosphere &doesn't react chemically in presence of water.

The handling of pet coke may also create instances of reduced air quality due to release of fugitive dust in to atmosphere. If released to the aquatic environment, pet coke incorporates in to sediment or floats on the surface, depending on the particle size density in relation to water.

Environmental Toxicity

Most eco-toxicity analyses of pet coke, as referenced by EPA, find that it has a low potential to cause adverse effect on aquatic or terrestrial environments. The environmental effects of pet coke have been tested along various pathways for exposure in the environment, including both aquatic and terrestrial endpoints in plants and animals. Aquatic and terrestrial toxicity tests have been performed to assess the hazard of pet coke releases to representative aquatic organisms and terrestrial soil-dwelling invertebrates and plants.

Human Health Effects

Most toxicity analyses of pet coke, as referenced by EPA, find it has a low health hazard potential in humans, with no observed carcinogenic, reproductive, or developmental effects. Only animal case studies of repeated-dose and chronic inhalation have shown respiratory inflammation attributed to the non-specific effects of dust particles rather than the specific effects of pet coke.

Inhalation and skin contact with pet coke were assessed to be the most likely exposure routes to humans. Most repeated-dose inhalation exposure studies (on rats and primates) found cases of irreversible respiratory effects and significantly increased lung weights. These effects were considered to be non-specific responses of the respiratory tract to high concentrations of dust particles rather than compound specific-induced effects. Pet coke was not found to be carcinogenic via inhalation. No excess skin or visceral cancers were observed in a lifetime skin painting study. Pet coke was not found to produce genetic mutations in bacteria and mammalian cells in standard in vitro toxicity tests or to produce chromosome aberrations of bone marrow in standard in vivo toxicity tests. Pet coke was not found to produce any reproductive or developmental effects following repeated inhalation or exposure to the skin.

Reactivity

Pet coke is generally stable under normal conditions; however, the substance has the potential to become flammable or explosive. Emissions from the combustion—either accidentally or purposefully—of pet coke can have impacts on human health and the environment, including the release of common pollutants, hazardous substances, and greenhouse gases.

When pet coke is combusted, common pollutants and hazardous decomposition products may be produced such as carbon monoxide, carbon dioxide, sulfur dioxide, nitrogen oxides, particulate matter, and heavy metals, depending upon the chemical composition of the feedstock for the chemical composition of pet coke). These releases may take place unintentionally, through the natural or unintended combustion of surface or air-borne dust particles, or intentionally, through the combustion of pet coke for electrical power generation or other like purposes.

Pet coke's use as a fuel is criticized because it commonly has higher greenhouse gas emissions relative to the amount of heat it generates when burned. Presents potential carbon dioxide (CO2) emissions for pet coke in comparison to metallurgical coke and several grades of steam coal. When pet coke or coal combust, CO2 forms from one carbon atom (C) uniting with two oxygen atoms.

Assuming complete combustion, 1 pound of carbon combines with 2.667pounds of oxygen to produce 3.667 pounds of carbon dioxide. Pet coke with a carbon content of90% and a heating value of 14,200 Btu per pound emits about 232 pounds of carbon dioxide per million Btu when completely burned.

Comparatively, Powder River Basin coal with a carbon content of 48% and a heating value of 8,800 Btu per pound emits about 202 pounds of carbondioxide per million Btu when completely burned, or 15% less than pet coke. Because coal has high hydrogen-to-carbon ratio compared to pet coke, part of its energy content comes from the combustion of hydrogen that is emitted as water vapor instead of carbon dioxide.

Pet coke handling will carry out from Terminal to Proposed boiler house.

Pet Coke & Fluidize Bed Combustion:

The most efficient method of directly burning Pet Coke is in a fluidized bed combustor (FBC). This is also the most versatile since the system can cope with a wide range of fuels and a range of moisture contents.
The basis for a FBC system is a bed of an inert mineral such as limestone through which air is blown from below. The air is pumped through the bed in sufficient volume and at a high enough pressure to entrain the small particles of the bed material so that they behave much like a fluid.
The combustion chamber of a fluidized bed plant is shaped so that above a certain height the air velocity drops below that necessary to entrain the particles. This helps retain the bulk of the entrained bed material towards the bottom of the chamber. Once the bed becomes hot, combustible material introduced into it will burn, generating heat as in a more conventional furnace.
The fluidized bed has two distinct advantages for Pet Coke combustion: First, it has the ability to burn a variety of different fuels without affecting performance. Second is the ability to introduce chemical reactants into the fluidized bed to remove possible pollutants.
In FBC plants burning coal, for example, limestone can be added to capture sulphur and prevent its release to the atmosphere as sulphur dioxide. Power stations have been built that are devoted specifically to this fuel source and these plants use FBCs.
Of the four different types of combustion technologies discussed above, the FBC technology is best suited for a range of small and medium scale operation for combined heat and power.
With technological advancements the FBC boilers give efficiency of as high as 80-82% and can be used for a wide variety of fuels.

Mechanism of Fluidized Bed Combustion
When an evenly distributed air or gas is passed upward through a finely divided bed of solid particles such as sand supported on a fine mesh, the particles remain undisturbed at low velocities. As the air velocity is gradually increased, a stage is reached when the individual particles are suspended in the air stream and the bed is called "*fluidized*".

At higher velocities, bubbles disappear, and particles are blown out of the bed. Some amounts of particles have to be re-circulated to maintain a stable system and is called as "*circulating fluidized bed*".
The fluidized bed combustion (FBC) takes place at about 840°C to 950°C. Since this temperature is much below the ash fusion temperature, melting of ash and associated problems are avoided. The lower combustion temperature

is achieved because of high coefficient of heat transfer due to rapid mixing in the fluidized bed and effective extraction of heat from the bed through in-bed heat transfer tubes and walls of the bed. The gas velocity is maintained between minimum fluidization velocity and particle entrainment velocity. This ensures a stable operation of the bed and avoids particle entrainment in the gas stream.

Any combustion process requires three "**T**"s - that is Time, Temperature and Turbulence. In FBC, turbulence is promoted by fluidization. Improved mixing generates evenly distributed heat at lower temperature. Residence time is many times higher than conventional grate firing. Thus an FBC system releases heat more efficiently at lower temperatures. Since limestone can also be used as particle bed (in case the fuel with sulphur content is used), control of SOx and NOx emissions in the combustion chamber is achieved without any additional control equipment.

Plant Details:

The plant details as given by IOC Guwahati are as follows.

S. No.	**Description**	**Capacity m^3**	**Pressure, bar g**	**Temp , ^{0}C**
1	LDO storage tank	500	Atm.	35
2	LDO tank leak of 25 mm, 50 mm and 100 mm	500	3.0	35
3	Petcokefluegas pipeline (Pipeline dia. 500 mm)	62	5.0	135
4	LDO fluegas pipeline (Pipeline dia. 500 mm)	62	5.0	500
5	Steam Boiler	50	56.0	455

1.B.1. Population

The population inside the plant and the surrounding area is as follows:

S. No.		Day	Night
1.	**Inside the plant**	**70**	**50**

1.B.2. Chemical Inventory

The chemical inventory at this plant is LDO and PETCOKE. This data is purely based on the information provided by the IOC Guwahati.

The composition of LDO for our calculation is taken as follows:

Component	**Composition (vol%)**
Nonane	75
Xylene	25

The composition of LDO fluegas for our calculation is taken as follows:

Component	**Composition (vol%)**
Nitrogen	80
Carbon Dioxide	15
Oxygen	4.953
Carbon Monoxide	0.015
Nitrogen Dioxide	0.01
Sulphur Dioxide	0.022

The composition of Petcokefluegas for our calculation is taken as follows:

Component	**Composition (vol%)**
Nitrogen	76
Carbon Dioxide	11
Oxygen	5
Water	5
Carbon Monoxide	6
Nitrogen Dioxide	1
Sulphur Dioxide	1

CHAPTER 2: Identification of Hazards.

A specific legislation covering major hazard activities has been enforced by Govt. of India in 1989 in conjunction with Environment Protection Act, 1986. This is referred here as GOI rules 1989. For the purpose of identifying major hazard installations the Rules employ certain criteria based on toxic, flammable and explosive properties of chemicals.
Broadly hazards can be classified here as considering Pet Coke Boiler Operation:-
1. Fire
2. Explosion
3.OccupationalHealth
4. Environment

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

SNo.	**F&EI Range**	**Degree of Hazard**
1	0-60	Light
2	61-96	Moderate
3	97-127	Intermediate
4	128-158	Heavy
5	159-up	Severe

Hazard Identification Methods.
Hazards are present in any Boiler installation or unit that handles Pet Coke or stores flammable materials or operate high pressure & Temperature.
The mere existence of hazards, however, does not automatically imply the existence of risk.
The hazard assessment was based on the following methodologies.
a.) Inventory guidelines based on The Manufacture, Storage & Import of Hazardous Chemicals (Amendment) Rules, 2000 of the Environment (Protection) Act, 1986;

b.) Hazards associated with Boiler operation is as under:-

Hazards	Cause	Effect	Action
HIGH SUPER HEATER TEMPERATURE	-High excess air -Low feed water tempr or HP Heater not in service at constant firing load - Sudden increase in firing rate to increase steam pressure. - Inadequate spray water.	+ ve turbine expansion -Creep rate increase in tube metal, turbine parts & steam piping.	-Always keep HP heater In line when optimum loading of Pet Coke. -Slow down firing rate to limit the S. H Tempr. -Reduce excess air if more. -Check Spray control

Hazards	Cause	Effects	Action
LOW SUPER HEATER TEMPARATURE	-Soot deposit on super heater tube -Inadequate Air flow -High Spray -Sudden increase in Load & Pressure drop - High drum level	-Turbine expansion may be –ve. - May induce thermal stresses in S.H	- Check air flow, increase if necessary -Reduce spray, if more -Avoid sudden rise in load to boiler pressure drop. -Check feed water Tempr.

Hazards	Cause	Effects	Actions
Boiler pressure high	-Sudden drop in load/Steam flow - Uncontrolled fuel entry. - Turbine/Prime mover trips	Disturbance in drum water level. -Safety Valve may disturbed if pressure rise in frequent way - Boiler may trip at high pressure	- Open start up vent to control the pressure. -Control fuel, air, input & drum level - It TG/Prime mover has tripped first, allow boiler to trip but safety valve may lift - TG warm up vent put in auto, if pressure exceeds then it will be open accordingly. - Use Electromagnetic safety Valve to limit the frequent operation of spring loaded safety valve.
Hazards	Cause	Effects	Actions
BED TEMPR HIGH	-HIGH cv & LOW PET COCK/FUEL -Low PA/SD/SA flow - Sudden change in	-Chances of clinker formation. - Chances of refectory failure.	-Control bed temperature by circulation of Ash. - Increase PA/SA flow

	Load - Ash recirculation system trouble - Faulty bed thermocouple	- Chances of screen tube failure.	& reduce the Load by cutting feeder. - Feeder should be triped if Bed tempr increase beyond design. - If Bed tempr exceeds further than allow boiler to trip to avoid clinker formation. -Check the bed thercuople.

Hazards	Cause	Effects	Actions
BED TEMPR LOW	-High PA/FD/SA Flow w.r t Load. -Low & high ash content coal used. -Coke feeder trips or overfeeding of coal in to furnace. -Faulty bed thermocouple. -Water /screen/evaporator tube Leakage	-Boiler steam flow reduce. -Super heater tempr. drop. -Furnace draught fluctuate. -	-Boiler PA/FD/SA flow reduce if excessive. -Check bed thermocouple. -stop bed material supply if running. - check any leakage sound from furnace.

Hazards	Cause	Effects	Actions
Water wall/screen tube/evaporator tube failure	-Starved water wall - Block tube, erode tube, pitted tube, salt deposits	-Hissing steam leakage Noise from Boiler -Unstable flame fluctuating draught. -Bed temperature drops sharply . -Increase ID fan loading - Flue gas outlet tempr. decreased.	-Take shut down the boiler when boiler tube leakage noticed & maintain the drum level.

Hazards	Cause	Effects	Actions
SUPER HEATER TUBE FAILURE	-Inadequate steam flow & high gas temperature during hot start up. Erosion of tube due to high excess air. -Blocked tube -Starvation of tube -Salt deposition due to high water level in drum.	-Hissing noise noticed -Flue gas Tempr drops - Overloading of ID Fan	- As soon as leakage noticed, start reducing the load & trip the boiler - Try to locate leakage through manhole, before the boiler depressurized. - Boiler to be forced cooled when S.H. leakage noticed.

Hazards	Cause	Effects	Actions
FLAME FAILURE	-Dirty oil/gas burner -Faulty Flame sensor - Furnace pressure high -Low combustion Air	-Boiler will on Flame failure. - Chances of Furnace Explosion if unburn fuel moisture entered in Furnace. -Steam pressure & temperature may fall. -variation in Drum level.	-Purge the Boiler putting burner Back & purge burner as per cycle time. -Check the flame sensor & clean & clean the Photocell if found dirty. -Check the igniter circuit & H V transformer. -Clean the burner tip & nozzle regularly. -Ensure the Healthiness of explosion Vent & door

EXPLOSION HAZARDS ANALYSIS:

Hazards	Cause	Effects	Actions
Furnace Explosions	Accumulation of un burn fuel during lit up/start up of boiler.	-Improper burning. - Inadequate Air. SecondaryCombustion	-Always purge the boiler with min 40% full load air for about 5 minutes. No cut short in purging allowed. -Adjust fuel air ratio.
Over Pressure	Operating Deviation	Explosion	Standby Pressure Relive Valve
Over Temperature	Operating Deviation Human Error	Explosion	Alarm,High Alarm, High-High Alarm. & Trip Devices

- ➢ Many CFBC Boilers have suffered furnace explosions. Apart from causing severe losses to business, the occurrences have shaken the confidence of professional.
- ➢ PET COCK DUST EXPLOSIONS:
- A Dust explosions is the rapid combustion of a dust cloud. In a confined or nearly confined space, the Explosion is characterized by relatively rapid development of pressure with flame propagation & the evolution of large quantity of heat &reaction products. The required oxygen for this combustion is mostly supplied by the combustion air.
- The condition necessary for a dust explosions is a simultaneous presence of dust cloud of proper concentration in air that will support combustion & suitable ignition source.
- Minor flue gas explosions are called puffs or backs.
- ➢ EXPLOSIONS PREVENTION:

  -Ensure that Furnace is completely purged of Explosive mixture before Firing.

  -Fuel supply should be fed immediately if Fire is not established & resurging is done before restart.

  - Correct air fuel ratio is to be maintained so that dust concentration should be under explosive limits.

  -Explosion doors/vents/Bleed valve (in AFBC) must be perfectly operational. All protections, interlocks & fan drives sequence to be checked in each shut down as per operating schedule/recommendations.

CHAPTER :3 Credible Accidental events

An accident scenario forms a focal point of which enables use of the wisdom of hindsight and state-of-the-art knowledge to evaluate its impact in forecasting accident situations. The scenario is a reference point, as well as a link between the past, present and future.
Such scenarios are generated based on the properties of chemicals handled by industry, physical conditions under which reactions occur or products are stored, as well as geometries/material strengths of vessels and conduits, in-built valves and safety arrangements, etc.
External factors, such as site characteristics (topography, presence of trees, ponds, rivers in the vicinity, proximity to other industries or neighborhoods, etc.) and meteorological conditions, need also be considered.
In using maximum-credible accident scenarios(MCAS), the central criterion is what constitutes a credible accident. A credible accident is defined as: an accident that is within the realm of possibility to cause significant damage (at least one fatality).

Comprises both parameters — probable damage caused by an accident and its probability of occurrence. There may be types of accidents that may occur, but would cause very little damage. And there may be others that may cause great damage, but would have a very low probability of occurrence. Both would be considered accidents.
A credible accident scenario should contain two sets of information: a description of the situation and its probability of occurrence.

The description must not reduce the freedom of finding solutions and must not restrict the means available for solution. A good accident scenario should describe the most prime cause of an event. An example: Define a leak rate instead of an explosion pressure, because here, one could go further and describe the cause of the leak as well.
There may be number of accidents that occur quite frequently, but due to proper control measures or lesser quantities of chemicals released, they are controlled effectively. A few examples are leak from a gasket, pump or valve, release of a chemical from a vent or relief valve, and fire in a pump due to overheating. These accidents generally are controlled before they escalate by using control systems and monitoring devices — used because such piping and equipment are known to sometimes fail or malfunction, leading to problems.
On the other hand, there are less problematic areas/units that are generally ignored or not given due attention. This is because few or even no accidents

have been reported. In such situations, even a small leak may lead to a disastrous accident. Past accident analysis reveals that most of the catastrophic accidents occurred in ignorance (the accident was not foreseen) and either in areas marked yellow (not highly hazardous) or where the control arrangements were inadequate (control measures based on less credible scenarios).

In the present study, Maximum Credible Accident (MCA) Analysis is used for determining credible accident scenarios in the event of release of hazardous materials.

Maximum Credible Accident (MCA) constitutes a credible accident with maximum damage distance, which is believed to be probable. MCA analysis does not include quantification of the probability of occurrence of an accident. In practice, the selection of accident scenarios for MCA analysis is carried out on the basis of engineering judgment and past accident analysis.

The credible accident scenarios in this unit are:

i) Turbulent Jet fire takes place due to leak from pressurized liquid and vapor vessel/lines and upon ignition. The TJF will result in flare, which can cause damage due to heat radiation and over pressure.

ii) Pool formation takes place due to leakage from liquid vessel/lines. The pool on ignition will result in pool fire, which can cause damage due to heat radiation.

iii) Flashing liquid release due to rupture in liquid lines. These vapours can lead to flare if immediate ignition source is available. Otherwise the vapour can disperse in the atmosphere leading to flammable vapour cloud formation and unconfined vapour cloud explosion.

3.2.1. Assumptions made

Certain assumptions are made during the course of study and are listed below:

1..LDO storage tank location is as per plot plan submitted by IOC.

The fluegas pipeline sizes are considered based on the discussions with IOC Guwahati.

The credible accident scenarios expected in this facility are given below:

S.No.	Scenario
	LDO storage tank
1	25 mm leak
2	50 mm leak
3	100 mm leak
4	Catastrophic rupture of LDO 500 m^3 tank
	Fluegas 500 mm pipeline
5	Rupture of 500 mm LDO Fluegas Pipeline
6	Rupture of 500 mm Pet coke Fluegas Pipeline
	Steam Boiler
7	Blast of Steam Boiler

CHAPTER :4 Consequences Analysis

The accidental release of hazardous chemicals leads to subsequent events, which actually cause the damage. The damages are caused by

- Heat radiation
- Over pressure effects from explosions and
- Toxic effects

Heat radiation and overpressure effects are applicable to the LDO storage tank and Steam Boiler. Since LDO and Pet coke flue gases are handled in this unit, there is toxic effect. The nature of damage and extent of damage resulting from an accidental release of a chemical depend on several factors like nature of material, storage conditions, release conditions, atmospheric conditions etc. The sequence of probable events following the release of a material is schematically shown in **Fig 4.1.**

The best way of understanding and quantifying the physical effects of any accidental release of material from their normal containment is by means of mathematical modeling. This is achieved by describing the physical situations by mathematical equations for idealized conditions and by making corrections for deviation of the practical situations from ideal conditions.

In the present study, PHAST RISK MICRO 6.7 software from DNV Technica, London, is used. These models for various steps are described in the following sub-sections.

4.2 The Release Models and Source strength

From the flowchart (Fig. 4.1), it is clear that the first aspect to be considered is the modeling of release of hazardous substances. This depends on the nature of failure of the unit, content of the unit, and temperature and pressure conditions of the unit. The release may be instantaneous due to catastrophic failure of storage unit or continuous due to leakage or rupture of some component of the storage facility. The material discharged may be gas or liquid or the discharge could be manifested through two-phase flow.

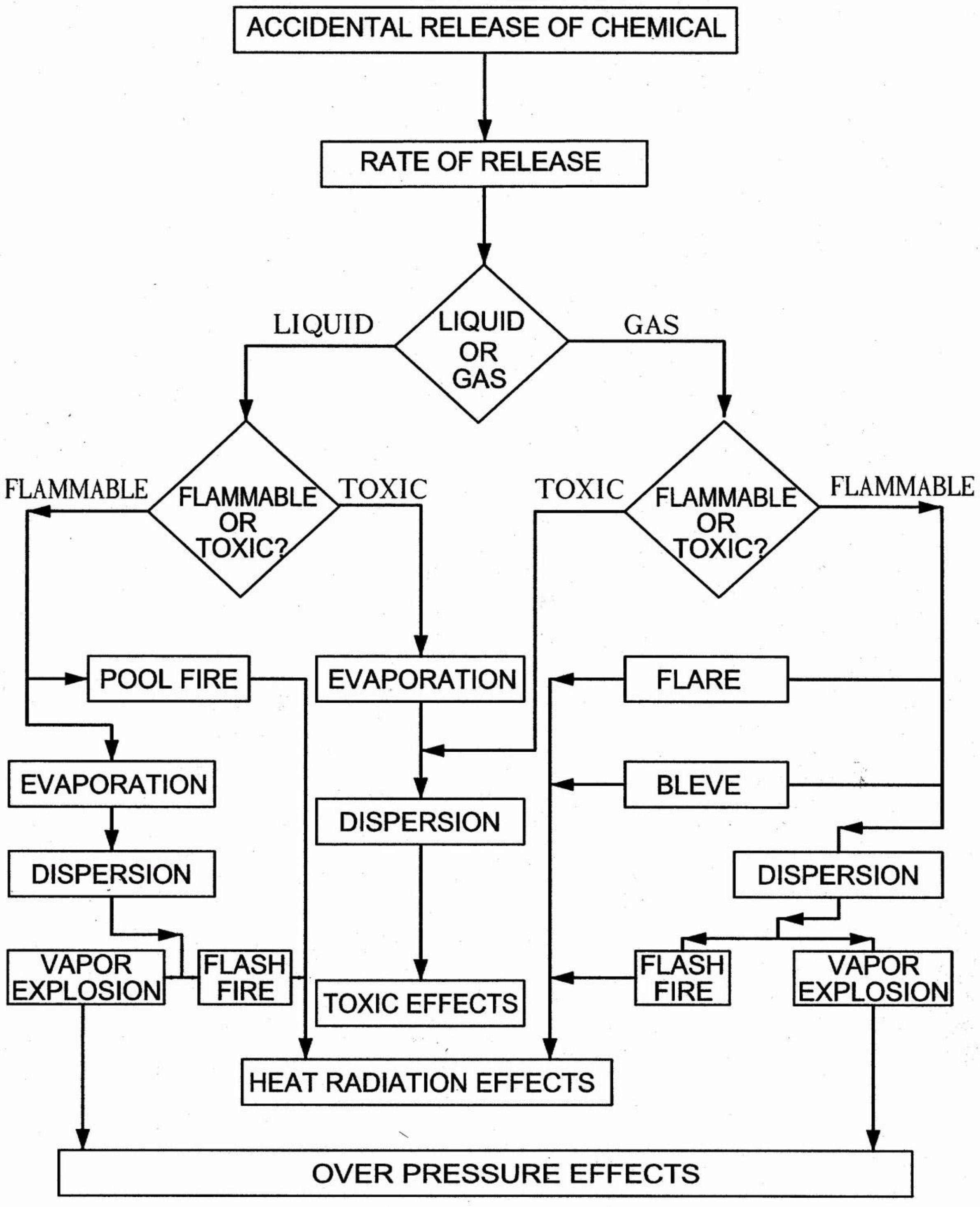


Fig.4.1. Probable events of release of chemical

4.2.1. Impact of Thermal Radiation: When a flammable material is released into atmosphere and if a source of ignition is available, this may result in a fire. Depending on the conditions, there are several ways in which these can occur, ultimately causing damage due to heat radiation. Damage due to heat radiation to both human beings and process plants are given in **Table 4.2.**

Table4.2: Damage due to incident radiation

Radiation level (within the fire)	**Damage to Equipment**	**Damage to People**
37.5 kW/m^2	Severe damage to unprotected plant	100% lethality in 1 min; 1% lethality in 10 sec
12.5 kW/m^2	Minimum energy to initiate secondary fires; Melts plastic tubing	1% lethality in 1 min.
4.0 kW/m^2		Injury to people
1.75 kW/m^2		Pain threshold reaches after 60 seconds
0.7 kW/m^2		Exposed skin reddens and burns on prolonged exposure

-31Thermal radiation and the extent of burn injury depend on the time duration of exposure. Exposure time, thermal load and lethality are calculated by probit equation. $Y = -36.8+2.5 \ln(t\, I^{4/3})$

Y is the probit value

t is time in seconds

and

I is radiation in (W/sq.m)

The lethality levels for different thermal loads and different exposure times are given in **Table 4.3.**

Table 4.3: Exposure time, heat radiation and damage levels

Intensity of radiation, kW/m^2	Exposure time, sec	% Lethality	% First degree burns
37.5	28	100	-
12.5	120	100	-
4.0	550	100	-
37.5	4	1	-
12.5	15	1	-
4.0	66	1	-
37.5	7	-	100
12.5	27	-	100
4.0	123	-	100
37.5	1	-	1
12.5	5	-	1
4.0	21	-	1

The above exposure times are for unprotected persons. For protected persons, the corresponding times will be 50% to 60% higher.

4.2.2. Impact of Overpressure: When a flammable vapor cloud ignites, under certain conditions it may result in deflagration thus causing damage due to over pressure effects. The damage depends on the level of overpressure as indicated in **Table4.4**.

Table:4.4 Damage due to overpressure

Overpressure	Damage to Equipment	Damage to People
0.3 bar	Heavy structural damage	100% lethality
0.1 bar	Repairable structural damage	50% lethality
0.03 bar	Major glass damage	Threshold lethality
0.1 bar	10% glass damage	Severe lung damage

4.3. Meteorological Data

Evaporation and dispersion of hazardous gases are highly dependent on meteorological conditions like wind speed, direction, stability class etc. Hence proper meteorological information is essential for the estimation of affected zones due to accidental release of chemicals.

4.3.1 Stability Class

The dispersion of materials into atmosphere in addition to wind speed and direction is influenced by atmospheric stability. The term stability refers to the turbulent exchange processes between layers of air stacked one over the

above in the atmosphere. These exchanges are suppressed under stable conditions and enhanced when the atmosphere is unstable.

With increasing wind speed the plume becomes more elongated or slender, and more rapidly diluted irrespective of the nature of the atmospheric turbulence. But the wind also influences the turbulence. At wind speeds in excess of 6 m/s, the stability is determined by the wind. The interaction of the wind with vegetation, buildings and topography also gives rise to turbulent exchange processes, which can be taken into account only crudely in any theory.

The atmospheric conditions of interest are divided into five categories, i.e. A, B, C, D, E and F, where A is the most unstable (strong thermal convection), D represents the neutral condition (purely mechanical turbulence) and F is the stably stratified case where the mechanical turbulence is strongly damped. Neutral conditions correspond to a vertical temperature gradient of about 1°C per 100 m. The wind speed and stability relation is given in **Table 4.5.**

Table 4.5: Relation of Turbulence types to weather conditions

	Day			**Night time**		
Surface wind speed (at10 a.m/p.m) m/s	**In coming solar Radiation**			**Cloud cover**		
	Strong	**Moderate**	**Slight**	**Thin** **<3/8**	**Moderate** **>3/8**	**Over cast** **>4/5**
<2	A	A-B	B			D
2-3	A-B	B	C	E	F	D
3-5	B	B-C	C	D	E	D
5-6	C	C-D	D	D	D	D
>6	C	D	D	D	D	D

A - Extremely unstable conditions

B - Moderately unstable conditions

C - Slightly unstable conditions

D - Neutral conditions

E - Slightly stable conditions

F - Moderately stable conditions.

The minimum and maximum wind speeds are taken as 1.0 m/s and 3.0 m/s respectively in the plant area. So, three atmospheric stability classes, i.e. neutral (D), slightly stable (E) and moderately stable (F), are considered in this study. The dispersion calculations are carried out for two wind speeds, i.e. 1.0 m/s and 3.0 m/s.

4.4. Software used

In this project, we have used the PHAST RISK MICRO 6.7 software for detail damage calculations. The details of the software are as follows.

4.4.1. Introduction

PHAST RISK MICRO 6.7 is a software product designed to provide a total service for chemical process hazard analysis to DNV Technica's customers in industry. PHAST RISK MICRO provides the most advanced collection of available consequence models for hazard analysis. The models are derived from the industry standard risk analysis program PHAST RISK. The program itself is easy to use and is supplied complete with training and on-line support. Regular updates make the latest technical developments available in a practical format. All of this is backed up by DNV Technica's unmatched experience in safety and risk consultancy.

PHAST RISK MICRO 6.7 has many new features and enhancements to existing features. The new version makes PHAST an even more useful and productive consequence modeling tool. However, the overall structure of the program is unchanged, which allows immediate use of the new version by experienced users.

The results of PHAST RISK MICRO are compatible with DNV Technica's risk analysis program PHAST RISK. If a full risk analysis is required, the consequence modeling study results from PHAST will complement the risk analysis study.

4.4.2. Key Features of PHAST RISK MICRO

Some of the key features of the PHAST RISK MICRO program are:

- Scenario based case definition.
- Menu driven screens.
- Full range of process failures (including relief valves and disk ruptures).
- Extensive pipe work modeling (bends, junctions, frictional losses etc.).
- Regular and expanded memory options.
- Full range of graphical output, e.g.

- Cloud footprints
- Side views
- Free jet plumes
- Over-pressure and Radiation footprints and graphs
- Concentration versus distance footprints
- Pool evaporation rate graphs
    - Contours and Effect zones

- Effects considered

- Discharge

- Rainout

- Pool spread and vaporization

- Dispersion

- Flash fires

- Explosion (Early & Late Ignition)

- Jet fires

- Pool fires

- Toxicity

- Complete parametric description of cloud allowing manual analysis if required. (Includes ground and centerline concentration, temperature, liquid fraction content, radius, height etc.).
- Manual override of discharge calculations.
- Full parametric control of modeling. e.g. entrainment coefficients, explosive efficiency etc.
- Scalable graphical output - directly importable into most major word processors and desktop publishing packages.
- Multiple plots from different cases or different weather conditions.
- Ignition source location can be specified by the user.
- Five surface spillage types catered for, including user-defined.
- Complete phenomenology of two-phase releases (flashing, rainout etc.).
- Automatic choice of appropriate model at each stage of dispersion calculation.
- Time varying releases.
- Thermo physical data for chemicals from DIPPR (AIChemE chemical database).
- Capability to define multi-component mixtures.
- In building releases.
- Direct input models.

4.5. Results of Consequence Analysis

The material that is stored is LDO which is flammable liquid and any leakage / spillage results in jet fires/flares or pool fires in the presence of immediate ignition source. For the present study, the Lower Flammable Limit (LFL) distances, heat radiation damage distances, overpressure damage distances and toxic damage distances are presented in **Table 4.5.**

Table 4.5

Heat Radiation Damage Distances

S.NO	Scenario	Release rate (kg/s)	Type	LFL distance (m)		4.0 KW/m2 Damage distance (m)		12.5 KW/m2 Damage distance (m)		37.5 KW/m2 Damage distance (m)	
				D1 / E1/F1	D3 / E3/F3	D1 / E1/F1	D3 / E3/F3	D1 / E1/F1	D3 / E3/F3	D1 / E1/F1	D3 / E3/F3
500 m³ LDO Storage Tank											
1	Catastrophic rupture of 500 m³ LDO Storage Tank	-	Late pool fire	57.31/ 155.14/ 331.52	27.40/ 66.75/ 216.66	312.48/ 312.55/ 312.65	351.56/ 351.69/ 351.83	177.65/ 177.71/ 177.77	177.64/ 177.74/ 177.83	-	-
2	25 mm leak	6.733E+00	Jet Fire	12.69/ 12.45/ 12.09	12.71/ 12.47/ 12.18	29.59 / 29.63 / 29.45	27.95 / 27.85 / 27.55	23.36 / 23.39 / 23.25	21.19 / 21.11 / 20.88	19.48/ 19.51/ 19.39	17.09/ 17.03/ 16.85
			Late Pool Fire			104.34/ 104.39/ 104.52	121.41/ 121.40/ 121.49	54.85 / 54.85 / 54.87	55.46 / 55.35 / 55.33	-	-
3	50 mm leak	2.69E+001	Jet Fire	22.11/ 22.06/ 22.42	24.83/ 24.95/ 25.9	48.49 / 48.44 /	45.36 / 45.18 /	38.09 / 38.05 /	34.21 / 34.08 /	31.71/ 31.68/ 31.4	27.54/ 27.43/ 27.1

					3	48.02	44.67	37.72	33.70	1	3
			Late Pool Fire			184.41/ 184.49/ 184.64	209.87/ 209.95/ 210.13	102.31/ 102.29/ 102.28	102.28/ 102.21/ 102.13	-	-
4	100 mm leak	1.08E+002	Jet Fire	35.08/ 35.82/ 38.02	42.31/ 43.85/ 45.50	76.52/ 76.17/ 75.10	71.19/ 70.78/ 69.73	59.76/ 59.48/ 58.66	53.40/ 53.09/ 52.32	49.59/ 49.37/ 48.69	42.83/ 42.59/ 41.97
			Early Pool Fire			74.81/ 74.54/ 74.08	87.01/ 86.63/ 86.06	42.94/ 42.67/ 42.02	44.55/ 44.17/ 43.59	-	-
			Late Pool Fire			323.17/ 323.21/ 323.55	360.06/ 360.24/ 360.57	190.99/ 190.99/ 190.98	190.06/ 190.01/ 189.98	-	-

Overpressure Damage Distances

S.NO	Scenario	Release rate (kg/s)	0.03 bar Damage distance (m)		0.1 bar Damage distance (m)		0.3 bar Damage distance (m)	
			D1 / E1/F1	D3 / E3/F3	D1 / E1/F1	D3 / E3/F3	D1 / E1/F1	D3 / E3/F3
500 m^3 LDO Storage Tank								
1	Catastrophic rupture of 500 m^3 LDO Storage Tank	-	134.21/ 234.77/ 463.75	72.93/ 127.17/ 315.01	97.21/ 222.89/ 433.12	53.20/ 100.77/ 294.47	88.59/ 221.44/ 431.56	46.59/ 95.38/ 287.23
2	25 mm leak	6.733E+00	31.25/ 30.94/ 30.56	45.11/ 43.47/ 43.01	24.79/ 24.66/ 24.50	36.44/ 35.75/ 35.55	22.39/ 22.33/ 22.25	33.22/ 32.87/ 32.77
3	50 mm leak	2.69E+001	72.92/ 86.39/ 87.01	99.65/ 96.66/ 102.28	59.78/ 71.25/ 71.52	82.64/ 81.37/ 83.77	54.88/ 65.62/ 65.75	76.31/ 75.68/ 76.87
3	100 mm leak	1.08E+002	163.83/ 165.69/ 170.56	145.37/ 147.36/ 182.95	132.96/ 133.75/ 135.83	199.35/ 120.19/ 141.11	121.46/ 121.46/ 122.89	109.66/ 110.08/ 125.54

Overpressure Damage Distances

S.NO	Scenario	Release rate (kg/s)	0.03 bar Damage distance (m)		0.1 bar Damage distance (m)		0.3 bar Damage distance (m)	
			D1 / E1/F1	D3 / E3/F3	D1 / E1/F1	D3 / E3/F3	D1 / E1/F1	D3 / E3/F3
Steam Boiler								
1	Blast of Steam Boiler	-	833.03/ 833.03/ 833.03	833.03/ 833.03/ 833.03	332.10/ 332.10/ 332.10	332.10/ 332.10/ 332.10	179.34/ 179.34/ 179.34	179.34/ 179.34/ 179.34

Toxic Damage Distances

S.NO	Scenario	Release rate (kg/s)	Toxic Damage Distances for (l x r), m					
			IDLH-10000 ppm					
			D1	E1	F1	D3	E3	F3
1	Pipeline Rupture of Pet cokefluegas	1.98E+002	405.87	402.84	400.99	438.05	432.14	433.81
2	Pipeline Rupture of LDO fluegas	1.453E+002	134.49	129.47	120.65	140.79	136.32	127.33

D1, E1 & F1: Software nomenclature for Prediction of dispersion, evaporation & field dispersion modeling.

CHAPTER :5 Consequences Modeling

Preamble

The units and activities connected with Storage, Handling and Fuel Firing of products have been assessed for potential to initiate and propagate an unintentional event or sequence of events that can lead to an accident and/or emergency. Credible accident scenarios were initially constructed followed by the quantification for these identified scenarios. The quantification was carried out using mathematical modeling and the results are given in this chapter.

System Boundaries

Data collection and review of the facilities included understanding of the operations carried out as well as reviewing the operating parameters for each activity.

The assessment was based on well-recognized and accepted modeling methodologies. Each area where a fire/explosion or toxic hazard exists, and is separated from other area by distance or isolation valves, has been identified as a study area. Inventory data has been defined for each volume between isolation valves. This typically includes such physical characteristics as composition, pressure, and temperature.

For all the above ground facilities, the releases are considered to be in the horizontal direction as a worst case. The leaks from piping and valves are assumed to be continuous. The range of leak sizes ie. 10% leak and full bore rupture were assessed as applicable depending on the maximum flow rate in each pipe section. The leak size is limited to the maximum flow rate. The available mitigation measures have been considered.

The damage potential associated with the various hazardous outcomes was assessed based on predefined impairment criteria for losses. For the purposes of this assessment, a fatality is conservatively assumed to result for any person receiving a dangerous thermal dose or worse (where "dangerous" is actually defined as a 1% risk of fatality). The risk estimates have been derived using data and assumptions which are considered to be conservative (i.e. to over-estimate rather than under-estimate the risk level where judgment was required).

The most pessimistic meteorological conditions (wind speed 2.2 m/s, stability class F) and wind direction were taken for dispersion simulations. A vapour cloud in event of leak is assumed to disperse in the most probable wind direction (west to east).

In case of leak and /or rupture the corrective systems are assumed to respond within 5 min for all scenarios within the installation.

Identification and Construction of Hazardous Scenarios

Several hazardous scenarios were identified using information from past accidents and engineering judgment. Escape of petroleum product can take place in an installation due to leak or rupture in a pipeline, overflow of a product from tank, or failure of a tank or from transfer piping and associated connections (gasket, flanges, etc.). These could occur during the conduct of the normal activities/operations of the installation.

From the results of the preliminary hazard analysis, vulnerable locations were selected where leak of vapour or spill of liquid from the inlet/ outlet pipelines or catastrophic failure of vessels can occur. The list of representative potential events covers mainly the release of hydrocarbon which could lead to loss of life and/ or damage to property. The range of leak sizes representative for small and large leaks that have been considered for the assessment based on the pipe sizes.

Credible accident scenarios (CAS) were initially constructed followed by quantification using Cause-Consequence Analysis (CCA) for the identified scenarios. Depending on the amount of inventory released, release scenarios would result in the formation of a pool of hydrocarbon, with the potential to extend to the full surface area of the bund. Ignition of the spill would subsequently result in a pool fire.

In addition to the potential for a fire as a result of a spill, there is also the potential for a tank fire scenario. A full tank surface fire may occur as a result of Lightning strike, Earthquake, Terror Attack & Flood.

Depending on the type of the operating conditions and the composition of the material handled, one or more of the following potential hazards/consequences could be encountered due to loss of containment.

5. a..) Vapor Cloud Explosion Modeling:

The consequence of the hazardous events is generally estimated by using mathematical models. Over the years several models have been developed to estimate effects of the hazards.

However, there is no standard available presently to determine efficiency or accuracy of the models. Hence output of the models may vary considerably, Therefore the use of the models should be limited for use as guideline only, as they may differ from reality. However, accuracy of the output of the models considerably depends on accuracy of assumptions and data while giving input to the models.

Most of the models are complicated in nature, hence, several computer software are developed for the estimation of consequences. However, operation of these software needs clear understanding of fundamentals of process, parameters and knowledge of development of loss scenarios.

Directly, VCE condition may not applicable for 80 TPH CFBC Pet Coke Boiler operation. However under Worst case Scenario (Missile attack, Earthquake, Plane Crash etc) VCE may occur as per Turbulent mixing of Pet Coke dust & air flow :-

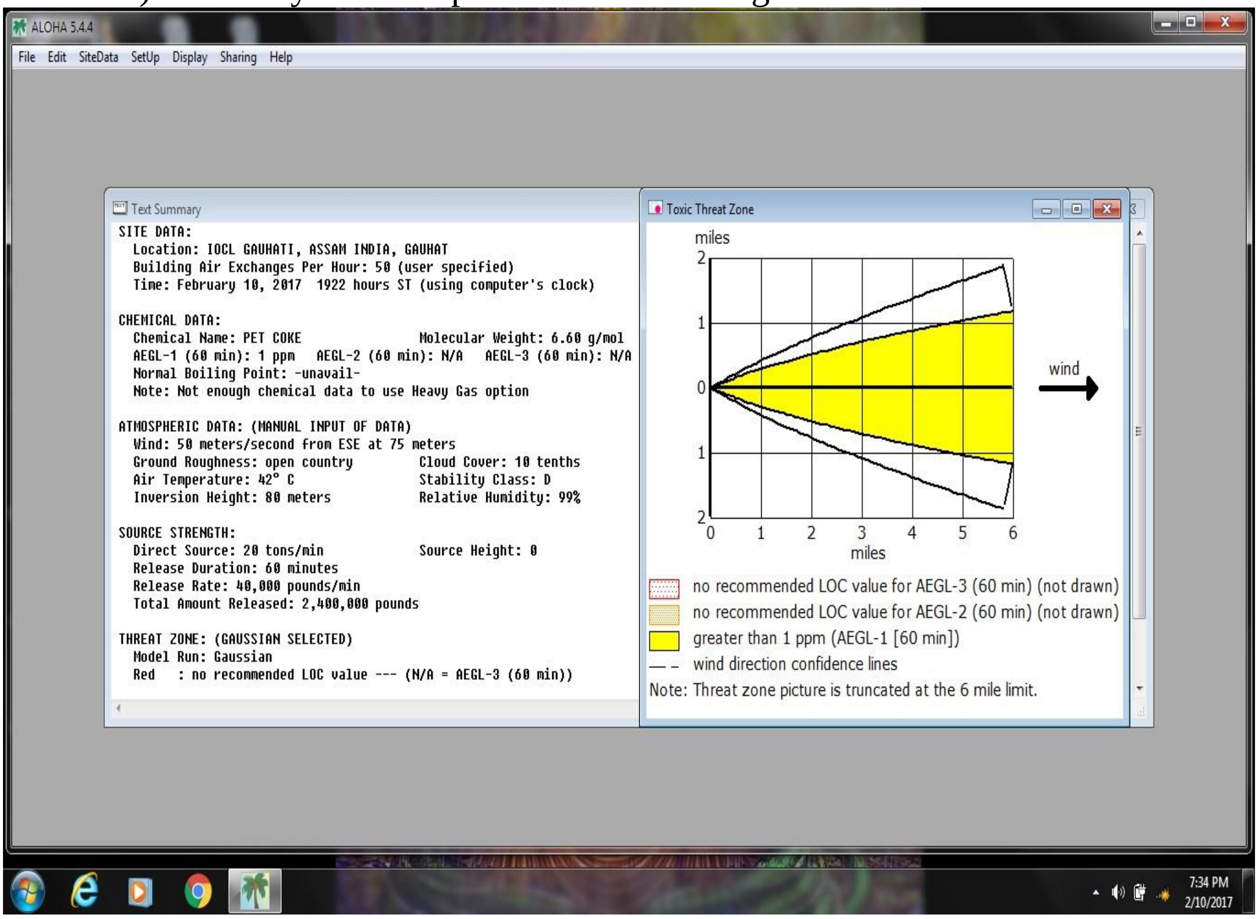


Fig:5.a.ALOHA VCE Modeling.

5 **b.) Fire Analysis**:

Fire hazards associated with Pet Coke operation, Furnace Explosion, Electrical Fire.

Fire Scenario Time Line: Timeline includes the following elements (not necessarily in this order):

1. Scenario starts with ignition of a fire in a specific fire source
2. Fire growth involving the affected fuel,
3. Heat transfer from the fire to other items within the zone of influence,
4. Propagation of the fire to other materials,
5. Damage to identified targets (e.g., cables and equipment),
6. Detection of the fire – Detection can actually occur before ignition given an incipient detection system.
7. Automatic initiation of suppression systems if present,
8. Manual fire fighting and fire brigade response,
9. Successful fire extinguishment ends the scenario.

Fuel limited fires:
A fire where the fuel burning rate is limited only by the surface burning rate of the material.
Generally applies to fires in the open or fires in large compartments:-

Sufficient air is always available for the fire (plenty of oxygen to support burning) Fire generates hot gases (convective fraction) and emits Radiative heat (radiative fraction)

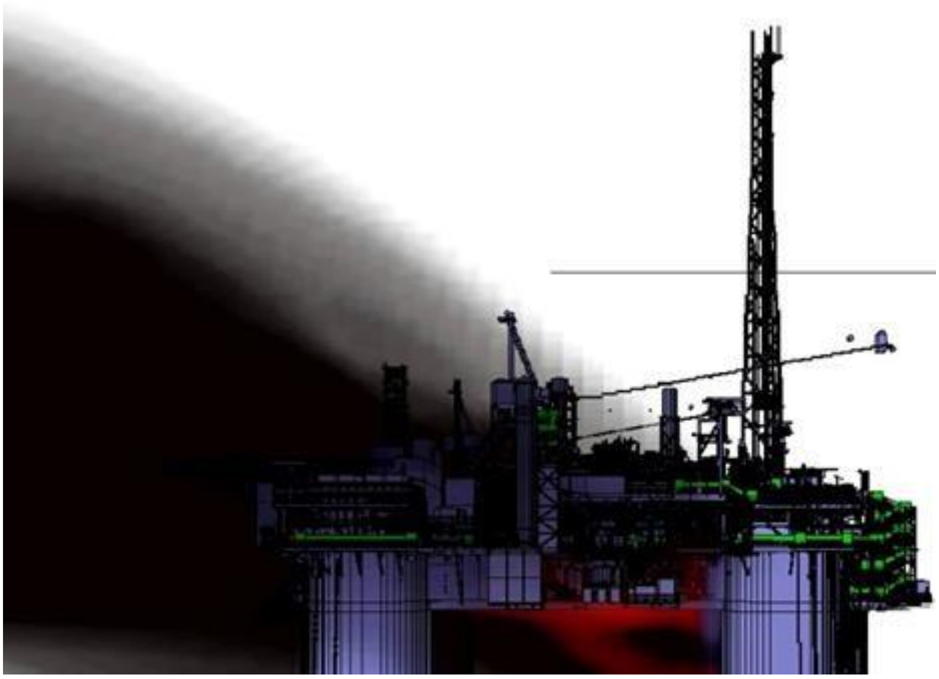


Fig:5.Pet coke dispersion-Graphic image.

5. c.) Toxic Release Analysis

Toxic release may occur under following failure:-
-HCL storage leakage
-Toxicity by Petcoke

HCL storage leakage:-
Storage is very close to the proposed boiler installation. HCl vapour stored in HCL Tank may cause explosion. Naptha & HSD storage is also close to HCL storage. Rupture of this tanks may impact to HCL storage & proposed Boiler.

Toxicity by Petcoke:

Two-year inhalation toxicity study of Pet coke in rats and monkeys.

Sprague-Dawley rats and Cynomolgus monkeys were exposed to dust aerosol concentrations (0, 10.2, and 30.7 mg/m3) of micronized delayed process petroleum coke for 6 hr/day, 5 days/week over 2 years. With the exception of pulmonary effects, particularly in the rats, no significant adverse treatment-related effects were observed.

Both dust-exposed groups of both species exhibited a gray to black discoloration of the lung, an observation consistent with pulmonary deposition of the coke dust, as well as increased absolute and/or relative lung weight values. The pulmonary histopathology in the monkeys was limited to the deposition and phagocytosis of the test material by pulmonary macrophages. The rats also exhibited these responses, but with concomitant signs of chronic inflammation and focal areas of fibrosis, bronchiolization, sclerosis, squamous alveolar metaplasia, and keratin cyst formation. No difference in the mortality rate was observed between the control and exposed groups of rats. Lastly, no significant increases in chromosomal aberrations were observed in rodents of the 10.2 or 30.7 mg/m3 exposure groups when examined after 5 days, 12 months, and 22 months of exposure.

d.) Shelter in place Provisions:

Analyzing Evacuation Versus Shelter-in-Place Strategies depend upon degree of Exposure limit. More details are as under:-

SLNo	Risk	Recommended shelter
1.	Army/Terrorist Nuclear Detonation on Pet Coke Boiler	Develop a basement shelter strategy, including the storage of food, water, blankets, and other necessities at facilities and homes located near Boiler or near old Administrative Building.
2.	During Offsite Emergency	Boiler & Total employees evacuation.
3.	During Boiler Fire & Explosion	Recommended "Assembly point"

Chapter 6:

Assessment of Risk arising from the Hazards & consideration of its tolerability to Personnel, facility & the Environment which includes the following:-

Client Name: IOCL Refinery Guwahati	Risk Assessment Type Proposed Boiler				
Hazards	Risk	May Effect to	Pb	SV	Remedial Action
Fire	Severe burn, injury	Crew Operator	2	2	Follow SOP
Explosion	Equipment's& Building Damage	Crew Operator Engineers Storage Vessels	1	5	Provide suitable access to Fire Tender Provide suitable access to Ambulance
Asphyxiation from CO^2	Suffocation Fatal	Crew Operator Engineers	2	5	
Fall from Height	Fatal /Major injury	Commissioning Engineer	1	5	Use Safety Net Install Scaffolding
Noise	Partial/Permanent Deafness	Crew Operator	2	2	Use Ear Muff
Heat Stress	Sweating, Loss of Calcium Fatal	Crew Operator	3	3	Use Exhaust, Interval, Provide/Use Extra Salt
Electrical Fire, Short Circuit	Fatal /Major injury	Crew Operator Electrical Staff	3	3	Follow Electrical Work Permit PPE Isolation & Inbuilt
Slip, Trip & Fails	Fatal /Major injury	Crew Operator	3	3	Good House Keeping
Pet Coke	Occupational Health Environment	Crew Operator	4	4	Use Nose mask Periodic Health Check up
Fire & Explosion by -Earthquake -Terror Attack -Flood -Aircraft Crash & Lighting	-More Number Fatal -BLEVE -Mishap	-Crew Operator -All Engineers -All IOC Employees	1	4	-Glowing Light at Chimney -Conductivity -On/off Site Emergency Plan -Provide suitable

					access to Fire Tender -Provide suitable access to Ambulance.

	Probability			Severity			
1	Improbable – Unlikely	**X**	**1**	Negligible – remote possibility of harm	**1-6**	=	**Low priority**
2	Remote – May occur	**X**	**2**	Marginal – first aid injury possible	**8-12**	=	**Medium priority**
3	Possible – Likely to occur	**X**	**3**	Slightly dangerous – minor injury possible	**15-25**	=	**High priority**
4	Probable – Very likely to occur	**X**	**4**	Dangerous – major injury			
5	Very probable – very likely to occur soon	**X**	**5**	Very dangerous – could cause death			

The noise limits as per the Environmental (Protection) Rules of MOEF are as follows:

Locality/Zone	Day Exposure Limit	Night
Industrial	75 dBA	70 dBA

Chapter 7:

Calculation of physical effects of accidental scenarios, which includes frequency Analysis for incident scenarios leading to hazards to people & facilities (Toxic Dispersion) & consequences Analysis for the identified hazards covering impact on people & potential escalation.

The Failure Frequency, Consequence Analysis and finally the quantitative risk resulting from accidental releases are discussed in this Section. The general inputs to risk study are inventories, site diagram, location of facilities, local scaled map, local population size both day and night, local weather data both day and night, traffic density day and night, failure frequency data, PFD and P&IDs.

7.1 Failure Frequency

The release scenarios considered earlier can be broadly divided into two categories (i) catastrophic failures which are of low frequency and (ii) ruptures and leaks which are of relatively high frequency. Vapor or liquid releases from failure of gasket, seal and rupture in pipelines and vessels fall in second category whereas catastrophic failure of vessels and full bore rupture of pipelines etc. fall into first category.

Leaks from the flanges and valves etc. are more frequent and have high damage potential where damage distances extend beyond to other areas. However for such scenarios, it is important to consider the probability of occurrence of such an event, which may be calculated from failure frequencies and event probabilities.

Typical failure frequencies are given in **Table 7.1.**

Table 7.1: General failure frequencies*

Item	Mode of failure	Failure frequency/yr
Atmospheric vessel	Catastrophic	$5x10^{-6}$
Pressure Vessel	Catastrophic	9.23×10^{-5}
Process Pipe lines		
	Small leak (<25mm)	5.282×10^{-3}
	Medium leak (25-50mm)	1.319×10^{-4}
	Large leak (>50mm)	2.274×10^{-4}
	Full bore rupture	1.15×10^{-6}
Process safety valve (PSV)	Lifts heavily	6.53×10^{-3}

*Sourced from DNV Leak

The starting point of the risk calculations is the potential leak frequency. Generic failure frequencies for each type and size of the Boiler component and safety features were used to determine the cumulative failure frequency of the event as envisaged. These are combined with the ignition probabilities to give ignited event frequencies.
This methodology was adopted for the estimation of frequency of occurrence and probability of an event.

> Events in the accident chain and safety features

An incident will occur only under the following chain of events.

1. Initiating event
Boiler Explosion, Pet Coke dust, etc.
2. Failure of protective/ warning devices
Instrumentations, human error.
3. Presence of ignition sources (fixed & mobile)
4. Failure of mitigation measures: SOP, firefighting equipment, Safety awareness training.

The assumption of the assessment is that risk of an accidental outcome can be contained if any of the systems identified in the chain of events functions as designed. The effectiveness of the safety systems in preventing and or mitigating the effects of Fire& Explosion has been assessed through event-tree. The technique gives due consideration to the element of time and sequence of activation as every leak of hydrocarbon.

Estimation of Probability

The probabilities of failure of the proposed Boiler & Instrument components that make the accident chain were combined to arrive at the probability of occurrence, i.e., whether it is Boiler Fire, Electrical Fire or Boiler explosion or any combination of consequences within the site. The methodology for identifying layers of protection and arriving at the estimate of frequency of an event is described.

It was assumed that the primary events are pipe leaks which have higher failure rates than Boiler vessel rupture. These primary events can lead to damage to vessels and escalation of fire situations.

The proposed system for Auto Shutdown on the units.

For each case, the probability of ignition was considered.

Being a new installation credit has been given to preventive, isolation and quick response mitigation measures.

The probability of each event was estimated considering the number and type of units and sequence of operation of safety systems available at each location.

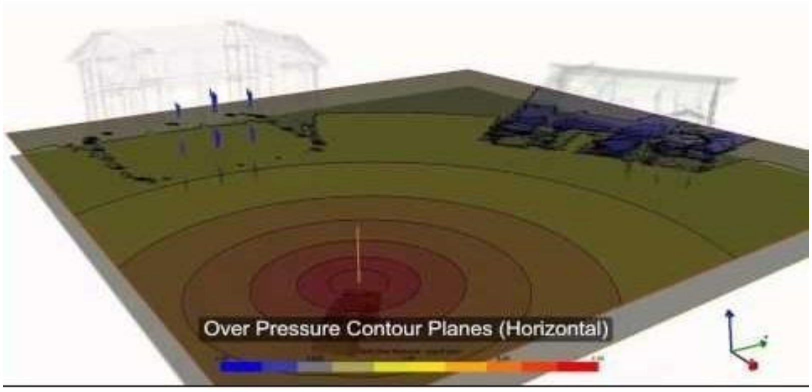


Fig:7.2 Probability Estimation.

Chapter 8: Damage Limit identification & quantification of the Risk & contour mapping on the layout.

Damage Contours Mapping

Damage contours are represented on Lay out for the damage distances computed for various hazardous scenarios at identified locations. The damage contours are drawn for the most credible scenarios with maximum impact only. In the present study, the damage contours are drawn for heat radiation damage distances, overpressure damage distances, and toxic damage distances are given in Fig. 8.1 to Fig. 8.11.

The fuel storage and unloading at the storage facility may lead to fire and explosion hazards. The damage criteria due to an accidental release of any hydrocarbon arise from fire and explosion. The vapors of these fuels are not toxic and hence no effects of toxicity are expected due nearby HCL storage.
Tank fire would occur if the radiation intensity is high on the peripheral surface of the tank leading to increase in internal tank pressure. Pool fire would occur when fuels collected in the dyke due to leakage gets ignited.

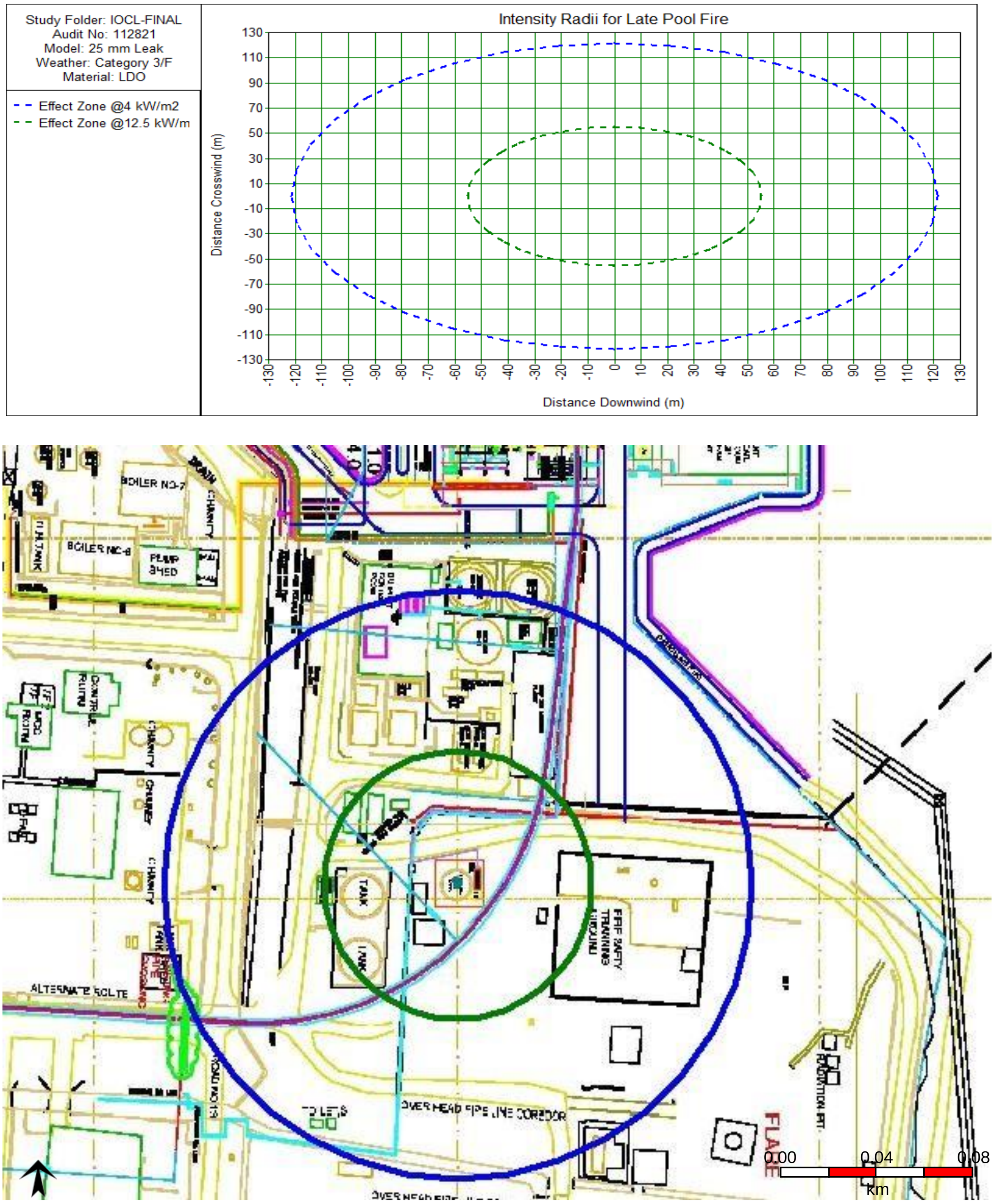
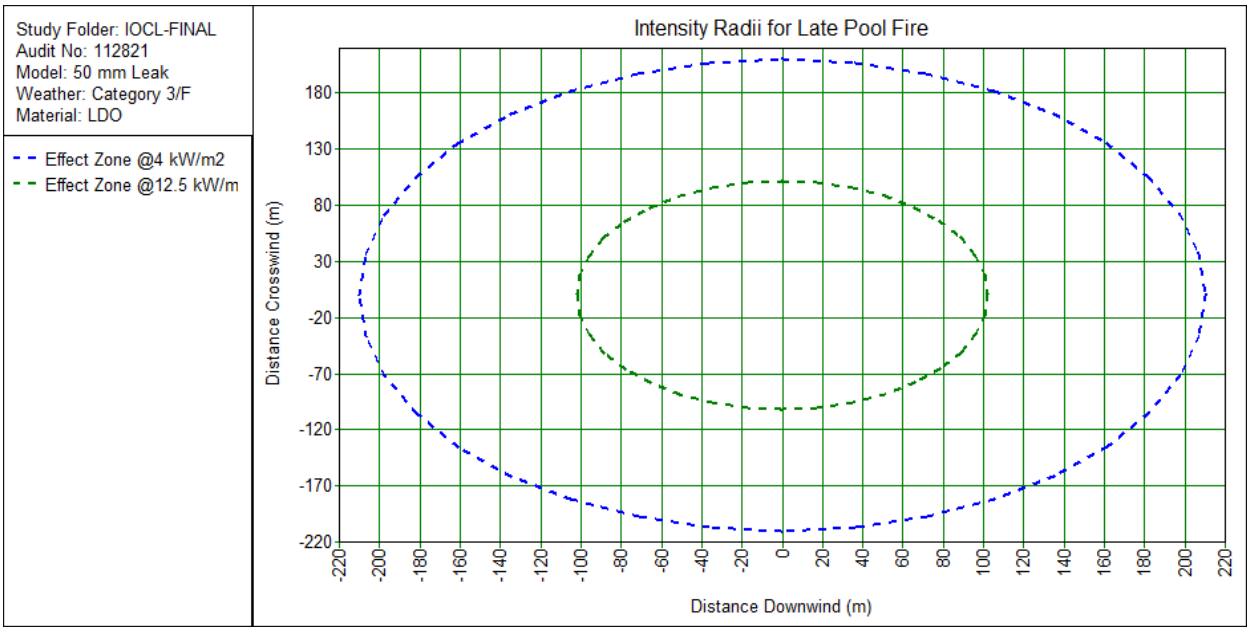


Fig. 8.1 Late pool fire damage distance for 25 mm leak for LDO Storage tank.



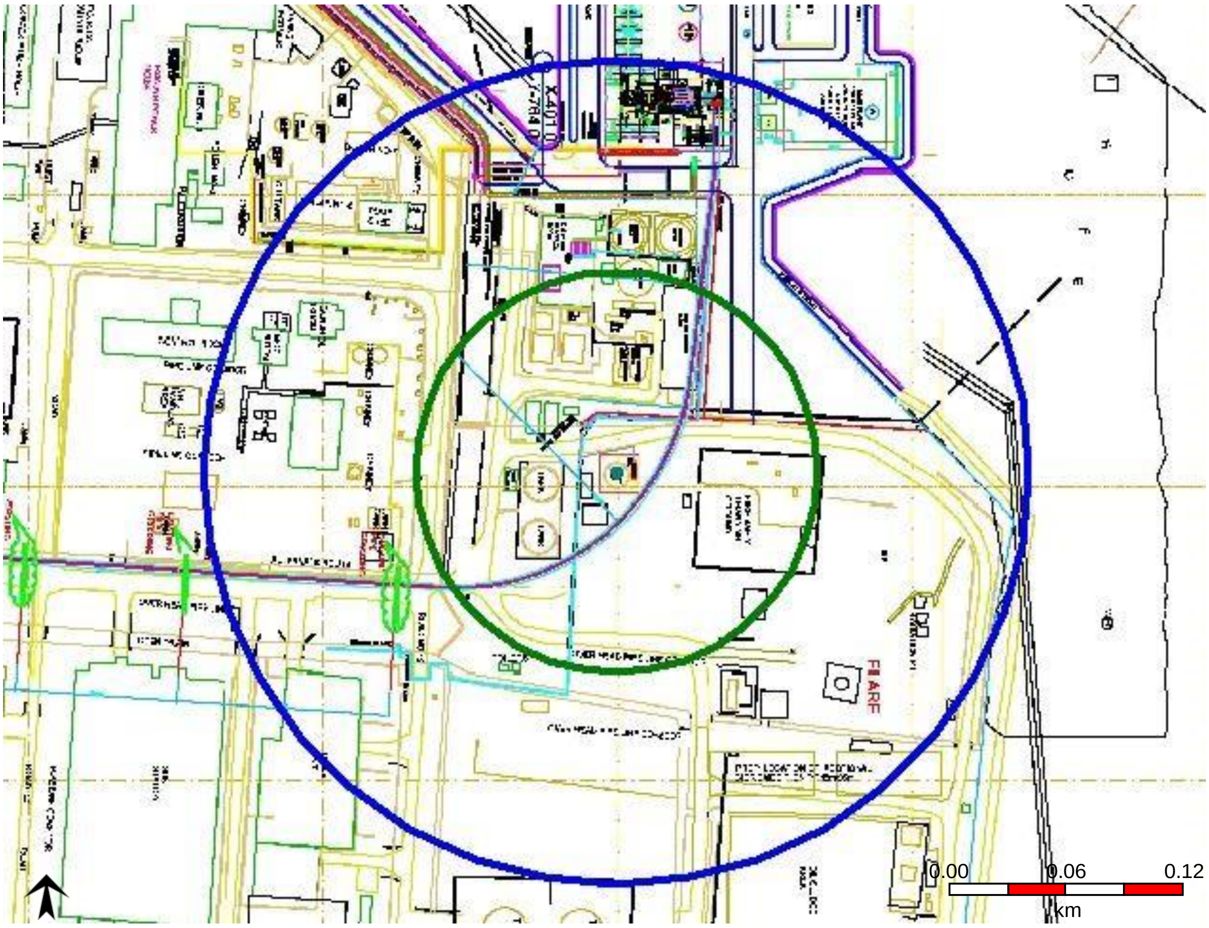
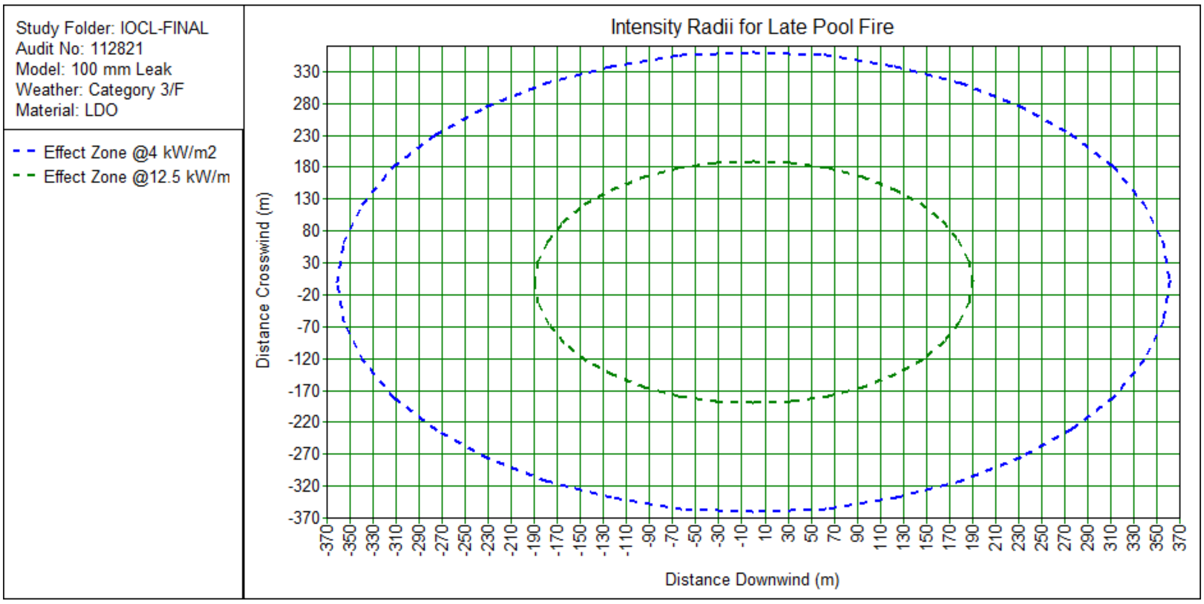


Fig. 8.2 Late pool fire damage distance for 50 mm leak for LDO Storage tank.



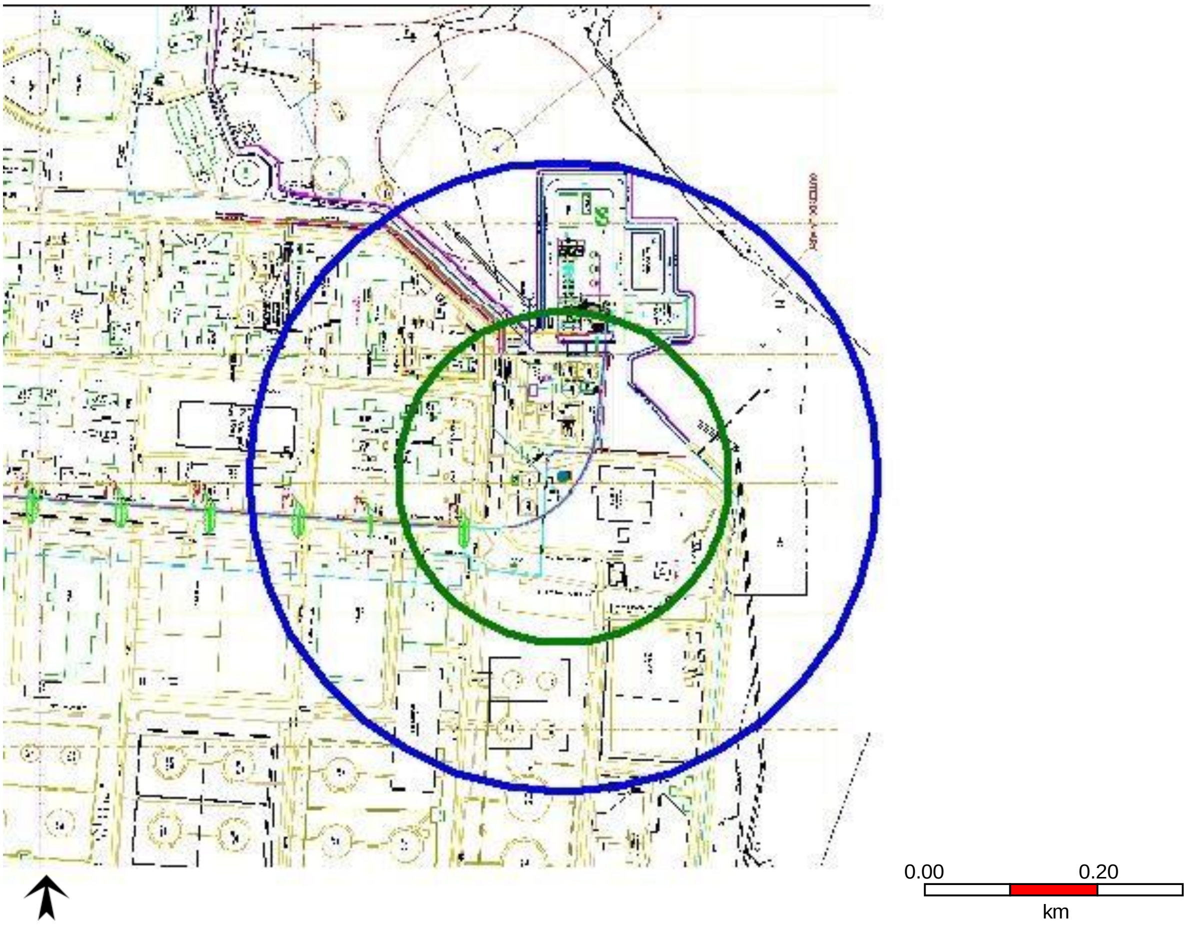
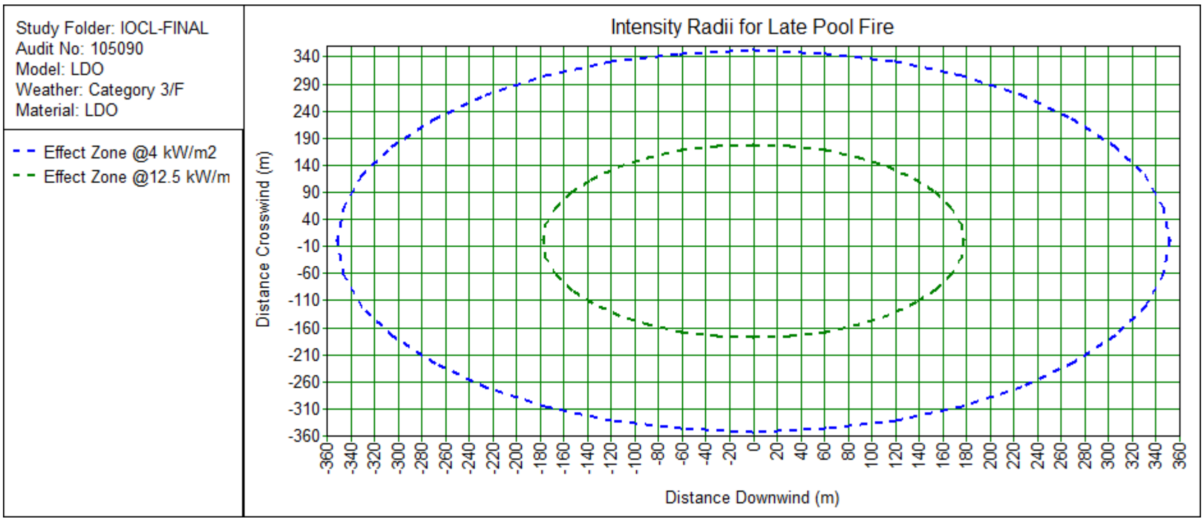


Fig. 8.3 Late pool fire damage distance for 100 mm leak for LDO Storage tank.



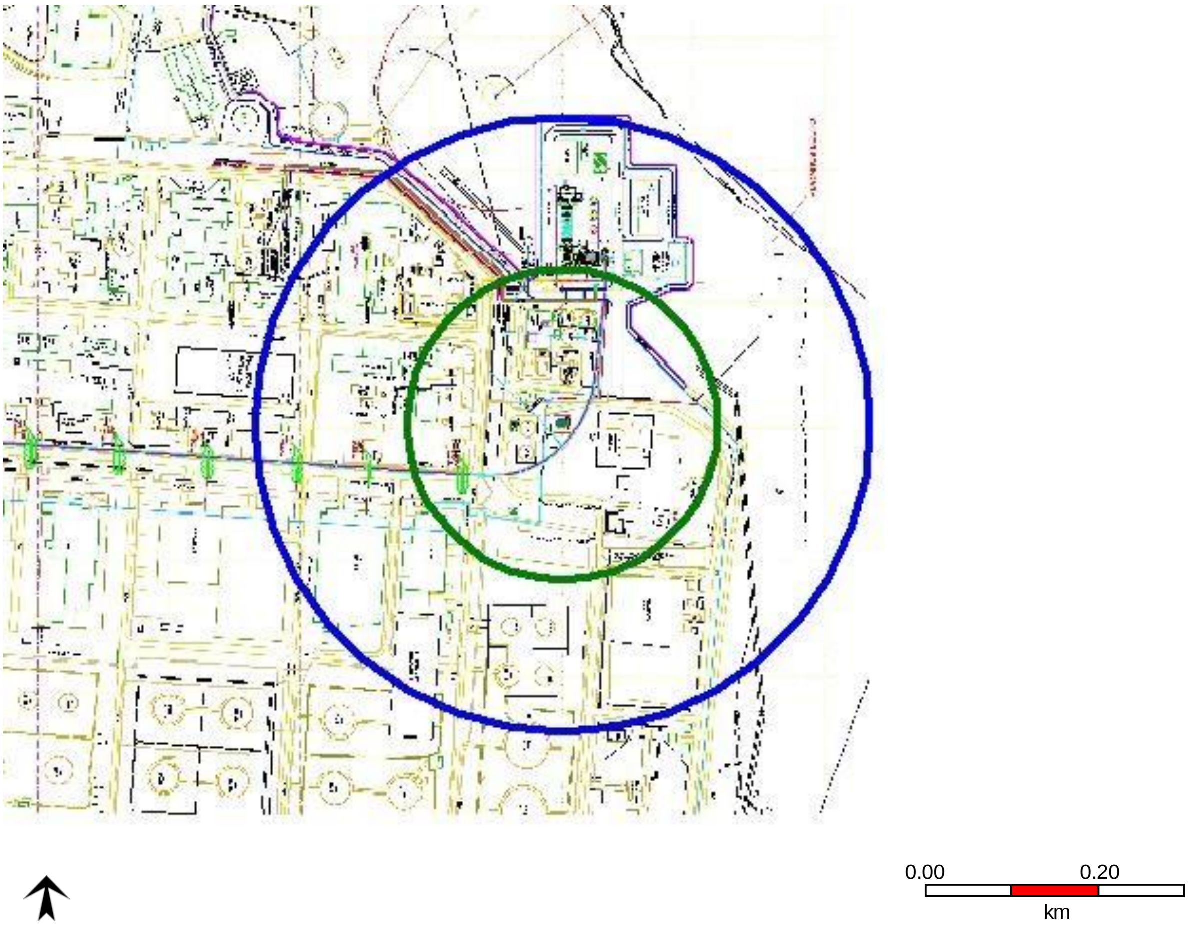
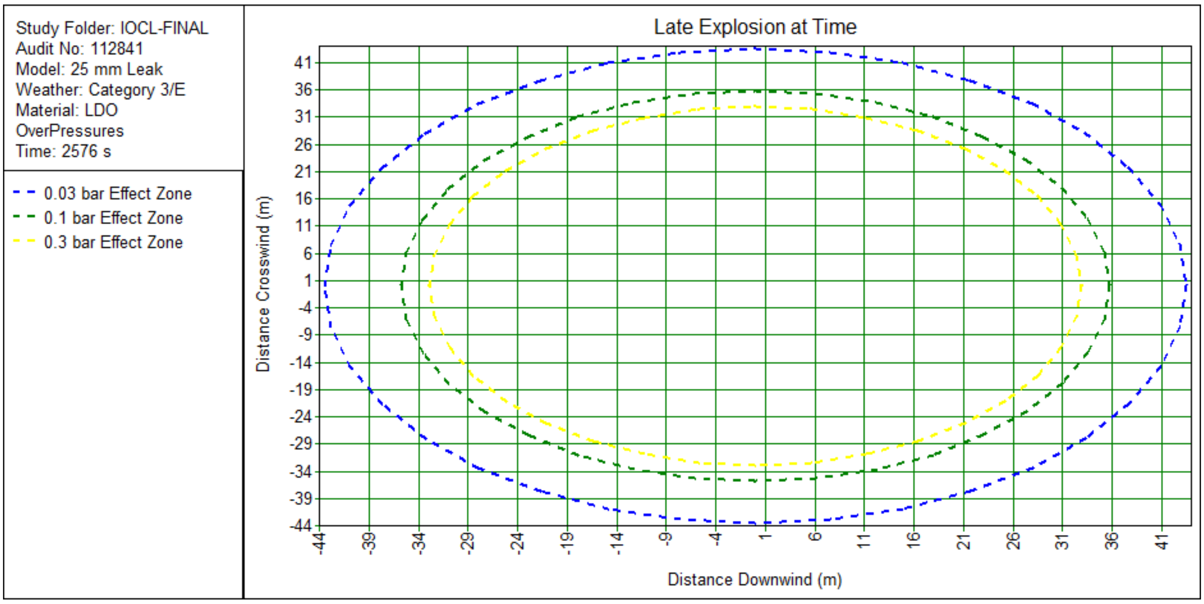


Fig. 8.4 Late Pool Fire Damage Distance for Catastrophic Rupture of 500 M^3 LDO Storage Tank.



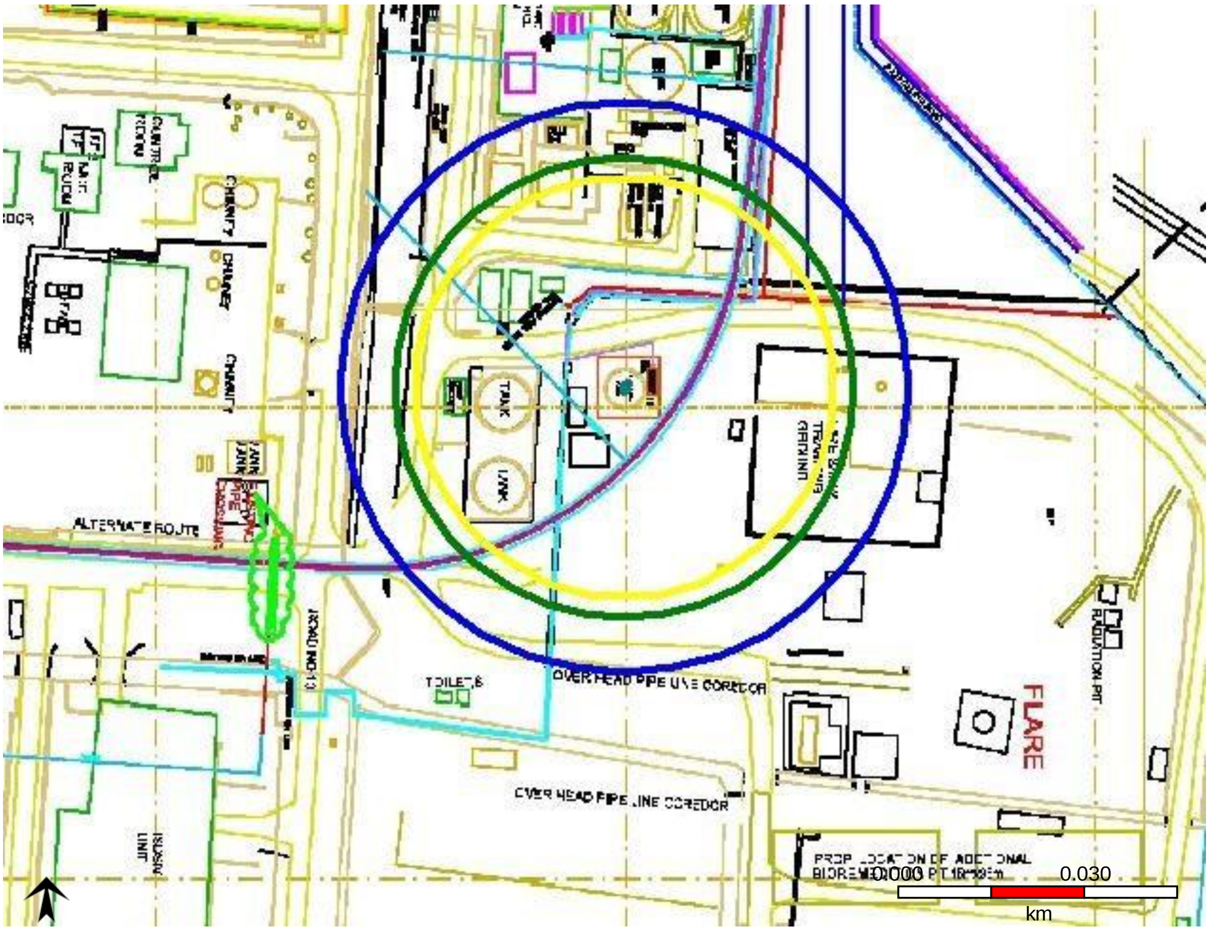
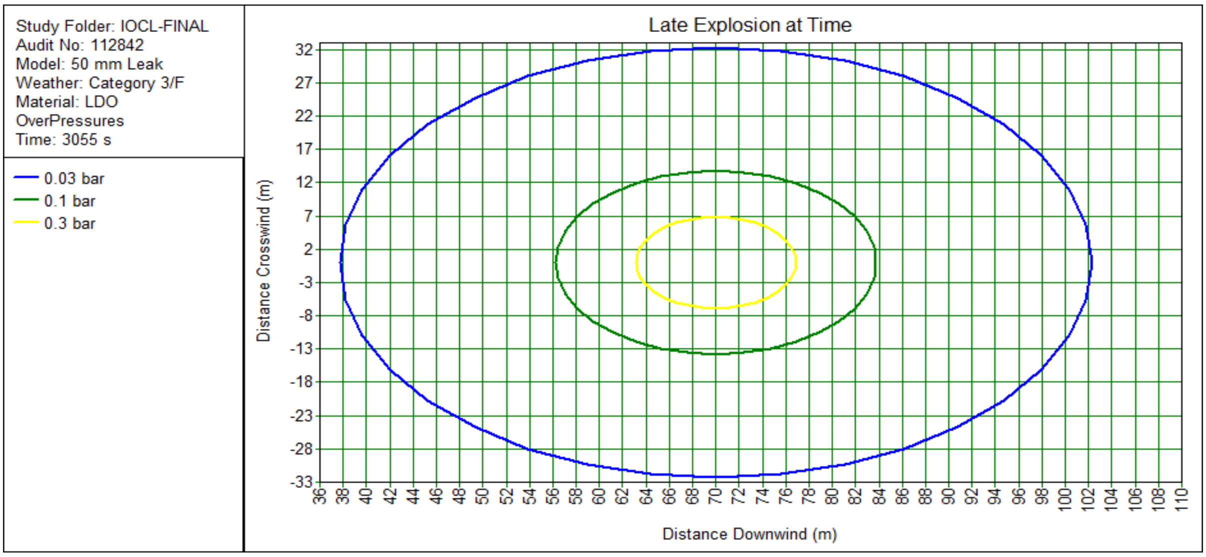


Fig. 8.5 Overpressure damage distance for 25 mm leak of LDO Storage Tank



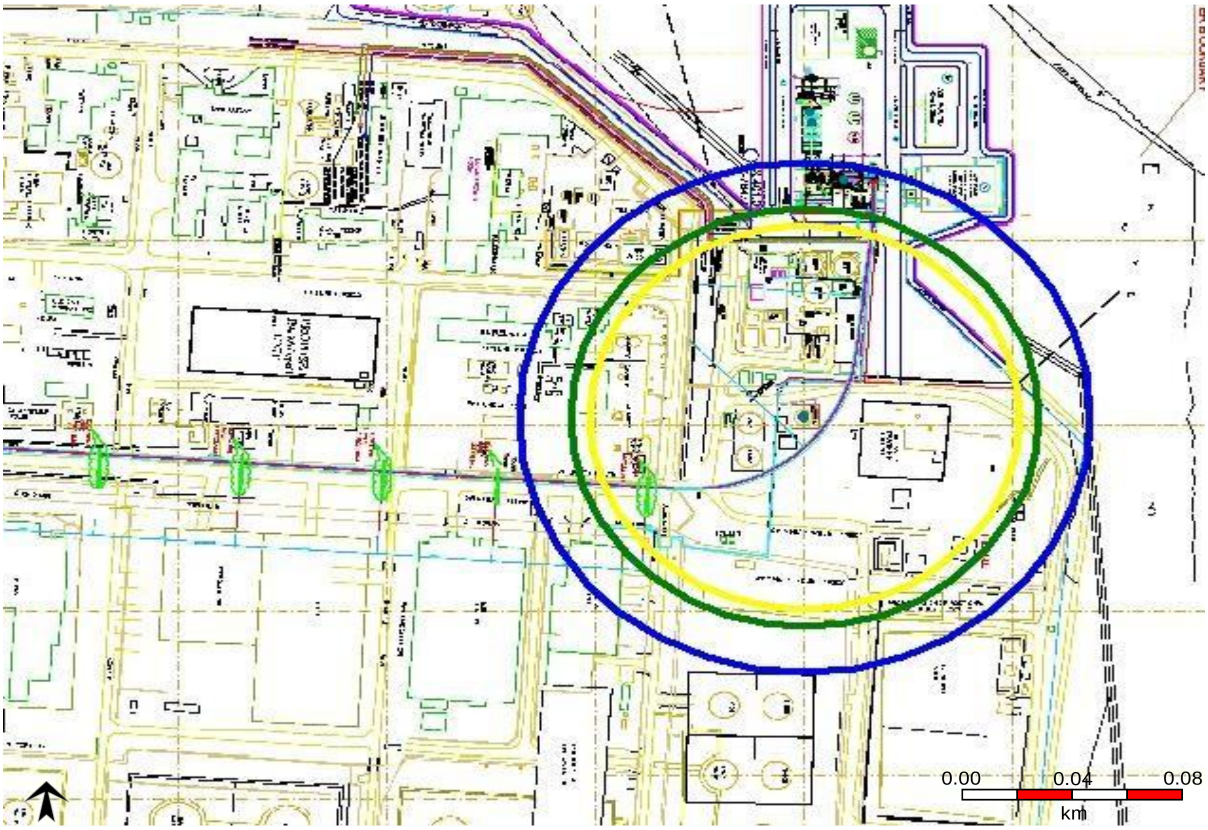
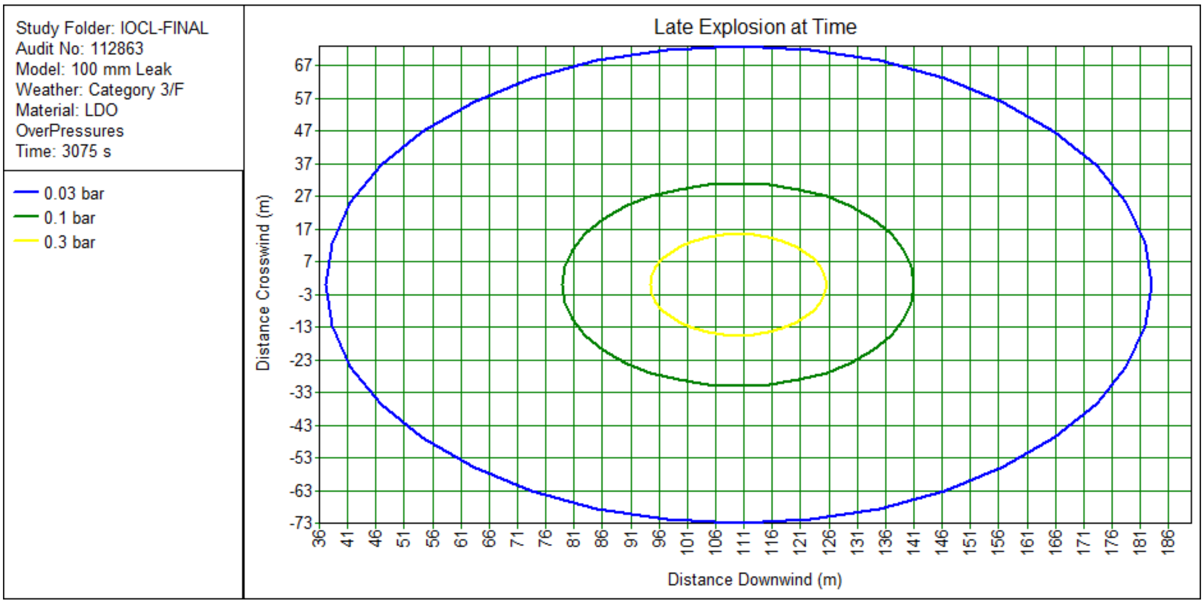


Fig. 8.6 Over pressure damage distance for 50 mm leak of LDO Storage tank



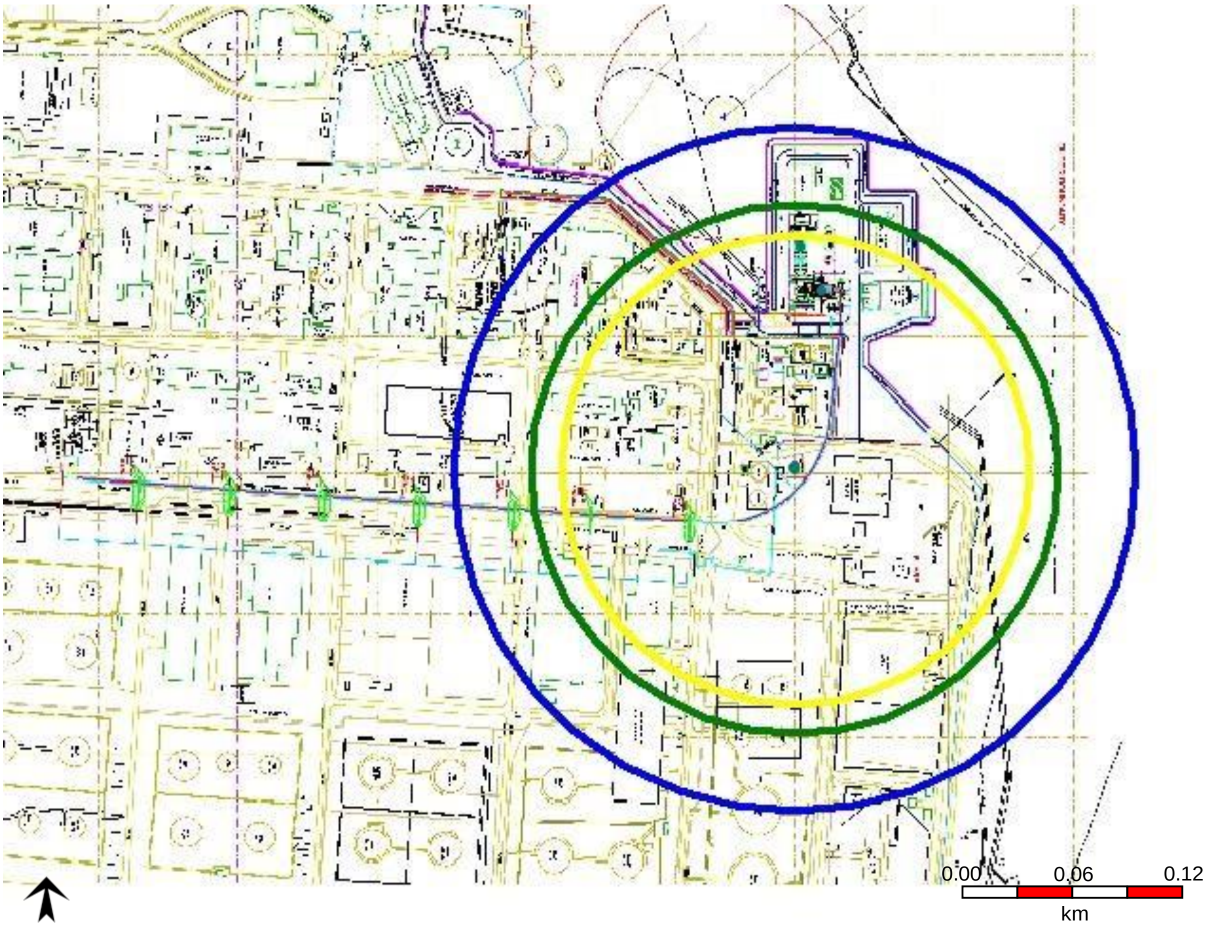
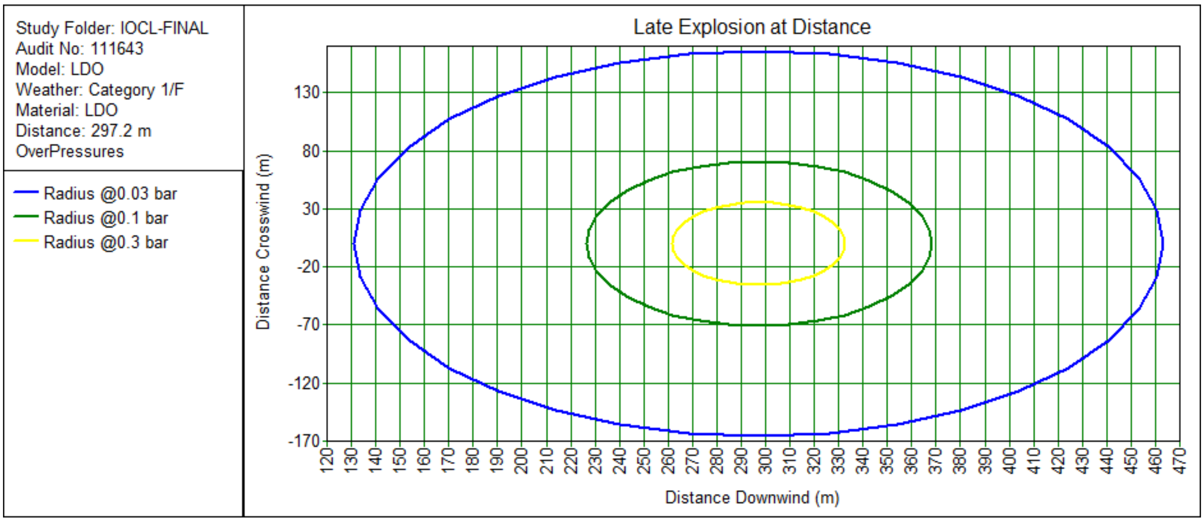


Fig. 8.7 Over pressure damage distance for 100 mm leak of LDO Storage tank



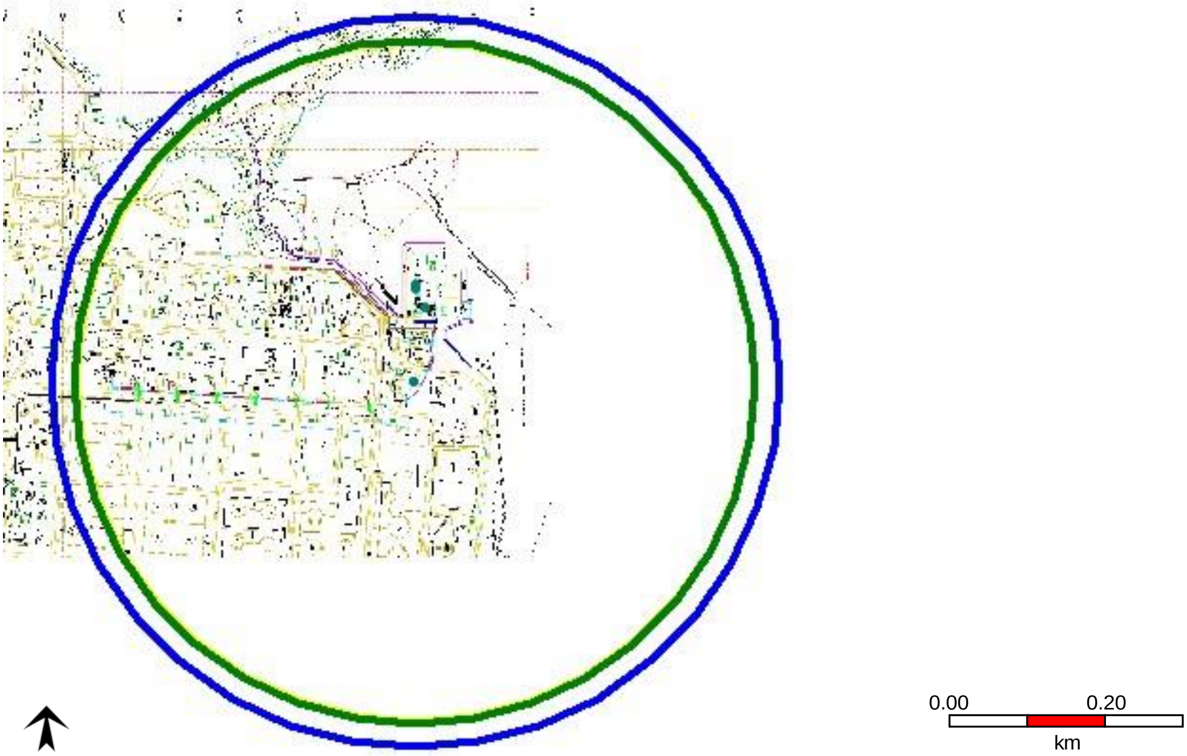
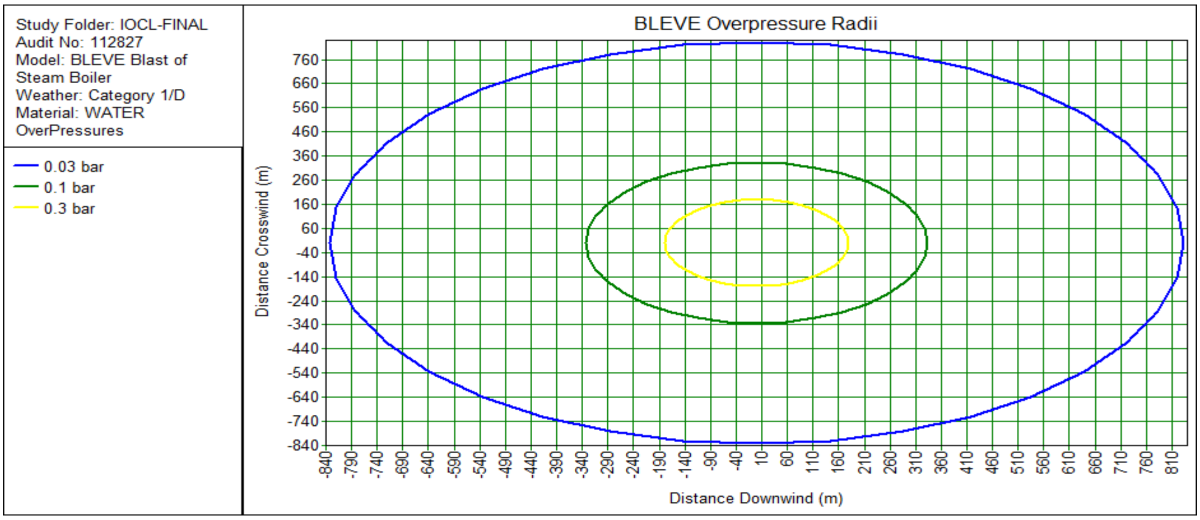


Fig. 8.8 Overpressure Damage Distances for catastrophic rupture of 500 M^3LDO Storage Tank.



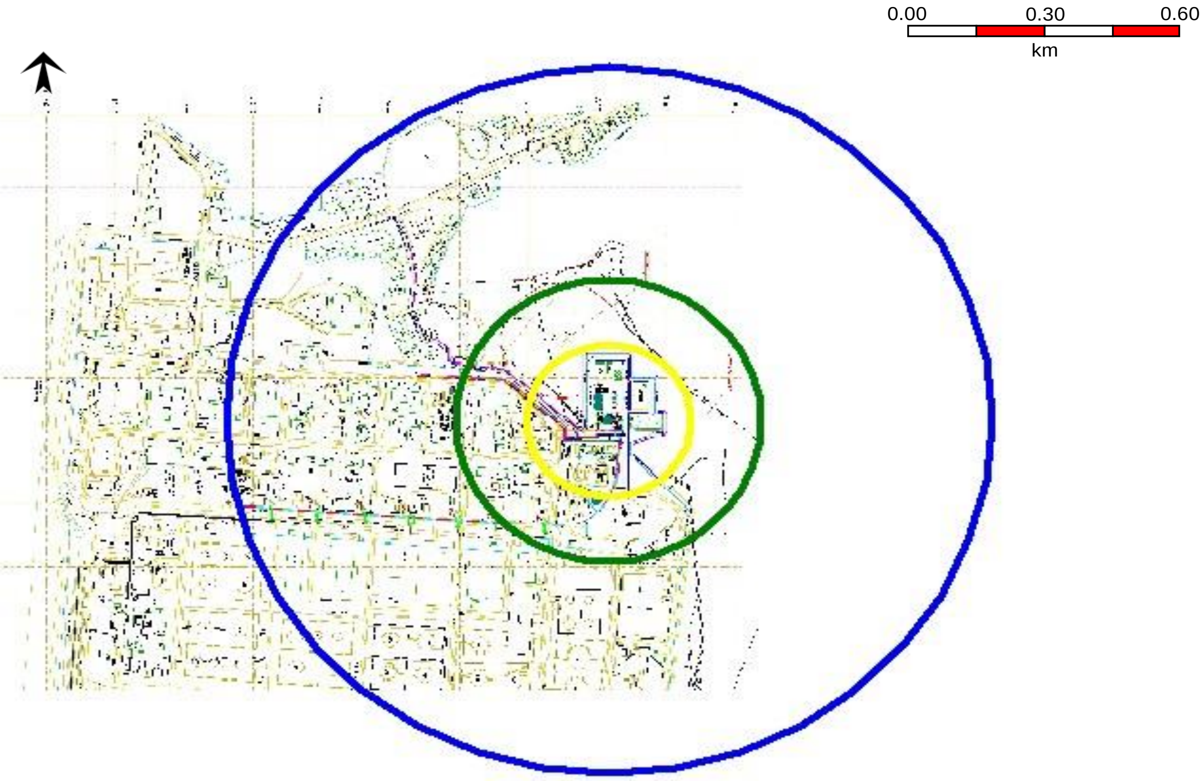


Fig. 8.9 Overpressure damage distance for Blast of Steam Boiler.

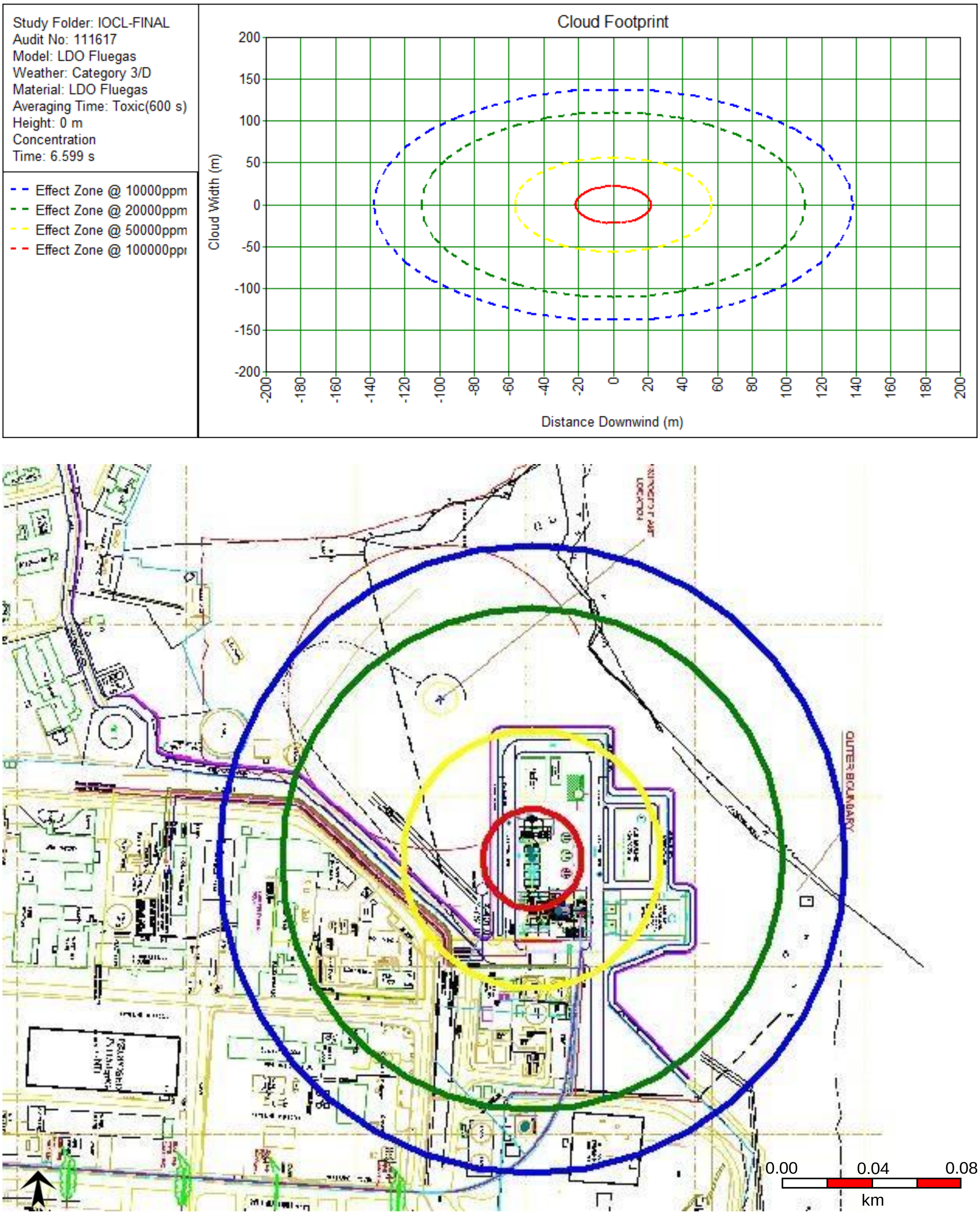
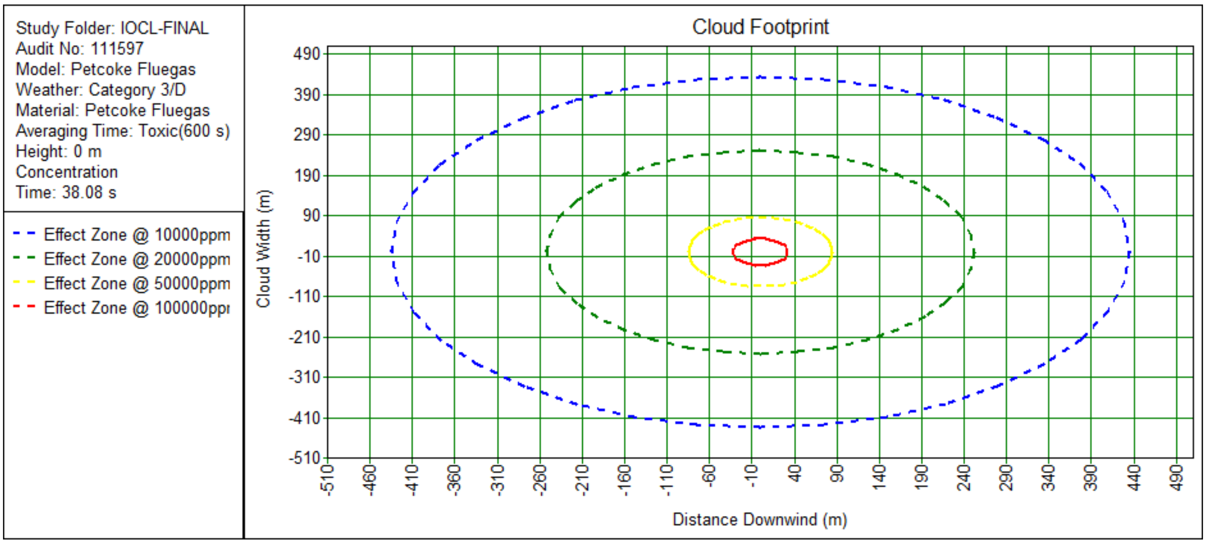


Fig. 8.10 IDLH-Toxic Damage Distances for rupture of LDO flue gas pipeline.



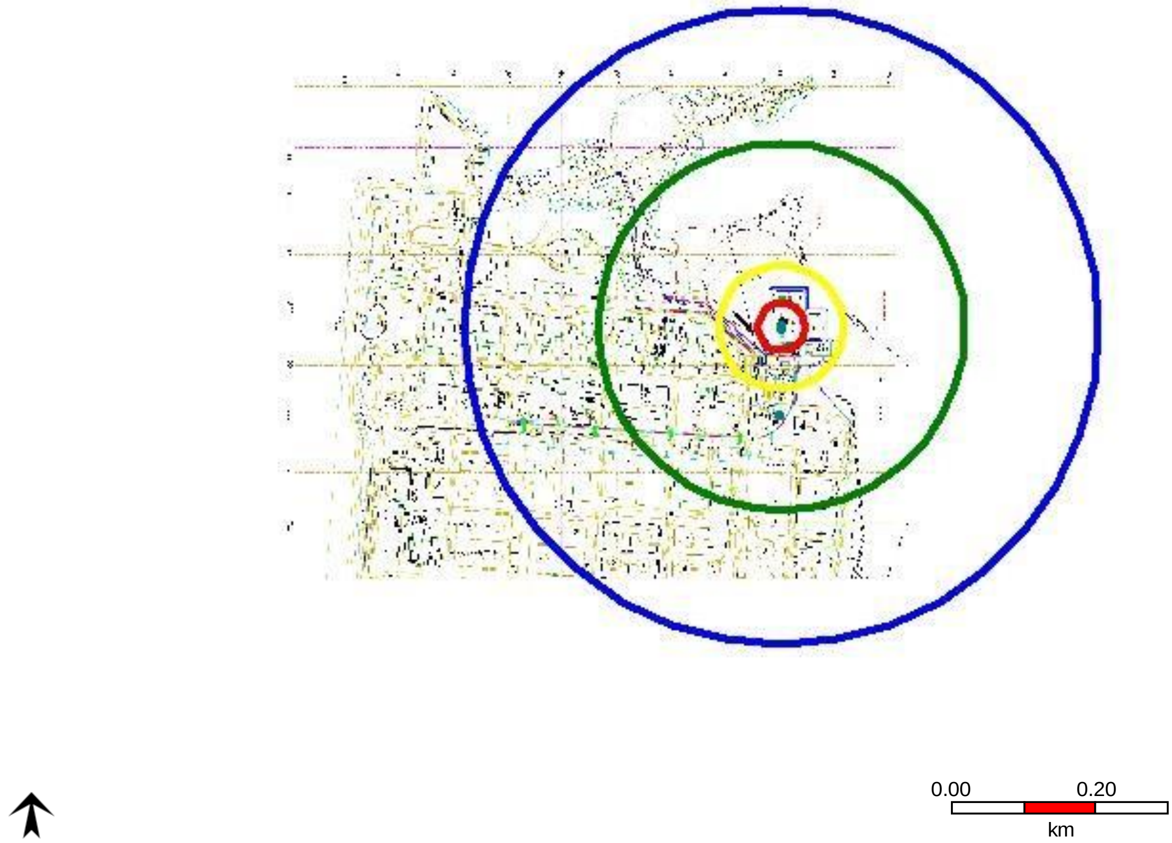


Fig. 8.11 IDLH-Toxic Damage Distances for rupture of Pet coke flue gas pipeline.

Chapter 9:
Individual Risk Quantification & contour mapping

According to Control of Major Accident Hazards (COMAH) regulations, the ALARP range for workers is from 1×10^{-3}/yr to 1×10^{-6}/yr, and is shown in **Fig. 9.1.**

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.
Risk criteria 2 = Societal Risk ("Group risk")
Cumulative probability per year that at least 10, 100 of 1000 people will be killed as a direct result of their presence within the impact area of an establishment and the occurrence of an event in which a dangerous chemical, dangerous waste or a pesticide is involved.

Chapter 10 :Societal Risk Quantification & contour mapping:

Societal risk is the relationship between the frequency of an event and the number of people affected and is represented by FN curve. There are essentially three major issues that the work on societal risk seeks to deal with:

- incremental development (a build up over time of population exposed to the risk)
- large developments outside the existing land use planning consultation distances and
- sufficiency of measures at the hazardous installation to reduce risks to as low as reasonably practicable (ALARP) in view of their risk profile.

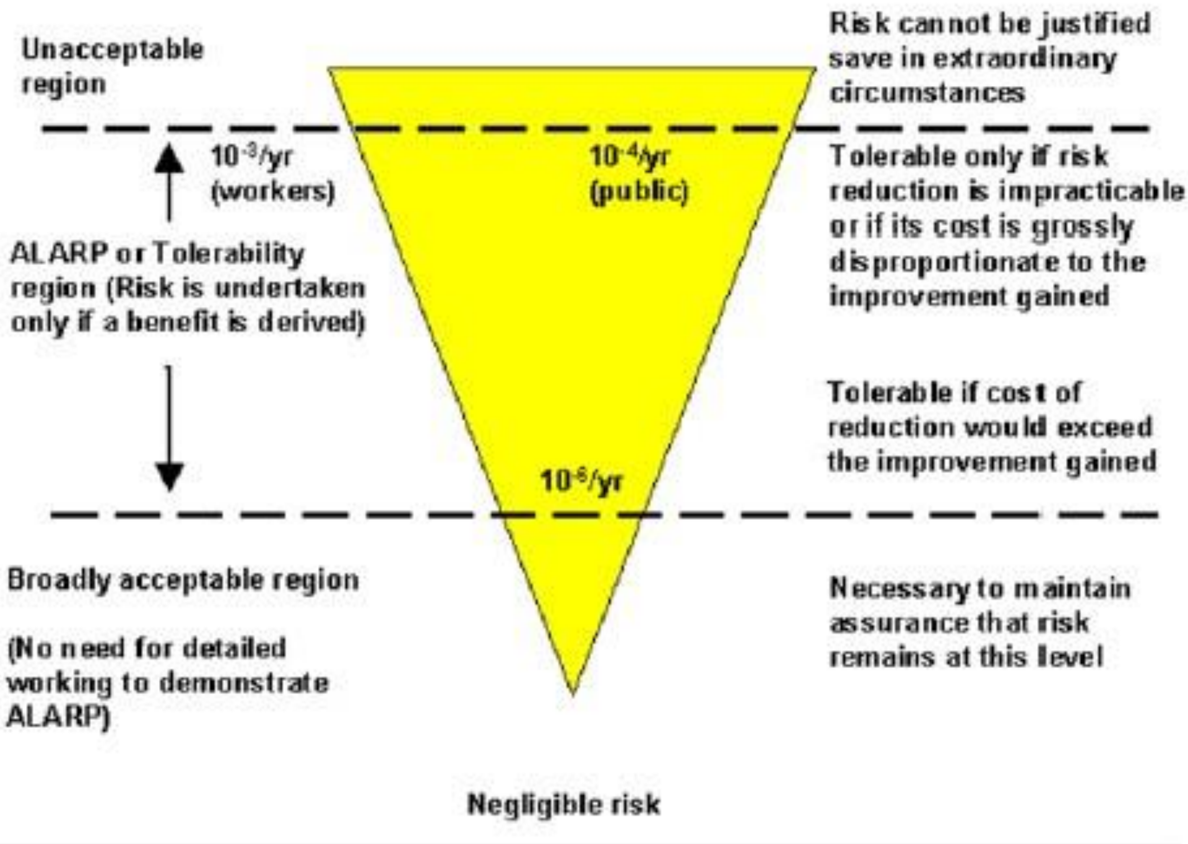


Fig. 9.1. Risk Criterion

The results have been shown in the **Fig. 9.2.1** to **10.4.2** for Individual risk and Societal risk respectively.

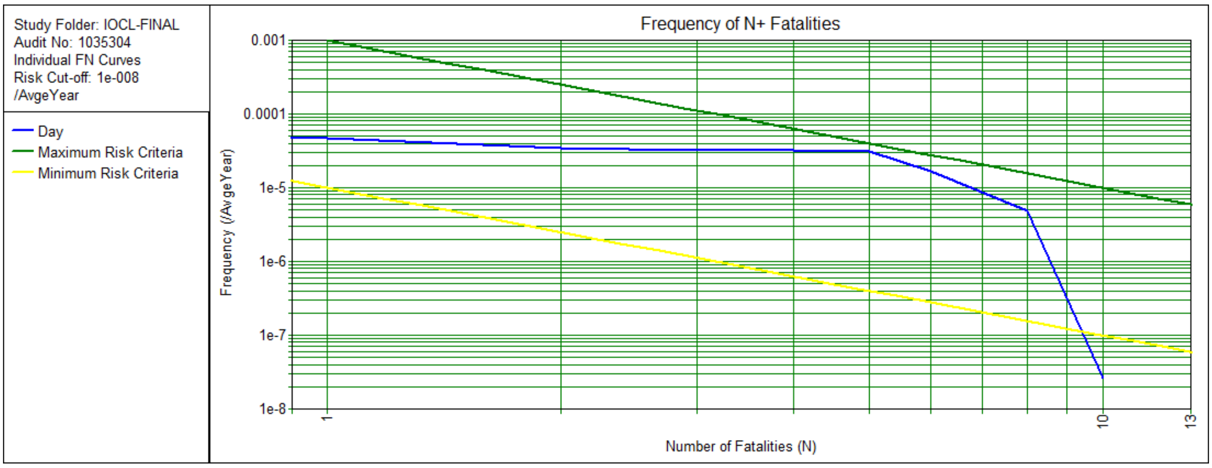


Fig.9.2.1 Societal Risk F-N Curve (Day).

Fig.9.2.2 Individual Risk Contours (Day).

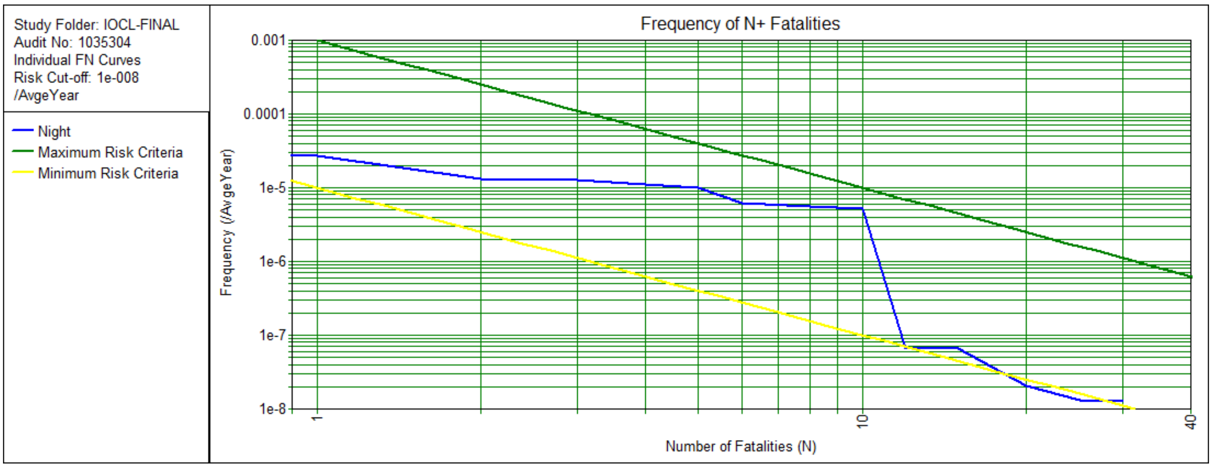


Fig.10.3.1 Societal Risk F-N Curve (Night).

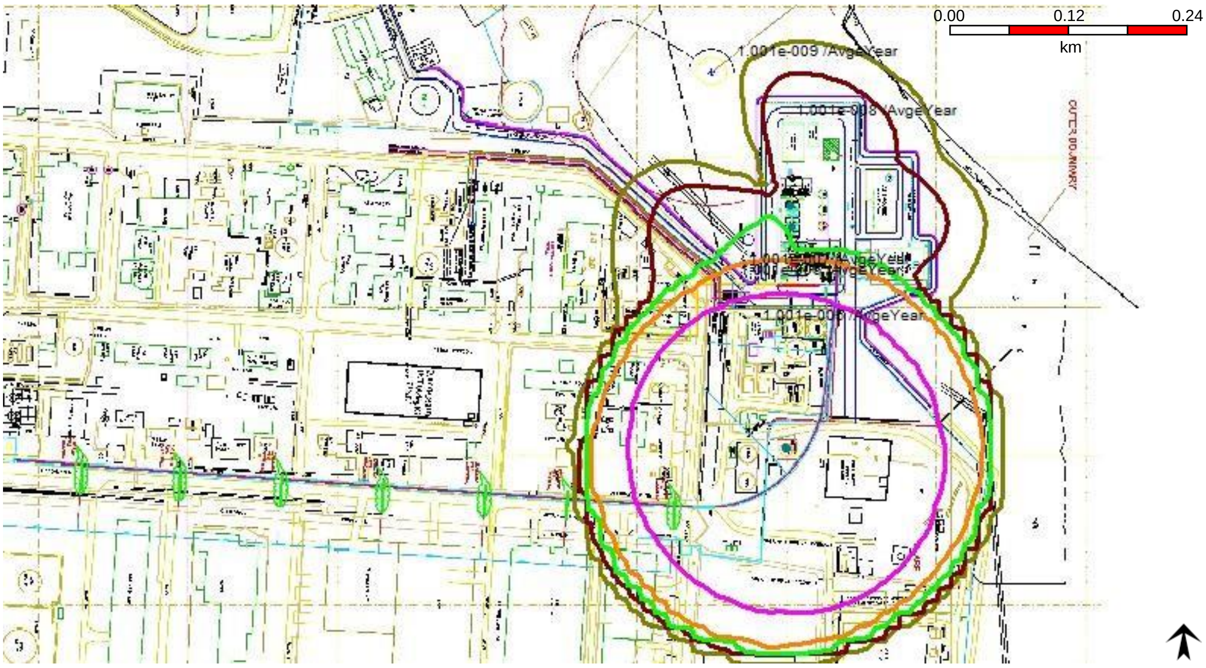


Fig.10.3.2 Individual Risk Contours (Night).

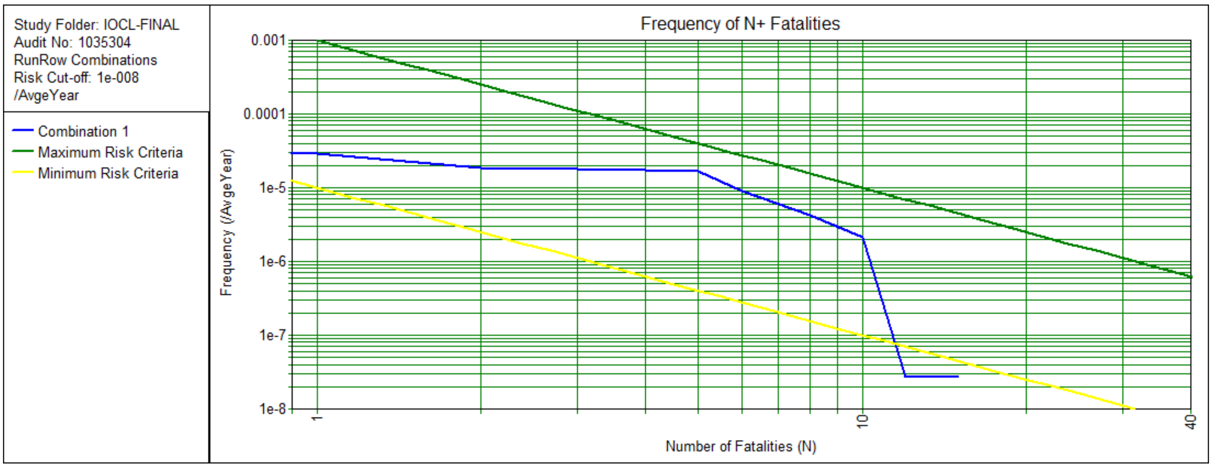


Fig.10.4.1 Societal Risk F-N Curve (Day and Night combination).

Fig.10.4.2 Individual Risk Contours (Day and Night combination).

CHAPTER 11:

EVALUATION OF RISK AGAINST THE RISK ACCEPTABLE LIMITS:

RISK ACCEPTABILITY CRITRIA:-

Risk is everywhere from home to work place & there is risk in whatever we do.

Statistical experience shows that there is chance of death 1 in 10,000 or 10^{-5}, when we take the risk of driving, flying or smoking. The chance of death from lightening or falling aircraft is estimated around 10^{-7} or 1 in 10000000. Thus we have a reasonable basis for setting criteria for covering risk to public at large for an industrial activity. It is therefore, generally accepted that the risk of death 1 in 100000 or 10^{-5} per year is alarming. Action needs to be taken to reduce the risk below the level 1 in 1000000 or 10^{-6} per year. The risk of death below 1 in 1000000 or 10^{0}-6 is generally accepted without concern for industrial people. This limit of acceptability is agreed as industrial risk criteria.

However, acceptability criteria for public or societal risk is much stiffer & it is generally agreed that public should be explored to much lower risk than employees calculation of social risk required population data.

To assess the risk posed by the installation, a comparison may be made with risk criteria for levels of risk that is considered tolerable for similar industries. A selection based on the type of industry was made among the criteria commonly adopted (Hazard identification & Risk Analysis – Code of Practice IS 15656:2006) & is given below:-

Application	Maximum Tolerable Risk (per Year)	Negligible Risk (Per year)
New Hazardous Installation	1.0E-6	1.0E-8

It can be seen that against these criteria the maximum risk at Boiler installation (1.0E-10) falls above the range of negligible risk.

Chapter :12

12. Risk reduction measures to prevent incidents, to control accidents:-

Major Findings of the Risk Assessment Study

The main findings are discussed under the following headings eg., potential impacts from consequence assessment and risk levels on persons inside and outside the installation.

i. Personnel stationed at the rest of installation such as at the Control Room, Admin, MCC room, electrical substation, and security areas will not be affected as these locations fall outside the fatality zone.

ii. The primary event at the proposed installation that has potential to cause secondary events arise due over pressure, Fire & Explosion.

iii. It is expected that the other Storage tanks in tank farm 2 may collapse and cause escalation of primary incident leading to a serious emergency situation.

iv. Hence emergency planning should particularly focus on Storages tank to prevent and contain the escalation of the primary events.

Incident Frequencies of Hazardous Outcomes within the installation. The analysis took into consideration the sequence of development of the event and the preventive and mitigation measures available within the installation.

The probabilities of these hazardous outcomes were assessed for proposed safety systems within the installation, considering the failure rates of primary events and available measures for detection and control.

The main findings are summarized below:-

a) The probability of a hazardous outcome for the operation was estimated to be in the range from 10-7 to 10-15 per year.

b) These frequency values for the individual outcomes can be considered to be extremely low due to the provision of several safety features and redundancies provided.

c) It can also be inferred the frequency of occurrence of secondary events will be extremely low as they require primary events for initiation, which itself is low.

Summary of Risk levels arising at the Installation

Individual risk levels inside the installation were evaluated at locations where people are stationed.

The maximum individual risk (IR) is the cumulative effect of several events that may have impact on specific locations. These areas have been identified based on the distribution of personnel with the installation.

Table - Risk at manned location

Manned location	Event	Risk to personnel (/Year)
Boiler House	Flash Fire/ Electrical Fire	1.43E-11
	Pet Coke Fire	1.43E -11

It can be seen that against these criteria the maximum risk at the installation (1.0E-10) falls below the range of negligible risk.

Control of ignition sources:

Fire & Explosion in a pet coke Boiler containing high pressure can be ruptured due to human error, Terror Attack, Natural disaster (Earthquake, Lighting, Flood) & may cause significant damage.

a. All activities within the area, however found well protected.

b. IOCL has included several types of protection & statutory compliance within the licensed areas. However, over time, switches & fixtures, cables connection joints, etc., may deteriorate due to moisture or aging and cause sparks and become potential source of ignition.

c. To avoid any incident that may arise due to miscommunication and prevent any ad-hoc decisions or changes to operational sequences, IOCL is advised to prepare a manual of approved operations, covering all units and activities for the proposed boiler operations.

Site specific emergency planning

Proposed Boiler installation needs on Site emergency Planning & Preparedness covering the storage and activities within the installation. Several primary events (e.g., Furnace Explosion , tank fires, fires at HSD, etc.) if realized could result in escalation and secondary events as noted in the risk Assessment. Though these are events of low probability, they need to be addressed in the development of the site specific emergency plans accordingly.

On Site Emergency Plan as per MSIHC (Rules) 1989-2000

1. Key personnel of the Organization & responsibilities assigned to them in case of emergency.

2. Out side organizations if involved in assisting during on-site emergency:

(a) Type of accidents.

(b) Responsibility assigned.

3. Details of liaison arrangement between the organisations.

4. Information on the preliminary hazard Analysis :

(a) Type of accidents.

(b) System elements or events that can lead to a main accident.

(c) Hazards.

(d) Safety relevant components.

5. Details about the site

(a) Location of dangerous substances.

(b) Seat of key personnel.

(c) Emergency control room.

6. Description of hazardous chemicals at plant site :

(a) Chemicals (quantities and toxicological data).

(b) Transformation if any which could occur.

(c) Purity of hazardous chemicals.

7. Likely dangers to the plant,

8. Enumerate effects of :

(i) stress and strain caused during normal operation.

(ii) fire and explosion inside the plant and effect if any of Fire and explosion out side.

9. Details regarding :

(i) warning, alarm and safety and security systems.

(ii) alarm and hazard control plans in line with disaster control and hazard control planning, ensuring necessary technical and organizational precautions.

(iii) reliable measuring instruments, control units and servicing of such equipment's.

(iv) precautions in designing of the foundation and load bearing parts of the building.

(v) continuous surveillance of operations.

vi) maintenance and repair work according to the generally recognised rules of good engineering practices;

10.. Details of communication facilities available during emergency and those required for an off-site emergency.

11.. Details of fire fighting and other facilities available and those required for an off-site emergency.

12.. Details of first aid and hospital services available and its adequacy.

13..Under Environment (Protection) Act, 1989 in COMPLIANCE OF MoE&F:-

i.) In compliance with MoE&F guideline maximum permissible limits is as Under:

Steam generation Capacity (ton/hour)	Particulate Emission matter (mg/nm^3)
15 & above	150**

Note:* To meet the respective standards, bag filter/ESP is recommended as control equipment with the boiler.
** All emission normalized to 12 per cent carbon dioxide.

ii.) Under Manufacture, Storage & Import of Hazardous Chemicals Rules, 1989-2000, it is suggested to prepare External Safety Audit Report, Safety Report & Conduct Emergency Mock Drill periodically.

iii) It is suggested to proceed approval of this proposed boiler from Boiler/Factory Dept.

iv) Recommended to carry out Mock Drill especially on Boiler emergency by creating Scenario of Boiler Fire & Explosion.

14.RiskAssessment of leakage & location near refinery & proposed measure for risk reduction:

L D O, Naptha, HSD, HCL etc are stored near proposed boiler.
-Extension of Storage Vessels dyke wall height.
-Inbuilt Safety measures in storage Tank & Boiler operation.
- Effective Emergency Drills is organized periodically.

Cascade or secondary events: Primary events such as Fire & Explosion from Boiler may have potential to affect neighboring units leading to secondary/ cascade events and resulting in escalation of the primary incident. These secondary events may result in multiple tank Fire and impact areas external to the installation.

Cascade potential of primary events causing secondary events occurs when overpressures from VCE are above 0.3 bar and/or when heat radiation from fire is above 37.5 kw/m2

FIRE EXPLOSION AND TOXICITY INDEX FOR STORAGE FACILITY

Table Risk Index

Category	Index Risk
Acceptable Region	<0
Low Risk	0
Moderate Risk	0.67
Significant Risk	1.33
High Risk	2
Unacceptable Region	>2

PHYSIOLOGICAL EFFECTS OF THRESHOLD THERMAL DOSES

THRESHOLD DOSE (kj/m2)	Effect
375	3rd degree burn
250	2nd Degree burn
125	1st degree burn
65	Threshold of pain, no reddening or blistering of skin caused

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

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

Pet Coke Conveyor System : Risk Assessment

Pet Coke carrying Belt Conveyor may cause accidents during the maintenance procedures including cleaning the belt conveyor, repairs, assembling or dismantling the conveyor and cleaning the hopper. Crossing over and crossing below the moving belt conveyor, while gathering material samples coming off the bin feeder of the conveyor belt may cause serious injuries.

Table: Hazards, Probability, Severity & Remedial measures for Pet Coke Conveyor:-

SNo	Hazards	Probability Against 1 on scale	Severity In %	Remedial Measures
1.	Failure to provide adequate maintenance Procedures	0.83	28	Standard opera rating & preventive maintenance procedures to be adhered.
2.	Failure to Follow adequate maintenance Procedures	0.75	16	Administrative Control
3.	Failure to provide Safe Crossing Facility	0.17	2	Engineering Control & Cautionary Notice to be placed at Vulnerable areas
4.	Failure to use Safe Crossing Facility	0.08	1	Approved Ruled & Procedures & strictly adhere.
5.	Adverse site/Geological conditions	0.08	1	Safe Lay out

6.	Failure of Mechanical devices	0.08	1	Inbuilt Safety measures in design

It can be noted that "Failure to follow adequate maintenance procedure" and "Failure to provide adequate maintenance procedure" were two hazards falling into the category of "very high" risk. The risk assessment matrix indicates that highest priority should be given to these hazards. Their existence is very likely to contribute a higher number of injuries.

Most of the incidents happened during the processes of cleaning the belt or repairs while the belt was in motion. Special attention should be focused on preventing any maintenance work on a moving belt conveyor. Therefore, the largest portion of the available resources should be allocated to prevent and control these hazards. There is one hazard placed in "medium" risk category and three hazards in "low" risk category. Additional resources can be allocated to avoid or mitigate these four hazards. Although having a lower probability of occurrence, they still contribute to fatal incidents.

Ignoring these hazards could also increase their frequency of occurrence and severity in the future.

Risk Assessment Matrix table for Conveyor System:

P R O B A B I L I T Y	Almost Certain			
	Very Likely	-Failure to provide adequate maintenance Procedures - Failure to follow adequate maintenance Procedures		
	Likely			Failure to provide Safe crossing Facility
	Possible			-Failure to use Safe crossing Facility. -Adverse site/Geological conditions -Failure of Mechanical Components
		High	Medium	Low
	S EV E R I T Y			

Risk: VH H M L

Two hazards were placed into the category of "very high" risk including "Failure to provide adequate maintenance procedures" and "Failure to follow adequate maintenance procedure" They contributed to almost 90 percent of all conveyor-related injuries. The risk assessment matrix indicates that the largest portion of the available resources should be allocated to prevent and control these two hazards.

LIST OF MAJOR ACCIDENTS EVENTS.

SNo	Scenario Description	Fire / Explosion/Toxic Events					
		JF	PF	FF	VCE	Injury/ Reportable Accident	L 1
1	Over Pressure	No	No	Yes	No	No	L 1
2	Over Heating	No	No	Yes	No	No	L 1
3	Leak in LDC	Yes	No	Yes	Yes	No	L 1
4	Electrical Short Circuit	No	No	Yes	No	No	L 1
5	Conveyor Failure	No	No	No	No	Yes	L 1
6	Pet Coke Crusher Failure	No	No	No	No	Yes	L 1
7	Pet Coke Fire	No	No	No	No	Yes	L 1

JF : Jet Fire

PF: Pool Fire

FF : Flash Fire

VCE: Vapor Cloud Explosion

L 1/L2/L3: As per On site Emergency Planning

Table A: Risk Classification Screening

S No.	Hazard Description	Initiating Event Likely hood	Unmitigated Consequences		Risk Class	Corrective Action
			Life Safety	Property Damage		
I	Pet Coke Handling Hazards					
1	Fire in Pet Coke storage	2	2	2	B	Regular inspection, water spray, isolation from ignition sources
2	Pet Coke dust explosion in conveyer bunker	4	3	4	B	Dust Suppression System. Proper ventilation, spark proof electrical equipment.
3	During Pet Coke handling Injuries like slipping	4	2	-	A	Proper PPE's
4	Respiratory problem due to Pet Coke dust	3	3	-	B	Dust mask should be provided
5	Sudden slow down of conveyer belt	2	2	2	B	Safety guard on the moving part
6	Pet Coke Crushed particles Explosion	4	2	2	A	Speed limit to crushing process
7	Conveyor cleaning	3	3	2	B	Training, proper supervision, PPE's
8	Fall from the height during work on conveyor belt, conveyer control room etc	3	4	-	C	Safety belt, safety net should provided, training
9	Struck by falling object	4	2	2	A	Safety helmet, safety net
II	Pet Coke Boiler Hazards					
1	Explosion in boiler due to over pressure and temperature	2	4	4	B	-Standby Pressure Relive Valve -Alarm, High alarm, High High alarm & Trip Devices. -Continuous monitoring, maintenance
2	Explosion in boiler due to improper combustion of fuel.	2	4	4	B	Regular inspection, maintenance
3	Burn injury due to hot water and hot steam pipeline leakage	3	3	3	B	Inspection, maintenance
4	Exposure to the hot surface of pipeline or machineries.	3	2	-	A	Regular inspection, maintenance
5	Burn injury by hot fly ash	4	2	-	A	Maintenance, proper exhaust
6	Catches on the moving part of the machinery like F.D. fans or motors	3	2	2	A	Proper fencing on the moving part of turbine
7	Burst of the equipment body due to over pressure and over temperature	3	2	4	A	Regular inspection, maintenance

8	Slip or trip of operators from the height during routine work/inspection.	4	4	2	B	Training, proper supervision, PPE's
9	Electric shock and electric burn routine work, maintenance or inspection of electrical panels.	4	4	2	B	Training, PPE's should provided
10	Slip, trip and from the height during routine work, Maintenance.	4	4	2	B	Safety belt, safety harness should provided, training

Table B: Risk Classification

Class	**GENERAL DISCRIPTION**	**ACTION**
A	Low risk events	Low risk level ;no further risk reduction action required
B	Moderate risk events	Required minor risk reduction improvements; generally addressed by codes, standards, company or industry practices
C	Moderate-High risk events	Generally required further analysis to determine an optimal risk reduction strategy or reliability analysis of propose risk controls
D	High risk events	High risk required immediate risk reduction analysis

Scale for: 1: High Hazard 2: Medium Hazard 3: Low Hazard 4: Extremely Low hazard

Observation and Recommendations:

- All the credible scenarios like 25 mm, 50 mm, 100 mm leaks and full bore rupture of LDO Storage tank and flue gas vapor lines have been considered as per the classification by HSE, UK, guidelines as minor, small, medium and large releases.

- From the previous accident records and hydrocarbon release databases, it has been observed that the pinhole leaks contribute highest percentage where as the second cause is small sized leaks of 25 mm diameter. In the present study, the damage distances are shown for the 25 mm, 50 mm and 100 mm leaks in Storage tank and are 19.51m, 31.71 m and 49.59 m respectively for 37.5 kW/m^2 heat radiation. This is well within the plant and affects the personnel working near that area only. Similarly in the case of overpressure the maximum damage distances for 0.3 bar is 431.56 m and is having minimum probability of occurrence. Whereas in the case of flue gas toxic effect the maximum damage distance for 10000 ppm is 438.05 m.

  - The Individual risk and societal risk are well within the ALARP range for this LDO storage facilities. And also, there is no individual risk of 0.001/Avg. yr for this LDO storage facilities. So, by following the Good SOP, the risk levels can be maintained within this range.
  - It is possible that LDO jet fires/flares may take place because of pipeline leaks or ruptures, and effects of heat radiation hazard are likely to be felt within the boundary limits.

- It is recommended to impart training to Crew members & associated staff regarding Emergency Handling.

- It is suggested to incorporate Pet Coke boiler while preparing Safety Report, Safety Audit Report & Emergency planning & preparedness.

- Prepare detailed check lists for periodic Safety Inspection (Pet Coke Boiler & Furnace), Boiler Emergency Rules & Procedures.

- Reliable power supply with Battery backup for highly critical equipment's to be provided.

- Fire fighting should be provided as per OISD.

- Maintenance of the protective devices, i.e. pressure relief valves, bursting discs, tank vents, non return valves and alarm system, in the plant is particularly important and should be covered by a formal system with full documentation.

- It is recommended to carryout regular maintenance and testing of instruments, valves and flange joints as per strict schedule. Pipelines, PSVs require special attention to minimize the failure rate.

- Emergency start up and shut down system procedures should be developed for all the operations in the facility.

- Piping and Instrumentation diagram (P&ID) and control system of entire LDO transfer and filling system shall be displayed near control panel.

- Do's and Don'ts shall be prominently displayed in the places like pump/compressor house, and at all other work places.

- Important telephone numbers of emergency shall be displayed prominently in bold letters in the pump/compressor house, control room, security gate, and plant In-charge room.

- Operational Safety Recommendation for 80 TPH CFBC Pet Coke Boiler are as under:

  - ✓ Furnace safe guard supervisory system (FSSS) & integrated Combustion control.

  - ✓ Boiler Purging to be ensured incase of tripping/start-up/shutdown of boiler.

  - ✓ Fire bed should be cleaned at appropriate time to avoid build-up of "fire bed thickness", if not, this would reduce the primary air supply successively & result into improper combustion.

  - ✓ Soot deposits in tubes should be cleaned from time to time with proper tool. Build up of deposits effects the steam generation adversely and result into higher fuel gas temp. & higher stack loss.

  - ✓ The cyclone bottom opening should be kept air tight & leak proof, else, it would reduce cyclone efficiency. The dust collected should be taken out from time to time (say once per shift) & appropriately disposed avoiding secondary pollution.

  - ✓ Good quality feed water should be used for boiler & appropriate chemicals should be added, as directed by boiler supplies, for avoiding tube deposits, else it would reduce steam generation.

  - ✓ CO_2 % should be checked once day to ensure proper boiler operation & take corrective actions, if required.

It is found the study that the Risk for the proposed Boiler Installation of Pet Coke Boiler at IOCL-Guwahati within the tolerable/acceptable limits.

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