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QUANTITATIVE RISK ASSESSMENT REPORT

PREPARED FOR

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DIST DIBRUGARH

ASSAM 786 602

INDIA

CONDUCTED & PREPARED BY

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QUALITY CONTROL SHEET

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WE EXPRESS OUR SINCERE THANKS TO MANAGEMENT & EMPLOYEES OF ***ASSAM GAG COMPANY LTD, ASSAM (INDIA)*** *FOR THEIR CO-OPERATION & UNSTINTED HELP WITHOUT WHICH THE* ***'QUANTITATIVE RISK ASSESSMENT'*** *COULD NOT HAVE BEEN POSSIBLE. THE COURTESY EXTENDED TO OUR TEAM IS HIGHLY APPRECIATED.*

For: GREEN CIRCLE CONSULTANTS (I) PVT.LTD.

AUTHORISED SIGNATORY

ABBREVIATION

API	American Petroleum Institute
ESD	Emergency Shutdown system
ID	Internal Diameter
ROV	Remote Operated Valve
P & ID	Piping and Instrument Diagram
PFD	Process Flow Diagram
PPM	Parts Per Million
LFL	Lower Flammable Limit
UFL	Upper Flammable Limit
AIHA	American Industrial Hygiene Association
MSDS	Material Safety Datasheet
NH	No Hazards
NR	Not Reached
CNG	Compressed Natural Gas

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EXECUTIVE SUMMARY

- 24 hr/day, 7 days/week monitoring of gas flow pressures.
- Plan for rapid pressure loss on the pipeline through a series of valves along the route
- Pipeline marker signs to identify the area where the pipeline is buried.
- Public awareness program to remind people to call before they dig near the pipeline
- Mobile patrol to guard against unauthorized activity.
- Leakage surveys.
- Periodic in-line inspections using sophisticated electronic equipment will check for changes in the steel pipe wall
- Security management plan, including random patrols of cell above ground facilities and the use of other modern security protocols
- Emergency Response Plan, developed with input from local and provincial emergency responders
- Ensure first responders have the training needed to deal with pipeline emergencies
- Always follow "Dial before dig"
- High quality steel and testing at manufacture.
- Application of fusion bond epoxy coating to protect the pipeline against corrosion.
- Cathodic protection (impressed current on the pipeline) to protect against corrosion.
- Specialized welding techniques.
- X-ray or ultrasonic testing of each weld.
- Pre-operation hydrostatic tests to verify structure integrity under extreme pressure.

OBJECTIVE AND SCOPE OF STUDY

Introduction:

M/s **Assam Gas Company Ltd**. has gas compressor station and the gas pipelines going to the nearby villages and tea garden Hence, a quantitative risk assessment (QRA) was under taken to assess the risk impacts associated with the compressor stations and existing pipelines existing and new installation, and to establish whether these risks comply with the applicable criteria.

Assam Gas Company Ltd., **Dibrugarh, Assam** has engaged the services of Green Circle Consultants India Pvt. Ltd, Vadodara, for carrying out QRA report. Green Circle Consultants India Pvt. Ltd has the requisite software and specialized manpower resources for this purpose. The latest version of the renowned PHAST Risk software package of DNV is used by Green Circle Consultants (I) Pvt. Ltd for carrying out the risk analysis.

QRA study for Assam Gas Company Ltd., Dibrugarh, Assam has been carried out based on data provided by Assam Gas Company Ltd., Vadodara. The study has been carried out in accordance with the International codes of practices using PHAST (Process Hazard Analysis Software Tool) – 6.53 software.

The full terms of potential hazardous scenarios and consequence events associated with the installation and operation of the proposed Gas pipelines and compressor station Unit was considered in the analysis. Based on the operations to be carried at the plant, the Risk Analysis, affected distances and the damage of property and population from the identified scenarios considering the Maximum Credible Loss Scenario (MCLS) & Worst case scenario. Maximum credible loss scenarios have been worked based on the inbuilt safety systems and protection measures to be provided for the operation of the facility & the Worst case scenario i.e. 100% catastrophic rupture have been worked out based on failure of the inbuilt safety system.

We have assumed Maximum credible loss scenario (MCLS) i.e. Nozzle failure and Worst case Scenario i.e. catastrophic rupture for compressor as per the guidelines suggested by DNV – UK. Similarly, maximum inventory at the time of failure is assumed.

Objective of Study

The main objective QRA (Quantitative Risk Analysis) is to determine the potential risks of major disasters having damage potential to life and property and provide a scientific basis for decision makers to be satisfied about the safety levels of the facilities to be set up. This is achieved by the following:

- Identification of hazards
- Identify the potential failure scenarios that could occur within the facility.
- To Asses, the potential risks associated with identified hazards to which the plant and its personal and community outside may be subjected. Consequences analysis of various hazards is carried out to determine the vulnerable zones for each probable accident scenario.
- Evaluate the process hazards emanating from the identified potential accident scenarios.
- Analyze the damage effects to the surroundings due to such accidents.
- Evaluate Individual risk to surroundings from the OMPL Aromatics Complex.
- Conclusion and Recommendation to mitigate measures to reduce the hazard / risks.
- To provide guidelines for the preparation of On-site response plan.

Scope of the Study

M/s **Assam Gas Company Ltd.** has gas compressor station and the gas pipelines going to the nearby villages and tea garden Hence, a quantitative risk assessment (QRA) was under taken to assess the risk impacts associated with the compressor stations and existing pipelines existing and new installation, and to establish whether these risks comply with the applicable criteria.

Use of QRA Results

The techniques used for risk prediction within the QRA have inherent uncertainties associated with them due to the necessary simplifications required. In addition, QRA incorporates a certain amount of subjective engineering judgment and the results are subject to levels of uncertainty. For this reason, the results should not be used as the sole basis for decision making and should not drive deviations from sound engineering practice. The results should be used as a tool to aid engineering judgment and, if used in this way, can provide valuable information during the decision making process.

The QRA results are dependent on the assumptions made in the calculations, which are clearly documented throughout the following sections of this report. Conservative assumptions have been used, which helps to remove the requirement for detailed analysis of the uncertainty. The results show the significant contributions to the overall risk and indicate where worthwhile gains may be achieved if further enhancement of safety is deemed necessary.

Software Used

PHAST 6.53 (latest version) has been used for consequence analysis include discharge and dispersion calculations.

SITE CONDITION

Following diagram shows the location of pipeline distribution in the town

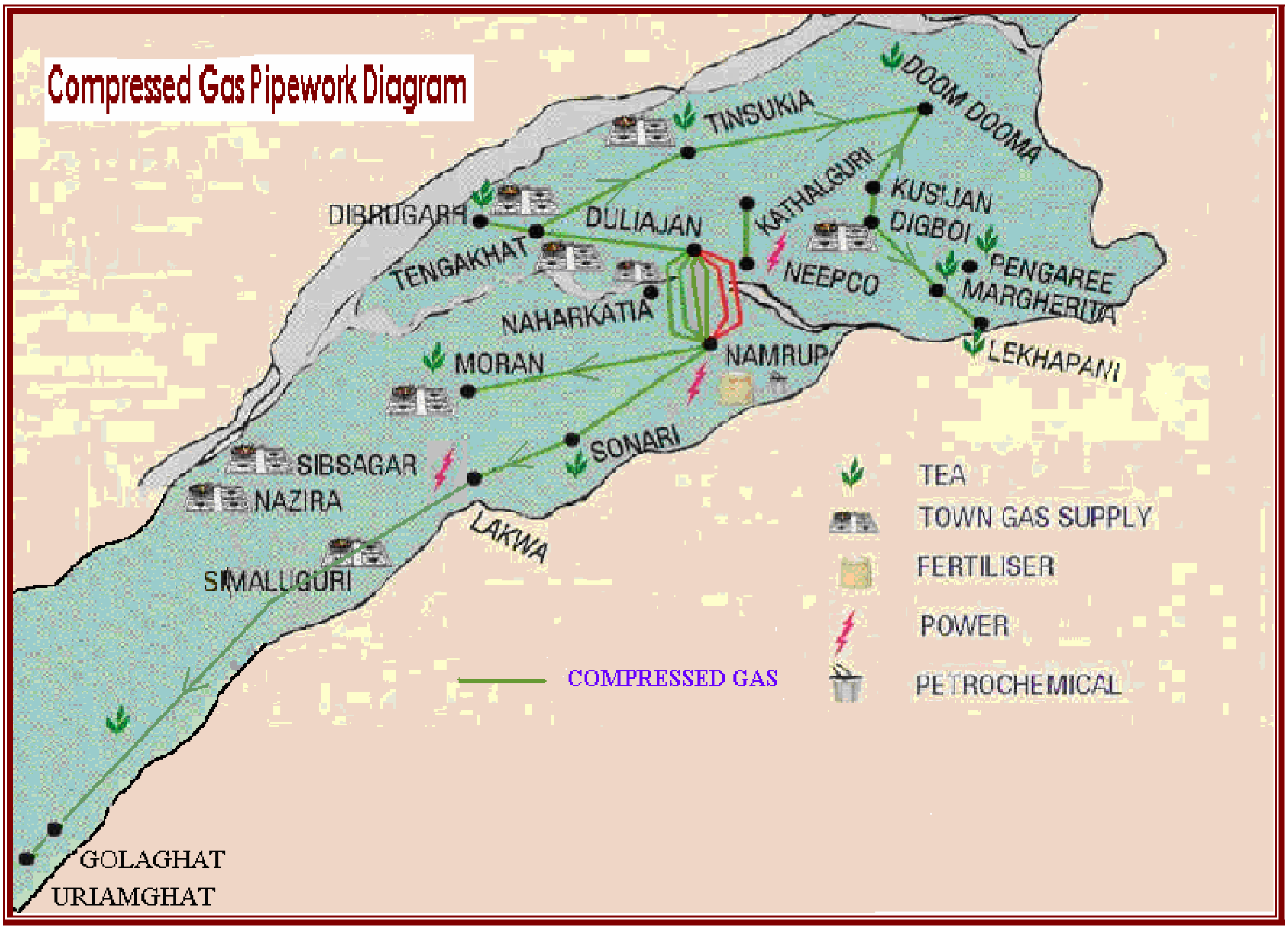


Figure 1 **Compressed gas pipe work diagram**

METEOROLOGICAL CONDITIONS

The consequences of released toxic or flammable material are largely dependent on the prevailing weather conditions. For the assessment of major scenarios involving release of toxic or flammable materials, the most important meteorological parameters are those that affect the atmospheric dispersion of the escaping material. The crucial variables are wind direction, wind speed, atmospheric stability and temperature. Rainfall does not have any direct bearing on the results of the risk analysis; however, it can have beneficial effects by absorption / washout of released materials. Actual behavior of any release would largely depend on prevailing weather condition at the time of release. For the present study we use the metrological data of the Assam

ATMOSPHERIC PARAMETERS

The Climatological data which have been used for the study is summarized below:

Table 1 Atmospheric Parameters

Sr. No.	Parameter	Max	Min.	Annual Average
1.	Ambient Temperature (°C)	33	28	30
2.	Relative Humidity (%)	90	75	80

The average value of the atmospheric parameters is assumed for the study.

WIND SPEED AND WIND DIRECTION

The wind speed and wind direction data which have been used for the study is summarized below:

Wind Speed	:	7 m/s, 3 m/s & 5 m/s
Atmospheric Stability	:	D and F
Wind Direction	:	All 360 deg.
Relative Humidity	:	70%

WEATHER CATEGORY

One of the most important characteristics of atmosphere is its stability. Stability of atmosphere is its tendency to resist vertical motion or to suppress existing turbulence. This tendency directly influences the ability of atmosphere to disperse pollutants emitted into it from the facilities. In most dispersion scenarios, the relevant atmospheric layer is that nearest to the ground, varying in thickness from a few meters to a few thousand meters. Turbulence induced by buoyancy forces in the atmosphere is closely related to the vertical temperature gradient.

Temperature normally decreases with increasing height in the atmosphere. The rate at which the temperature of air decreases with height is called Environmental Lapse Rate (ELR). It will vary from time to time and from place to place. The atmosphere is said to be stable, neutral or unstable according to ELR is less than, equal to or greater than Dry Adiabatic Lapse Rate (DALR), which is a constant value of 0.98°C/100 meters.

Pasquill stability parameter, based on Pasquill – Gifford categorization, is such a meteorological parameter, which describes the stability of atmosphere, i.e., the degree of convective turbulence. Pasquill has defined six stability classes ranging from `A' (extremely unstable) to `F' (moderately stable). Wind speeds, intensity of solar radiation (daytime insulation) and nighttime sky cover have been identified as prime factors defining these stability categories.

When the atmosphere is unstable and wind speeds are moderate or high or gusty, rapid dispersion of pollutants will occur. Under these conditions, pollutant concentrations in air will be moderate or low and the material will be dispersed rapidly. When the atmosphere is stable and wind speed is low, dispersion of material will be limited and pollutant concentration in air will be high. In general, worst dispersion conditions (i.e. contributing to greater hazard distances) occur during low wind speed and very stable weather conditions.

Surface Wind Speed	Day time insolation			Night time condition		Anytime
	Strong	Moderate	Slight	Thin Overcast > 4/8 low cloud	≥ 3/8 cloudiness	Heavy overcast
<2	A	A-B	B	F	F	D
2-3	A-B	B	C	E	F	D
3^	B	B-C	C	D	E	D
4-6	C	OD	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: Slighrly stable conditions

F: Moderately stable conditions

Windrow for Dibrugarh, Assam is given below.

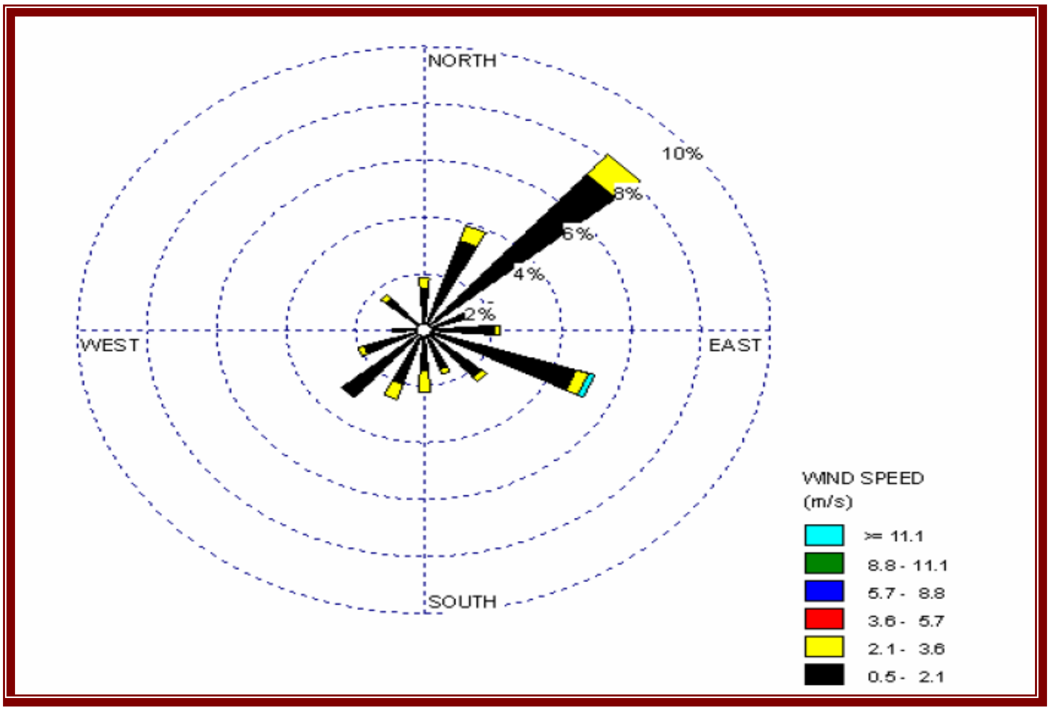


Figure 2 **Wind rows for Dirugarh, Assam**

METODOLOGY ADOPTED FOR CONSEQUENCE ANALYSIS

Consequences of loss of containment can lead to hazardous situation in any industry handling potentially hazardous materials. Following factors govern the severity of consequence of the loss of containment.

- Intrinsic properties; flammability, instability and toxicity.
- Dispersive energy; pressure, temperature and state of matter.
- Quantity present
- Environmental factors; topography and weather.

Consequence analysis and calculations are effectively performed by computer software using models validated over a number of applications. Consequence modeling is carried out by PHAST (version 6.53) of DNV Software, UK.

PHAST uses the Unified Dispersion Model (UDM) capable of describing a wide range of types of accidental releases. The Model uses a particularly flexible form, allowing for sharp-edged profiles, which become more diffuse downwind.

PHAST contains data for a large number of chemicals and allows definition of mixtures of any of these chemicals in the required proportion. The calculations by PHAST involve following steps for each modeled failure case:

- Run discharge calculations based on physical conditions and leak size.
- Model first stage of release (for each weather category).
- Determine vapor release rate by flashing of liquid and pool evaporation rate.
- Dispersion modeling taking into account weather conditions.
- In case of flammable release, calculate size of effect zone for fire and explosion.
- The hazardous materials considered in this study are mostly flammable liquids.

Flow chart for consequence analysis is shown in the form of event tree for release of flammable liquid.

Following figure gives the brief idea of the methodology should be adopted for the study.

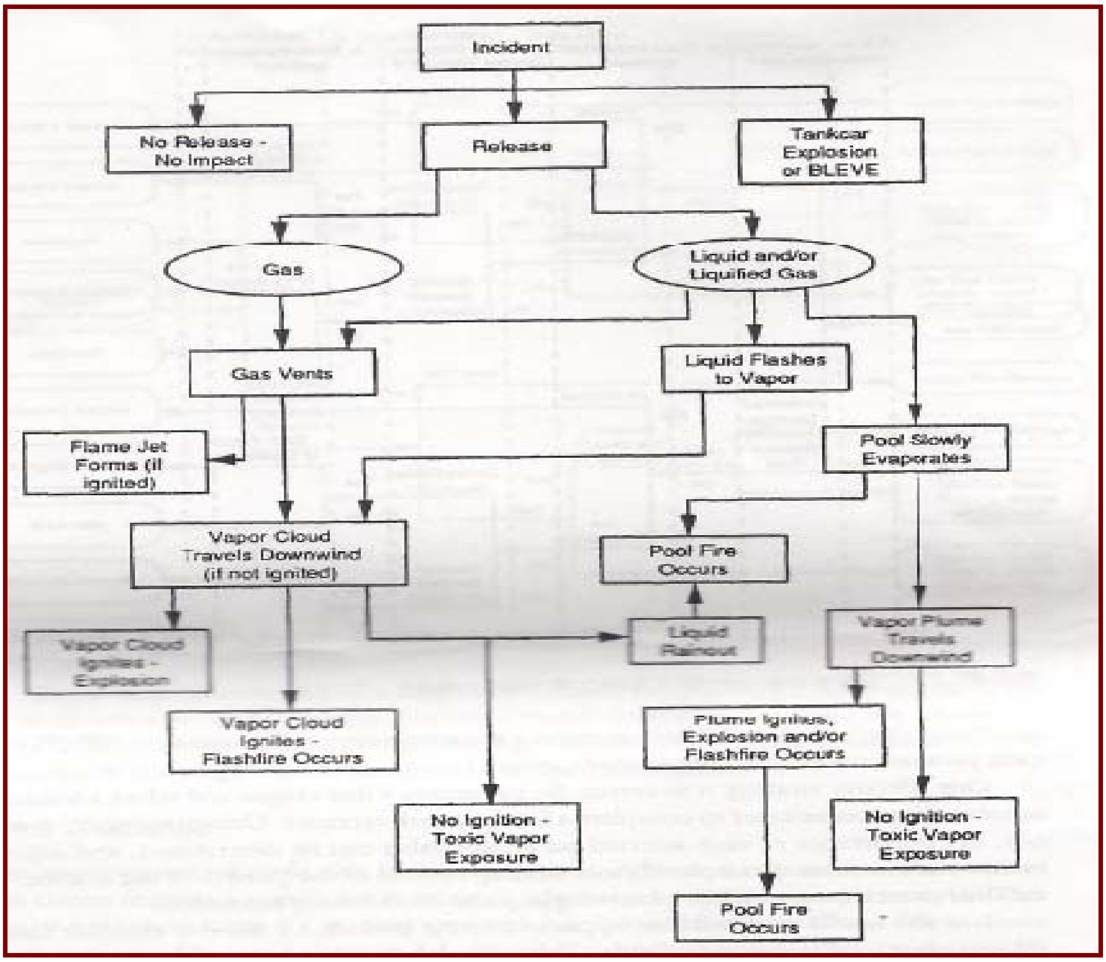
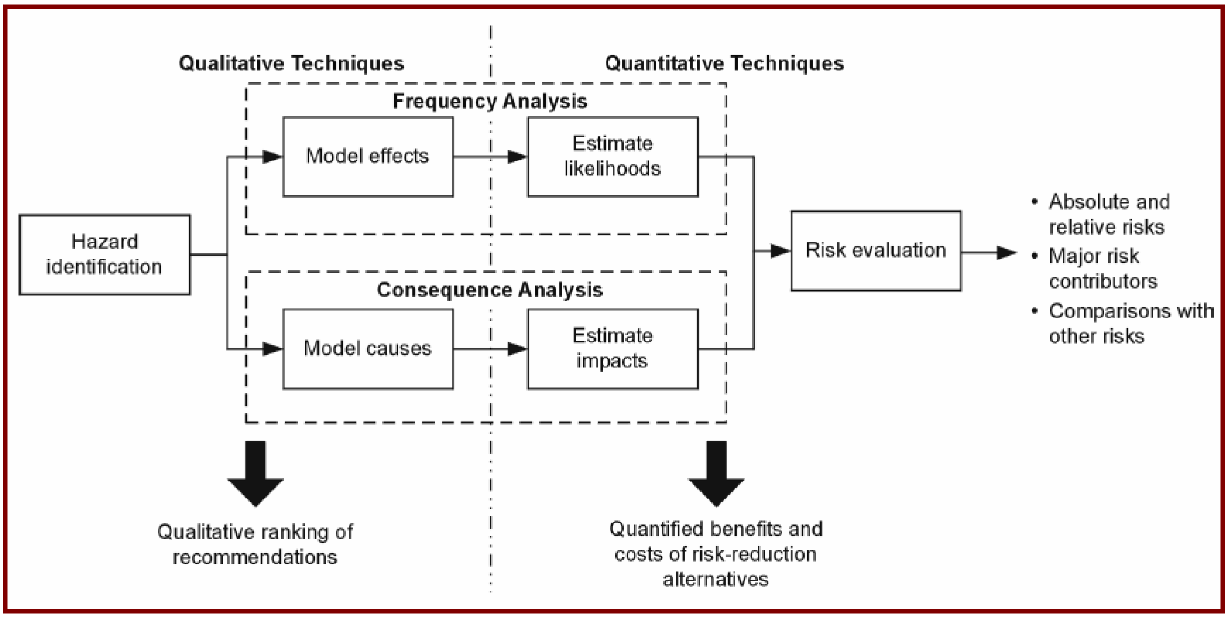


Figure 3 **Methodology adopted for the study**



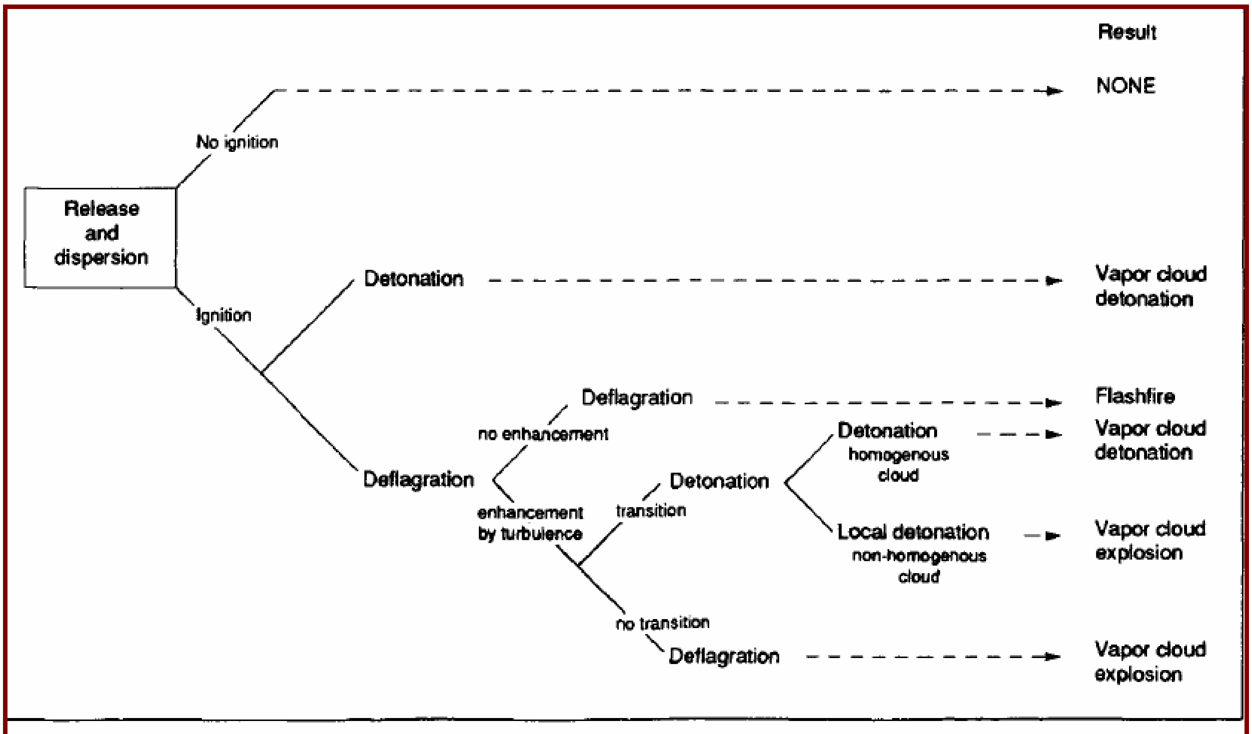
HAZARDS OF MATERIALS

DEFINITIONS

The release of flammable gas or liquid can lead to different types of fire or explosion scenarios. These depend on the material released, mechanism of release, temperature and pressure of the material and the point of ignition. Types of flammable effects are as follows.

a. Flash fire:

It occurs when a vapor cloud of flammable material burns. The cloud is typically ignited on the edge and burns towards the release point. The duration of flash fire is very short (seconds), but it may continue as jet fire if the release continues. The overpressures generated by the combustion are not considered significant in terms of damage potential to persons, equipment or structures. The major hazard from flash fire is direct flame impingement. Typically, the burn zone is defined as the area the vapor cloud covers out to half of the LFL. This definition provides a conservative estimate, allowing for fluctuations in modeling. Even where the concentration may be above the UFL, turbulent induced combustion mixes the material with air and results in flash fire.



Event tree for vapor cloud explosions and flash fires.

b. Jet Fire:

Jet flames are characterized as high-pressure release of gas from limited openings (e.g. due to small leak in a vessel or broken drain valve). Boiling liquid expanding vapor explosion (BLEVE) or fireball: A fireball is an intense spherical fire resulting from a sudden release of pressurized liquid or gas that is immediately ignited. The best known cause of a fireball is a boiling liquid expanding vapor explosion (BLEVE). Fireball duration is typically 5 – 20 seconds.

c. Vapor cloud explosion

When a large quantity of flammable vapor or gas is released, mixes with air to produce sufficient mass in the flammable range and is ignited, the result is a vapor cloud explosion (VCE). Without sufficient air mixing, a diffusion-controlled fireball may result without significant overpressures developing. The speed of flame propagation must accelerate as the vapor cloud burns. Without this acceleration, only a flash fire will result.

d. BLEVE and Fireball

BLEVE is defined as any sudden loss of containment of a fluid above its normal boiling point at the moment of vessel failure. A common cause of this type of event is fire engulfment of a vessel which contains liquid under pressure, where the heating both raises the pressure in the vessels and lowers the yield strength of the material.

The BLEVE event can give rise to a blast wave, to fragment projection and if a flammable fluid is involved, to either a fireball, a flash fire or a vapor cloud explosion. Fireballs modeled in the QRA are outcomes of BLEVE and not independent events.

e. IMPACT

Estimation of damage or impact caused due to thermal radiation or toxic effects is generally based on the published literature on the subject. Probit relations are used for these calculations. The actual potential consequences from these likely impacts can then be visualized by superimposing the damage effect zones on the proposed site plan and identifying the elements within the project site as well as in the neighboring environment, which might be adversely affected, should one or more hazards materialize in practice.

f. Thermal Damage

The effect of thermal radiation on people is mainly a function of intensity of radiation (heat flux) and exposure time. The effect is expressed in terms of the probability of death and different degrees of burn.

g. Threshold Limit Value (TLV)

TLV is the permitted level of exposure for a given period on a weighted average basis (usually 8 hours for 5 days in a week).

h. Risk

A measure of both the incident likelihood (frequency) and the magnitude of the damage consequence to human life and property resulting from a given activity.

i. Accident (sequence)

A specific combination of events or circumstances that leads to an undesirable consequence

j. Hazard

A chemical or physical condition that has the potential for causing damage to people, property, or the environment

k. Event tree (analysis)

A logic model that graphically portrays the range of outcomes from the combinations of events and circumstances in an accident sequence. For example, a flammable vapor release may result in a fire, an explosion, or in no consequence depending on meteorological conditions, the degree of confinement, the presence of ignition sources, etc. These trees are often shown with the probability of each outcome at each branch of the pathway

l. Risk analysis

The development of a quantitative estimate of risk based on engineering evaluation and mathematical techniques for combining estimates of incident consequences and frequencies

FLAMMABLE HAZARDS ASSOCIATED WITH HYDROCARBONS

Methane

Methane is a chemical compound with the chemical formula CH4. It is the simplest alkane, and the principal component of natural gas. Burning methane in the presence of oxygen produces carbon dioxide and water. The relative abundance of methane makes it an attractive fuel. However, because it is a gas at normal temperature and pressure, methane is difficult to transport from its source. In its natural gas form, it is generally transported in bulk by pipeline or LNG carriers; few countries transport it by truck.

Potential health effects of methane

Methane is not toxic; however, it is highly flammable and may form explosive mixtures with air. Methane is violently reactive with oxidizers, halogens, and some halogen-containing compounds. Methane is also an asphyxiant and may displace oxygen in an enclosed space. Asphyxia may result if the oxygen concentration is reduced to below 19.5% by displacement the concentrations at which flammable or explosive mixtures form are much lower than the concentration at which asphyxiation risk is significant. When structures are built on or near landfills, methane off-gas can penetrate the buildings' interiors and expose occupants to significant levels of methane. Some buildings have specially engineered recovery systems below their basements to actively capture such fugitive off-gas and vent it away from the building.

Uses

Methane in the form of compressed natural gas is used as a vehicle fuel, and is claimed to be more environmentally friendly than other fossil fuels such as gasoline/petrol and diesel. Research into adsorption methods of methane storage for this purpose has been conducted.

Table 2 Hazardous properties of methane

Sl. No.	Properties	Values
1.	LFL (%v/v)	5
2.	UFL (%v/v)	15
3.	Auto ignition temperature (°C)	580 ^{0}C

5.	Normal Boiling point (°C)	-161.6 ^{0}C
6.	Flash point	-188 ^{0}C

Methane (CH4) is a major greenhouse gas. It is produced during anaerobic decomposition of manure and accumulates around manure storage areas

Methane emissions from manure depend on the way manure is managed (liquid manure systems produce more methane than solid manure systems) and environmental factors such as temperature and moisture (warmer temperatures and moist conditions will produce greater amounts of methane).

Methane Characteristics

Methane is an odorless gas and is lighter than air. Because methane is lighter than air, it tends to rise and accumulate near the higher, stagnant parts of enclosed buildings and tightly closed manure storage pits. It is most likely to accumulate during hot, humid weather.

Methane is extremely difficult to detect without gas detection instruments. Concentrations in confinement livestock housing are normally well below the levels that may be explosive; however, explosions attributed to methane have occurred around manure storage pits without proper vents.

Methane can displace oxygen in confined areas, resulting in an oxygen-deficient atmosphere. Methane can explode at concentrations of 50,000 ppm or more (a level of 5 per cent). Health Effects

The Occupational Safety and Health Administration (OSHA) has no permissible exposure limit for methane, but the National Institute for Occupational Safety and Health's (NIOSH) maximum recommended safe methane concentration for workers during an 8-hour period is 1,000 ppm (0.1 percent). Methane is considered an asphyxiant at extremely high concentrations and can displace oxygen in the blood (Table 1).

Methane exposure levels and effects

Exposure level (ppm)	Effect or symptom
1000	NIOSH 8-hours TLV*
50,000 to 150,000	Potentially explosive

500,000 Asphyxiation

- TLV = Threshold Limit Value

Aerating manure

Aeration allows microorganisms to break down organic material through the addition of oxygen (O_2). Aerobic decomposition of manure lowers or eliminates methane emissions, but may increase nitrous oxide emissions.

Filtration of the ventilation air

Filtering exhaust air from animal houses to remove odour-causing gases, GHGs and dust particles may provide a way to reduce methane emissions. However, more research is needed in this area. Straight

Temperature control

Cooling of indoor stored manure can lead to a reduction in emissions.

Protect Yourself and Others from Exposure

- Make sure all pits and manure storage areas are adequately and appropriately ventilated.
- Smoking should not be allowed around manure pits.
- Frequently test the levels of methane in the barn using an explosion meter.
- Do not lower fans into the manure pit because this practice could cause methane explosion
- Prohibit all open sparks or flames in areas near pits or storage facilities.
- Electric motors, fixtures and wiring near manure storage structures should be kept in good condition to prevent a spark from igniting they methane.
- Entry into a confined space should not be performed without a proper breathing apparatus
- Post warning signs to keep people away from dangerous confined spaces.
- Have someone outside the manure pit to call for help if needed.
- Do not try to rescue a person who has been overcome by the gas. Call for help immediately.

DAMAGE CRITERIA

Damage estimates due to thermal radiations and overpressure have been arrived at by taking in to consideration the published literature on the subject. The consequences can then be visualized by the superimposing the damage effects zones on the proposed plan site and identifying the elements within the project site as well as in the neighboring environment, which might be adversely affected, should one or more hazards materialize in real life.

Thermal damage

The effect of thermal radiation on people is mainly a function of intensity of radiation and exposure time. The effect is expressed in terms of the probability of death and different degrees of burn. The following tables give the effect of various levels of heat flux.

DAMAGE DUE TO RADIATION INTENSITY

Table 3 Damage Due to Radiation Intensity

RADIATION kW/m2	DAMAGE TO EQUIPEMENT	DAMAGE TO PEOPLE
1.2	***	Solar heat at noon
1.6	***	Minimum level of pain threshold
2.0	PVC insulated cables damaged	
4.0	***	Causes pain if duration is longer than 20 sec. But blistering is unlikely.
6.4	***	Pain threshold reached after 8 sec. Second degree burns after 20 sec.

RADIATION kW/m2	DAMAGE TO EQUIPEMENT	DAMAGE TO PEOPLE
12.5	Minimum energy to ignite wood with a flame; Melts plastic tubing.	1% lethality in one minute. First degree burns in 10 sec.
16.0	***	Severe burns after 5 sec.
25.0	Minimum energy to ignite wood at identifying long exposure without a flame.	100% lethality in 1 minute. Significant injury in 10 secs.
37.5	Severe damage to plant	100% lethality in 1 minute. 50% lethality in 20 secs. 1% lethality in 10 secs.

FATAL RADIATION EXPOSURE LEVELS

Table 4 Fetal radiation Exposure Level

RADIATION LEVEL kW/m2	FATALITY		
	1%	50%	99%
	EXPOSURE IN SECONDS		
4.0	150	370	930
12.5	30	80	200
37.5	8	20	50

OVERPRESSURE DAMAGE:

Table 5 Overpressure Damage Criteria

OVER PRESSURE (mbar)	MECHANICAL DAMAGE TO EQUIPMENTS	DAMAGE TO PEOPLE
300	Heavy damage to plant & structure	1% death from lung damage >50% eardrum damage >50% serious wounds from

OVER PRESSURE (mbar)	MECHANICAL DAMAGE TO EQUIPMENTS	DAMAGE TO PEOPLE
		flying objects
100	Repairable damage	>1% eardrum damage >1% serious wounds from flying objects
30	Major glass damage	Slight injury from flying glass
10	10% glass damage	***

OVERPRESSURE DAMAGE :-(In Detail)

Table 6 Overpressure Damage

OVER PRESSURE		MECHANICAL DAMAGE TO EQUIPMENTS
Bar	kPa	
0.0014	0.14	Annoying noise (137 dB if of low frequency 10–15 Hz)
0.0021	0.21	Occasional breaking of large glass windows already under strain
0.0028	0.28	Loud noise (143 dB), sonic boom, glass failure
0.0069	0.69	Breakage of small windows under strain
0.0103	1.03	Typical pressure for glass breakage
0.0207	2.07	Safe distance" (probability 0.95 of no serious damage below this value);projectile limit; some damage to house ceilings; 10% window glass broken
0.0276	2.76	Limited minor structural damage
0.03-0.069	3.4-6.9	Large and small windows usually shattered; occasional damage to window frames
0.048	4.8	Minor damage to house structures
0.069	6.9	Partial demolition of houses, made uninhabitable
0.069-0.138	6.9—13.8	Corrugated asbestos shattered; corrugated steel or aluminum panels, fastenings fail, followed by buckling; wood panels (standard housing)fastenings fail, panels blown in
0.09	9.0	Steel frame of clad building slightly distorted

OVER PRESSURE		MECHANICAL DAMAGE TO EQUIPMENTS
Bar	kPa	
0.138	13.8	Partial collapse of walls and roofs of houses
0.138-0.207	13.8—20.7	Concrete or cinder block walls, not reinforced, shattered
0.158	15.8	Lower limit of serious structural damage
0.172	17.2	50% destruction of brickwork of houses
0.207	20.7	Heavy machines (3000 lb) in industrial building suffered little damage; steel frame building distorted and pulled away from foundations.
0.207-0.276	20.7—27.6	Frameless, self-framing steel panel building demolished; rupture of oil storage tanks
0.276	27.6	Cladding of light industrial buildings ruptured,
0.345	34.5	Wooden utility poles snapped; tall hydraulic press (40,000 lb) in building slightly damaged
0.345-0.482	34.5—48.2	Nearly complete destruction of houses
0.482	48.2	Loaded, lighter weight (British) train wagons overturned
0.482-0.551	48.2—55.1	Brick panels, 8–12 in. thick, not reinforced, fail by shearing or flexure
0.62	62.0	Loaded train boxcars completely demolished
0.689	68.9	Probable total destruction of buildings; heavy machine tools (7,000 lb) moved and badly damaged, very heavy machine tools (12,000 lb) survive
20.68	2068	Limit of crater lip

CONSEQUENCE ANALYSIS

INTRODUCTION

This section discusses the results of the consequence analysis of identified potential accident scenarios that may occur at the Compressor Unit at Assam Gas Company Ltd., Assam. The consequence analysis is carried out to determine the extent of spread (dispersion) by accidental release which may lead to jet fire, vapor explosion resulting into generating heat radiation, overpressures, explosions etc.

In order to form an opinion on potentially serious hazardous situations and their consequences, consequence analysis of potential failure scenarios is conducted. It is qualitative analysis of hazards due to various failure scenarios. In consequence analysis, each failure case is considered in isolation and damage effects predicted, without taking into the account of the secondary events or failures it may cause, leading to a major disastrous situation. The results of consequence analysis are useful in developing disaster management plan and in developing a sense of awareness among operating and maintenance personnel. It also gives the operating personnel and population living in its vicinity, an understanding of the hazard they are posed to.

Event Outcomes

Upon release of flammable / toxic gas & liquids, the hazards could lead to various events which are governed by the type of release, release phase, ignition etc. PHAST has an in-built event tree for determining the outcomes which are based on two types of releases namely continuous and instantaneous. Leaks are considered to be continuous releases whereas, ruptures are considered to be instantaneous releases. These types of releases are further classified into those which have a potential for rain-out and those which do not. Whether the release would leak to a rain-out or not depends upon droplet modeling which is the main cause of formation of pools. Fig 3, fig 4, fig 5, fig 6 presents the event trees utilized by PHAST to generate the event outcomes.

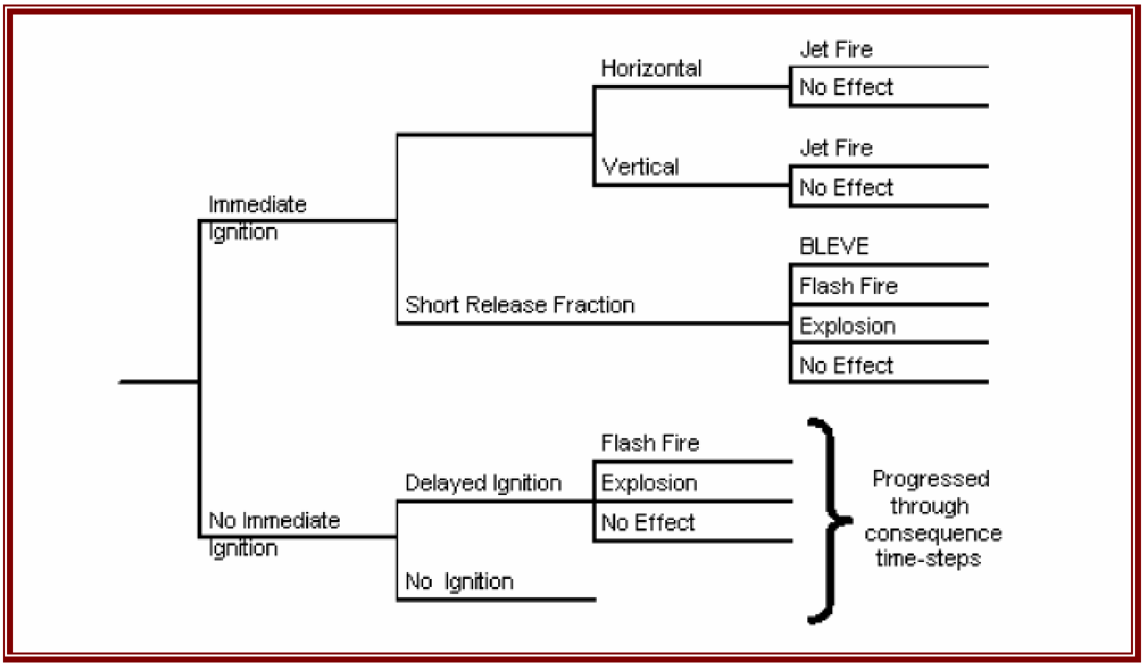


Figure 4 **Event Tree for continuous release without rain-out (from PHAST)**

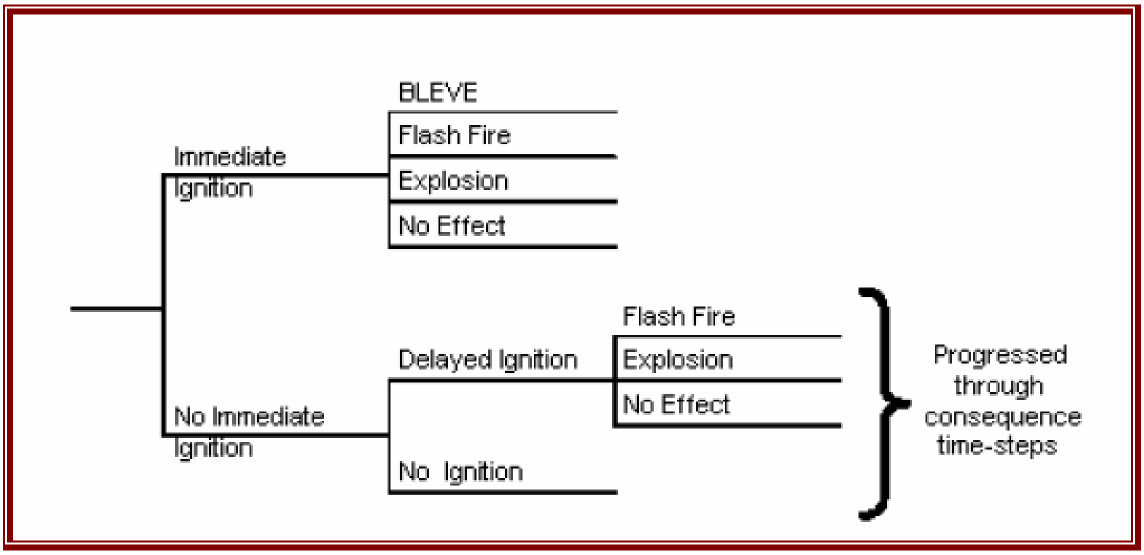


Figure 5 **Event Tree for Instantaneous release without rain-out (from PHAST)**

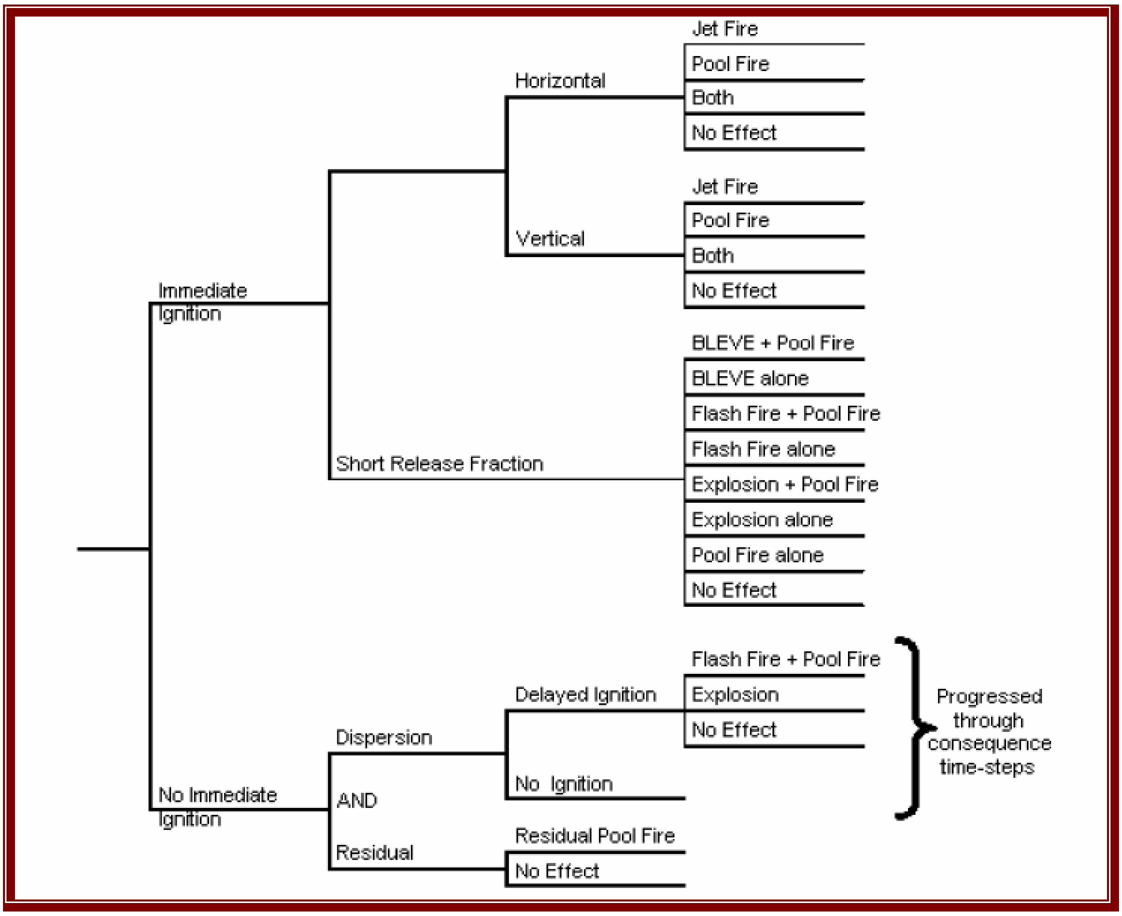


Figure 6 **Event Tree for continuous release with rain-out (from PHAST)**

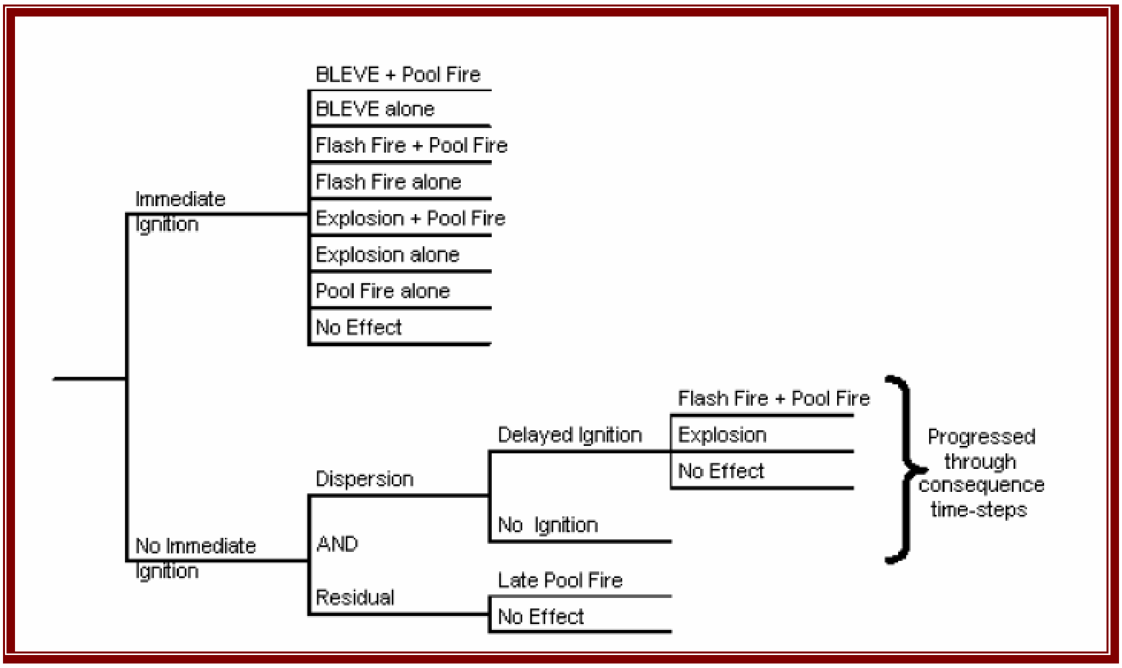


Figure 7 **Event Tree for Instantaneous release with rain-out (from PHAST**

MODES OF FAILURE

There are various potential causes and sources of leakage. This may be by way of failures of equipment or piping, due to pump seal failure, instrument tubing giving way, failure of the pipes, failure of process vessels etc. Following Table represents general mechanism for loss of containment for Piping and fitting, instruments, and human error.

(A). PIPING AND FITTING

Ref. No.	LOSS OF OCNTAINMENT	EXAMPLES OF POSSIBLE BASIC CAUSE	REMARKS
A.1	Flange/Gasket Leaks	- Incorrect gasket installed, e.g. incorrect material, incorrect size (thickness and diameter). - Incorrect installation, e.g. flange faces not cleaned, flanged face damaged, incorrectly tightened bolts, incorrect bolts used. - Flange replacement without gasket.	Possible flame impingement and localized heating of adjacent equipment.
A.2	Pipe Overstress Causing Fracture	- Inappropriate use of design codes. - Error in stress analysis calculations. - Lack of inspection during pipe erection, e.g. excessive cold pull. - Pipe testing incorrectly carried out. - Incorrect setting of spring hangers and pipe supports and sliding shoes not free to move. - Pipe not hydro tested because of bore size (or considered not	Pipe stresses would most likely cause a flange leak, unless there existed a combination of errors, e.g. installation of rogue materials and unsuitable pipe support, or error in stress calculation plus failure to pressure test.

Ref. No.	LOSS OF OCNTAINMENT	EXAMPLES OF POSSIBLE BASIC CAUSE	REMARKS
		critical) and no secondary test procedures carried out. - Omission to test because systems not clearly identified, or error in documentation. - Extreme temperature differential in pipework not catered for in design, i.e. cold and hot streams	
A.3	Over pressurization of Pipe work Causing Fracture	a) Inadequate Pressure Relief - Relief valve 'simmering' and hydrating, icing. - Incorrect setting of RV pressure. - Incorrectly sized RV. - Wrongly installed RV, e.g. due to transferred tag No. : or installation of incorrect spring material. - Abuse of locking system and all RVs isolated from system - Excessive back pressure caused by blockage of relief sub-headers with sludge, ice/hydrate, etc. - High pressure breakthrough into low pressure systems, which have inadequate relief capacity. - Blockage of RVs with debris/fines, e.g. molsieve dust, or	Careful attention required for handling hydrocarbons with "free" water. Rigorous adherence to procedures is essential. Relief capacity should always be adequate or high integrity trip system installed. Potential problem around molsieve vessels,

Ref. No.	LOSS OF OCNTAINMENT	EXAMPLES OF POSSIBLE BASIC CAUSE	REMARKS
		breakage of screens/package/demister. b) <u>Excessive Surge Pressure / Hammer</u> - Too rapid isolation or blockage of liquid full lines, i.e., operator closing isolation valve. - Rapid blockage of liquid lines, e.g. NRV failure. - Lines not or inadequately designed for two phase/slug flow. - Too rapid opening of valves and letdown of liquid under high differential pressure. - Rapid vaporization of cold liquid in contact with hot fluid. (Rapid phase transition). c) <u>Rupture Under Fire Conditions</u> - Direct fire impingement without any cooling (internal or external) or failure to effectively depressure equipment.	absorbers, columns and RVs. Consider needs to handle liquid slugs from feed line when pigging recommended. Particular care required at pig traps and at inlet PCVs/bypass. No remote depressurizing system available; requires review. Potential for catastrophic rupture of equipment, fragmentation and fireball effects.

Ref. No.	LOSS OF OCNTAINMENT	EXAMPLES OF POSSIBLE BASIC CAUSE	REMARKS
A-4	Failure of piping due to fatigue or vibration.	- Failure due to acoustic fatigue arising from:- e.g. failure to recognized problem exists in particular areas, failure to take adequate precautions (selection of incorrect valve at design stage or during maintenance, inadequate line support). Improper testing/inspection when in service, failure to report abnormally high noise levels (during normal and upset conditions). - Failure due to mechanical vibration arising from: e.g. failure to recognized problem, inadequate support, failure to report and minor excessive vibrations (under all plant conditions), maintenance error, (failure to correctly align rotating equipment and test for vibration prior to reinstatement? - Failure due to pressure or thermal cycling.	Vulnerable areas are piping downstream of PCVs and RVs operating at very high pressures. Particularly susceptible is small bore pipework associated with pressure letdown and two phase flow systems and compressors/ pumps. Regeneration gas pipework and connections to mol sieve vessels merit particular attention.
A.5	Failure of piping Due to installation of Wrong Materials	- Incorrect materials selection, e.g. at design stage, from supplier or site stores. - Incorrect material installed,	Strict system for supervision, inspection and verification of materials required during all modifications.

Ref. No.	LOSS OF OCNTAINMENT	EXAMPLES OF POSSIBLE BASIC CAUSE	REMARKS
		e.g. improper supervision and identification of materials after withdrawal from stores. -	
A.6	Failure of Piping Due to low Temperature Brittle fracture	- Rogue material used in construction, wrong material specified, or uncertainties in material specification. - Error in calculating minimum lower design temperatures. - Systems not designed for low temperature, (e.g. on emergency depressuring) and immediate repressurising.	A number of systems have been identified as bring vulnerable, particularly where condensate at high pressure may be depressurized.
A.7	Failure of Piping (or nozzles) Due to External Forces or Impact.	- Impact from equipment being moved during maintenance. - Impact of heavy lifting gear, e.g. cranes. - Impact from site transport, e.g. construction traffic, fire tender. - Impact on reinforced nozzle causing fractures elsewhere, e.g. valve, pump casing vessel. - Impact of Third party damage due to digging	Historically, failure of HP process piping due to mechanical impact is confined mainly to small bore piping. Strict control over site construction will of course be necessary. Any incident of impact on pipework during construction must be reported and damage investigated.

(B) HUMAN ERROR

Ref. No.	LOSS OF OCNTAINMENT	EXAMPLES OF POSSIBLE BASIC CAUSE	REMARKS
LOSS OF CONTAINMENT THROUGH HUMAN ERROR HAS BEEN ASSUMED IMPLICITLY IN SECTIONS A TO F HOWEVER EXAMPLES OR SOME TYPICAL OPERATING AND MAINTENANCE ERRORS ARE INCLUDED BELOW:-			
B.1	Operational Error	- Failure or inability to close instrument or sample valves. - Failure or inability to close drain and vent valves. - Leaving safety trips/systems out of commission after testing or inspecting. - Intentionally defeating trip systems for reasons of production.	
B.2	Error in De-commissioning	- Inadvertent or unauthorized opening of a pressurized system, e.g. filters, vessels. - Improver depressurizing and purging of a system prior to isolation or spading. - Failure to effectively isolate all process (and utility) and electrical connections.	
B.3	Error in Maintenance	- Failure to maintain effective isolation. - Failure to report damage to equipment during repair or modification. - Maintenance activities extended to systems, which are	

Ref. No.	LOSS OF OCNTAINMENT	EXAMPLES OF POSSIBLE BASIC CAUSE	REMARKS
		\`live'. - Improper supervision of contract maintenance staff, improper maintenance.	
B.4	Error in Re-commissioning	- Failure to close vents/drains, replace plugs. - Improper or lack or purging of equipment e.g. sphere receiver furnaces.	SOP, Safety audit
B.5	Supervision Error	- Design error for modifications. - Lack of supervision and control e.g. Authorization of permits isolation. - Failure to regularly test/inspect e.g. trip/alarm system, safety equipment. - Allure to regularly monitor e.g. noise vibration corrosion stream composition	

SELECTED FAILURE CASES

Selection is normally subjective on following parameters:

- Properties of material namely Toxic or Flammable.
- The likely severity of consequence in the event of accidental release based on inventory, operated pressure & operated temperature.
- The probability of failure of various equipments such as valves, flanges, pipe, pressure vessels etc. used in the plant.

The scenarios are considered to be confined to those equipment failures which involve the leakage of flammable or toxic products, of which the frequency of occurrence and the severity of the consequences have been taken into consideration and which may have a low probability of early detection.

Taking this factor into consideration, a list of selected failure cases was prepared based on process knowledge, inventory, engineering judgment, and experience, past incidents associated with such facilities and considering the general mechanisms for loss of containment. Cases have been identified for the consequence analysis.

Consequence analysis and calculations are effectively performed by computer software using models validated over a number of applications. Consequence modeling is carried out by PHAST (version 6.53) of DNV Software, UK.

PHAST uses the Unified Dispersion Model (UDM) capable of describing a wide range of types of accidental releases. The Model uses a particularly flexible form, allowing for sharp-edged profiles, which become more diffuse downwind.

PHAST contains data for a large number of chemicals and allows definition of mixtures of any of these chemicals in the required proportion. The calculations by PHAST involve following steps for each modeled failure case:

EFFECT OF RELEASE

When hazardous material is released to atmosphere due to any reason, a vapor cloud is formed. Direct cloud formation occurs when a gaseous or flashing liquid escapes to the atmosphere. Release of hydrocarbons and toxic compounds to atmosphere may usually lead to the following:

1) Dispersion of hydrocarbon vapor with wind till it reaches its lower flammability limit (LFL) or finds a source of ignition before reaching LFL, which will result in a flash fire or explosion.

2) Lighter hydrocarbon vapor (e.g. Natural Gas) or Hydrogen disperses rapidly in the downwind direction, being lighter than air. But comparatively heavier hydrocarbon vapor cloud like that of LPG, Propylene or Ammonia will travel downwind along the ground. If it encounters an ignition source before it is dispersed below the LFL, explosion of an unconfined vapor cloud will generate blast waves of different intensities.

3) A fireball or BLEVE (Boiling Liquid expanding Vapor Explosion) occurs when a vessel containing a highly volatile liquid (e.g. LPG, Propylene etc) fails and the released large mass of vapor cloud gets ignited immediately. It has damage potential due to high intensity of radiation and generation of the overpressure waves, causing large-scale damage to nearby equipment and structures.

4) Catastrophic failure of tanks/ pressurized vessels, rotary equipment and valves etc. can result in equipment fragments flying and hitting other equipment of the plant.

5) Release of toxic compounds results in the toxic vapour cloud traveling over long distances, affecting a large area, before it gets sufficiently diluted to harmless concentration in the atmosphere.

6) The material is in two phases inside the containment - liquid & vapor. Depending on the location of the leak liquid or vapor will be released from the containment. If vapor is released a vapor cloud will form by the mixing of the vapor and air. The size of the vapor cloud will depend on the rate of release, wind speed; wind direction & atmospheric stability will determine the dispersion and movement of the vapor cloud.

7) If liquid is released there will be some flashing as the boiling point of liquid is below the ambient temperature. The vapor formed by immediate flashing will behave as vapors release. The liquid will fall on the ground forming a pool. There will be vaporization from the pool due to the heat gained from the atmosphere & ground. There will be dispersion and movement of vapor cloud formed by evaporation of liquid.

The behavior of material released by loss of containment depends on the following factors:

- Physical properties of the material
- Conditions of material in containment (pressure and temperature)
- Phase of material released (liquid or gas)
- Inventory of material released
- Weather parameters (temperature, humidity, wind speed, atmospheric stability)
- Material with boiling point below ambient condition.

Statistical reports of consequence analysis are summarized below. table.7

Similarly pictorial presentations of consequence results are shown below the tabular report.

Failure associated with Pipelines

Pipelines laid under soil usually do not undergo major failures due to various threats. Above ground sections of the pipeline such as sectionalizing valve sections, valve pits, road crossings, etc are considered for the failures. Some of the main causes of loss of containment from pipelines are due to corrosion, operation beyond design conditions, third party impacts such as excavation etc.

Failure of Export pipeline is expected to take place due to the below mentioned causes.

Table 7 Failure of pipelines

DESCRIPTION:	Export Pipelines
Scenario	**Causes**
Loss of containment from Pipeline	External Impact (anchoring)
	Subsequent leakage due to corrosion. and erosion
	High pressure in pipeline due to blockage / high loading rate / communication failure with VSD
	Surge due to closure of downstream ESD
	FCV Malfunction / fails in open position
Loss of containment from Hose	High pressure from source
	Surge due to closure of downstream valve

The natural gas get into air due to leak / rupture of the pipeline would result into an environmental pollution. From analysis of various accidents in the gas compressor pipelines, it has been observed that gas leaking from a pipeline is associated with hazards. Of methane may develop into fire/explosion at the surface due to presence of some ignition source.

Major Accident Event Scenarios

Based on the sections identified for each unit, various failure scenarios were introduced into the model. These scenarios were based on various leaks sizes described below.

Table 8 Leak Size categories

Hole size range (mm)	Category	Nominal size considered for model
D <=5 mm	Small	5 mm
25mm >= D > 5 mm	Medium	25 mm
100mm >= D > 25mm	Large	100 mm
D > 150mm	Rupture	Rupture

PHAST software was used to model each of these scenarios to arrive at consequence results.

Source Data

CNG Composition is as follows :

Sr. No.	Material	State	% (v/v)
1	Methane	Gas	92.46
2	Ethane	Gas	4.39
3	Propane	Gas	0.80
4	Butane	Gas	0.14
5	Pentane	Gas	0.08
6	Hexane	Gas	0.04
7	Carbon dioxide	Gas	1.30
8	Nitrogen	Gas	0.62

It is necessary to know the chemical composition of the liquid and/or gas, permitting the other properties to be determined. These may include the molecular weight, density, molecular diffusivity, conductivity, and boiling point. Temperature- dependent properties, such as vapor pressure, heat capacities, heat of vaporization, and surface tension may also need to be determined. If there are several components in a mixture, the properties of each component must be known. There are several useful reference documents that provide summaries of properties of many chemicals (e.g., Perry et al. 1984, AIHA 1995, NFPA 1994, NOAA 1992, and Urben 1995).

CONSEQUENCE RESULTS COMPRESSOR UNIT 1

Maximum credible loss Scenario (MCLS): Leakage due to Flange failure or Hose Failure from outlet pipeline of compressor

Scenario details	CONCENTRATION AT DISTANCE (M)				
	Concentration in PPM		WEATHER CATEGORY		
			3F	7D	5D
5 mm leakage in outlet pipeline of compressor	UFL	164806	0.44	0.44	0.44
	LFL	43559.7	2.04	1.86	1.96
	LFL (frac)	21779.9	3.75	3.07	3.41
25 mm leakage in outlet pipeline of compressor	UFL	164806	2.36	2.31	2.35
	LFL	43559.7	8.82	7.49	8.06
	LFL (frac)	21779.9	21.17	16.46	18.33
100 mm leakage in outlet pipeline of compressor	UFL	164806	9.13	8.63	8.93
	LFL	43559.7	56.67	54.42	54.68
	LFL (frac)	21779.9	121.81	132.15	128.05

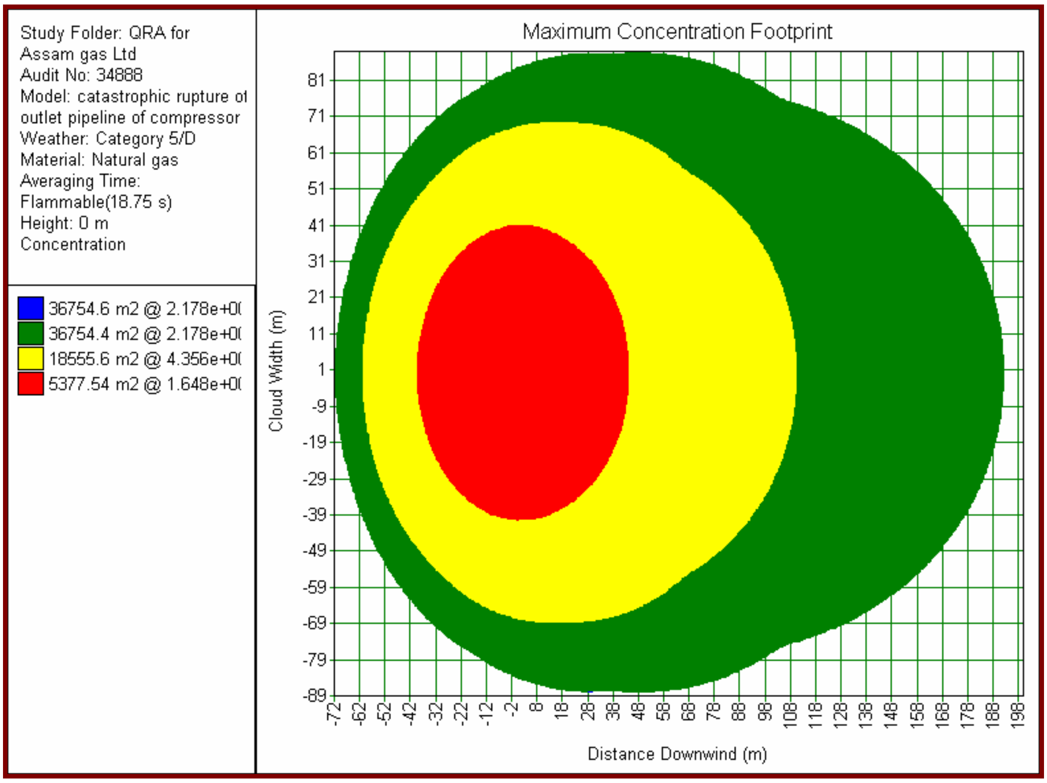
Scenario details	THERMAL DAMAGE DISTANCE BY JET FIRE				MAXIMUM DISTANCE AT OVERPRESSURE LEVEL (M)			
	RADIATION INTENSITY (KW / M2)	WEATHER CATEGORY			OVERPRESSURE (BAR)	WEATHER CATEGORY		
		3F	7D	5D		3F	7D	5D
5 mm leakage in outlet pipeline of compressor	**4**	NR	NR	NR	**0.02068**	NR	NR	NR
	12.5	NR	NR	NR	**0.1379**	NR	NR	NR
	37.5	NR	NR	NR	**0.2068**	NR	NR	NR
25 mm leakage in outlet pipeline of compressor	**4**	19.76	19.94	19.93	**0.02068**	37.70	25.55	26.19
	12.5	16.06	16.84	16.52	**0.1379**	24.58	14.03	14.19
	37.5	12.14	12.49	11.97	**0.2068**	23.55	13.11	13.24

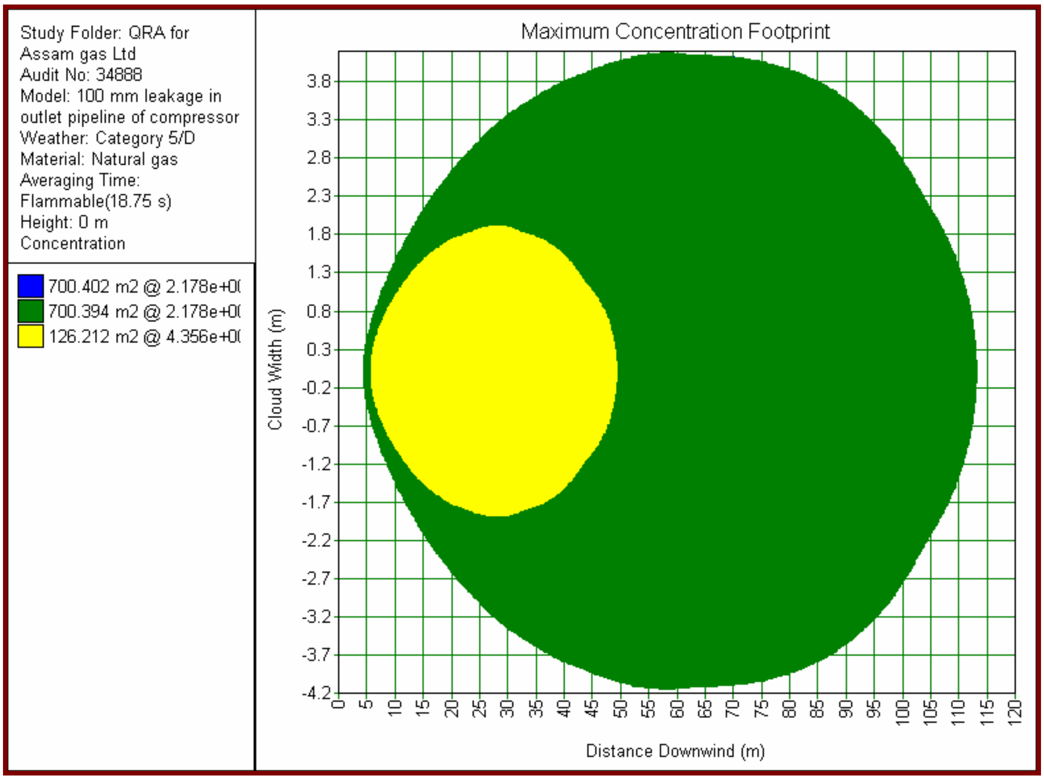
Scenario details	THERMAL DAMAGE DISTANCE BY JET FIRE				MAXIMUM DISTANCE AT OVERPRESSURE LEVEL (M)			
	RADIATION INTENSITY (KW / M2)	WEATHER CATEGORY			OVERPRESSURE (BAR)	WEATHER CATEGORY		
		3F	7D	5D		3F	7D	5D
100 mm leakage in outlet pipeline of compressor	**4**	80.83	80.84	80.66	**0.02068**	217.0	215.74	207.81
	12.5	62.55	65.97	64.26	**0.1379**	145.12	152.2	142.74
	37.5	49.01	55.06	51.53	**0.2068**	139.44	147.18	137.59

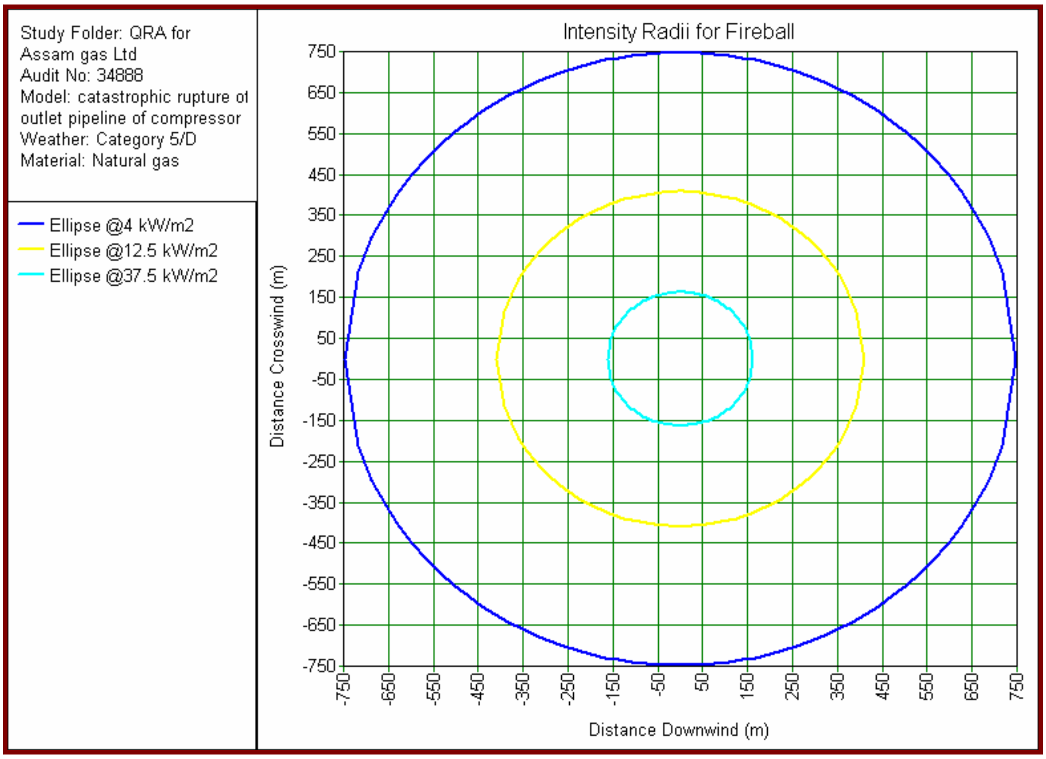
Worst Case Scenario (WCS):-100% Catastrophic Rupture

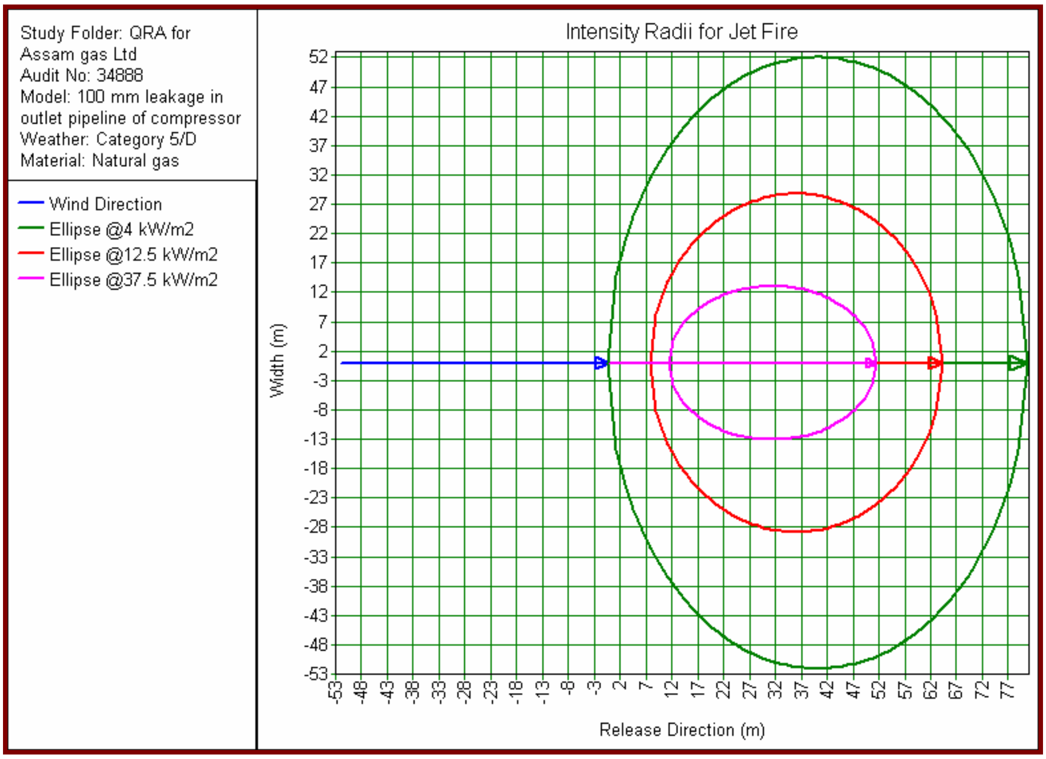
Scenario details	CONCENTRATION AT DISTANCE (M)				
	Concentration in PPM		WEATHER CATEGORY		
			3F	7D	5D
Rupture in outlet pipeline of compressor	UFL	164806	43.89	48.07	45.48
	LFL	43559.7	92.68	125.21	99.73
	LFL (frac)	21779.9	166.42	226.20	161.55

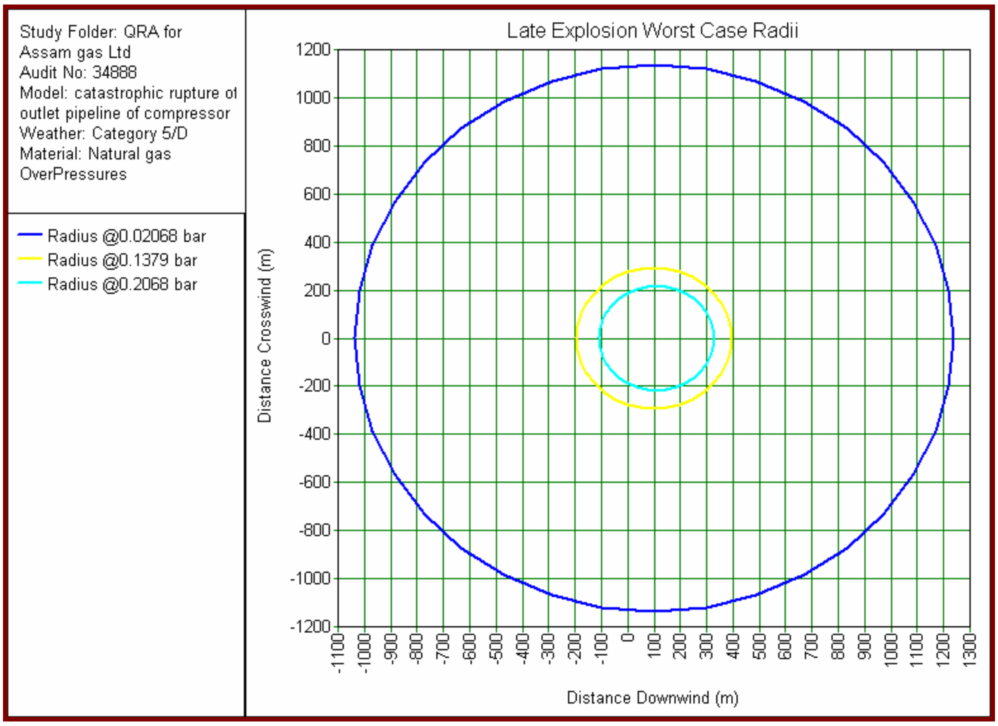
Scenario details	THERMAL DAMAGE DISTANCE BY FIRE BALL				MAXIMUM DISTANCE AT OVERPRESSURE LEVEL (M)			
	RADIATION INTENSITY (KW / M2)	WEATHER CATEGORY			OVERPRESSURE (BAR)	WEATHER CATEGORY		
		3F	7D	5D		3F	7D	5D
Rupture in outlet pipeline of compressor	**4**	789.44	748.14	748.14	**0.02068**	1392.73	1392.73	1392.73
	12.5	431.50	408.53	408.53	**0.1379**	360.61	360.61	360.61
	37.5	178.64	162.62	162.62	**0.2068**	279.03	279.03	279.03

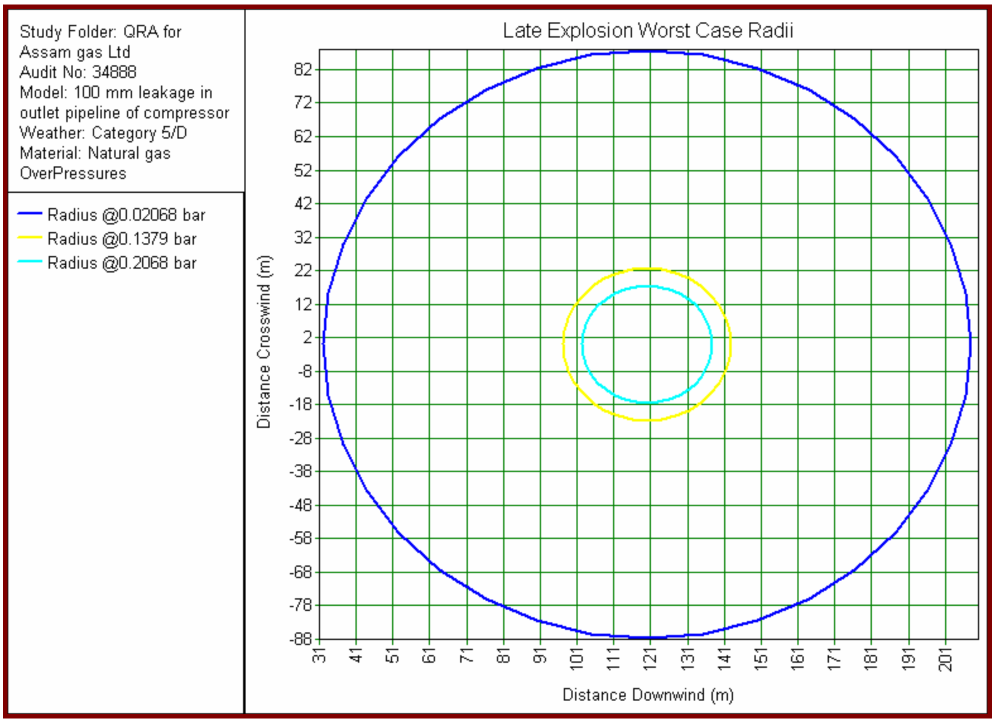

Study Folder: QRA for Assam gas Ltd
Audit No: 34888
Model: catastrophic rupture of outlet pipeline of compressor
Weather: Category 5/D
Material: Natural gas
Averaging Time: Flammable(18.75 s)
Height: 0 m
Concentration
36754.6 m2 @ 2.178e+0(
36754.4 m2 @ 2.178e+0(
18555.6 m2 @ 4.356e+0(
5377.54 m2 @ 1.648e+0(
Maximum Concentration Footprint
Cloud Width (m)
Distance Downwind (m)


Study Folder: QRA for Assam gas Ltd
Audit No: 34888
Model: 100 mm leakage in outlet pipeline of compressor
Weather: Category 5/D
Material: Natural gas
Averaging Time: Flammable(18.75 s)
Height: 0 m
Concentration
700.402 m2 @ 2.178e+0(
700.394 m2 @ 2.178e+0(
126.212 m2 @ 4.356e+0(
Maximum Concentration Footprint
Cloud Width (m)
Distance Downwind (m)


Study Folder: QRA for Assam gas Ltd
Audit No: 34888
Model: catastrophic rupture of outlet pipeline of compressor
Weather: Category 5/D
Material: Natural gas
Ellipse @4 kW/m2
Ellipse @12.5 kW/m2
Ellipse @37.5 kW/m2
Intensity Radii for Fireball
Distance Crosswind (m)
Distance Downwind (m)


Study Folder: QRA for Assam gas Ltd
Audit No: 34888
Model: 100 mm leakage in outlet pipeline of compressor
Weather: Category 5/D
Material: Natural gas
Wind Direction
Ellipse @4 kW/m2
Ellipse @12.5 kW/m2
Ellipse @37.5 kW/m2
Intensity Radii for Jet Fire
Width (m)
Release Direction (m)


Study Folder: QRA for Assam gas Ltd
Audit No: 34888
Model: catastrophic rupture of outlet pipeline of compressor
Weather: Category 5/D
Material: Natural gas
OverPressures
Radius @0.02068 bar
Radius @0.1379 bar
Radius @0.2068 bar
Late Explosion Worst Case Radii
Distance Crosswind (m)
Distance Downwind (m)


Study Folder: QRA for Assam gas Ltd
Audit No: 34888
Model: 100 mm leakage in outlet pipeline of compressor
Weather: Category 5/D
Material: Natural gas
OverPressures
Radius @0.02068 bar
Radius @0.1379 bar
Radius @0.2068 bar
Late Explosion Worst Case Radii
Distance Crosswind (m)
Distance Downwind (m)

CONSEQUENCE RESULTS COMPRESSOR UNIT 3,4,5

Worst Case Scenario (WCS):-100% Catastrophic Rupture in outlet pipeline of compressor

Scenario details	CONCENTRATION AT DISTANCE (M)				
	Concentration in PPM		WEATHER CATEGORY		
			3F	7D	5D
Rupture in outlet pipeline of compressor	UFL	164806	46.52	50.80	48.13
	LFL	43559.7	98.50	130.30	105.33
	LFL (frac)	21779.9	175.65	236.77	169.10

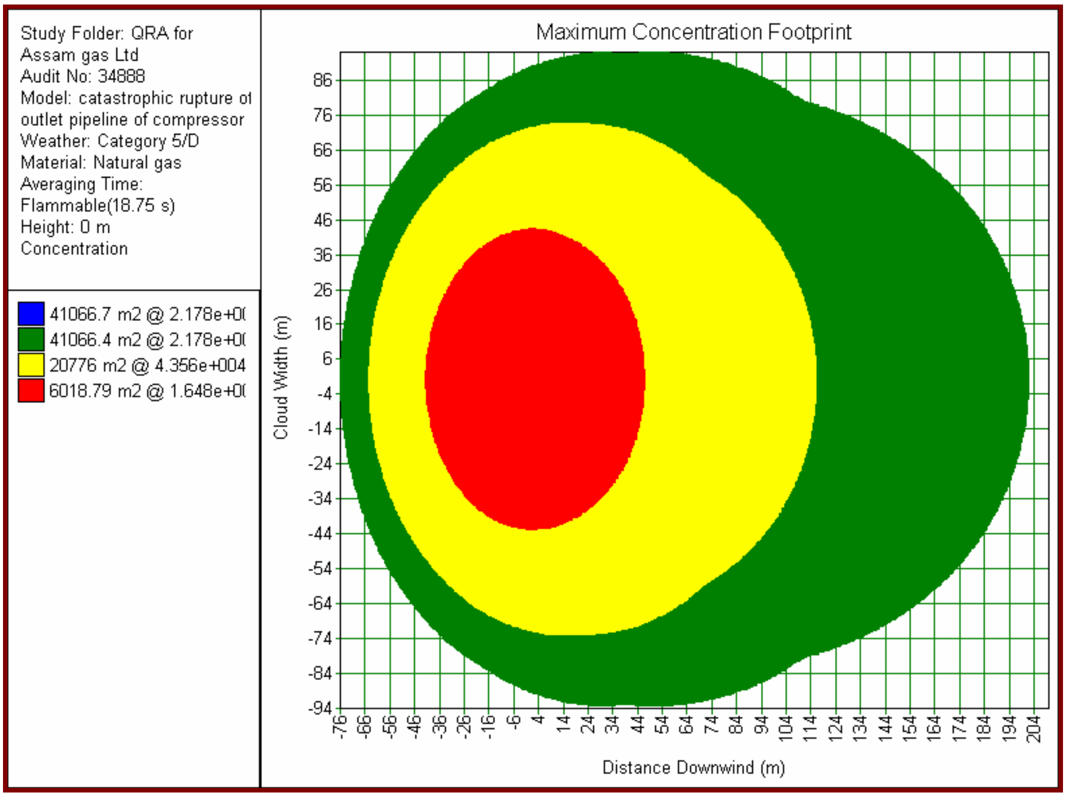
Scenario details	THERMAL DAMAGE DISTANCE BY FIRE BALL				MAXIMUM DISTANCE AT OVERPRESSURE LEVEL (M)			
	RADIATION INTENSITY (KW / M2)	WEATHER CATEGORY			OVERPRESSURE (BAR)	WEATHER CATEGORY		
		3F	7D	5D		3F	7D	5D
Rupture in outlet pipeline of compressor	**4**	844.38	799.41	799.41	**0.02068**	1478.08	1478.08	1478.08
	12.5	462.98	438.03	438.03	**0.1379**	382.71	382.71	382.71
	37.5	194.80	177.62	177.62	**0.2068**	296.13	296.13	296.13

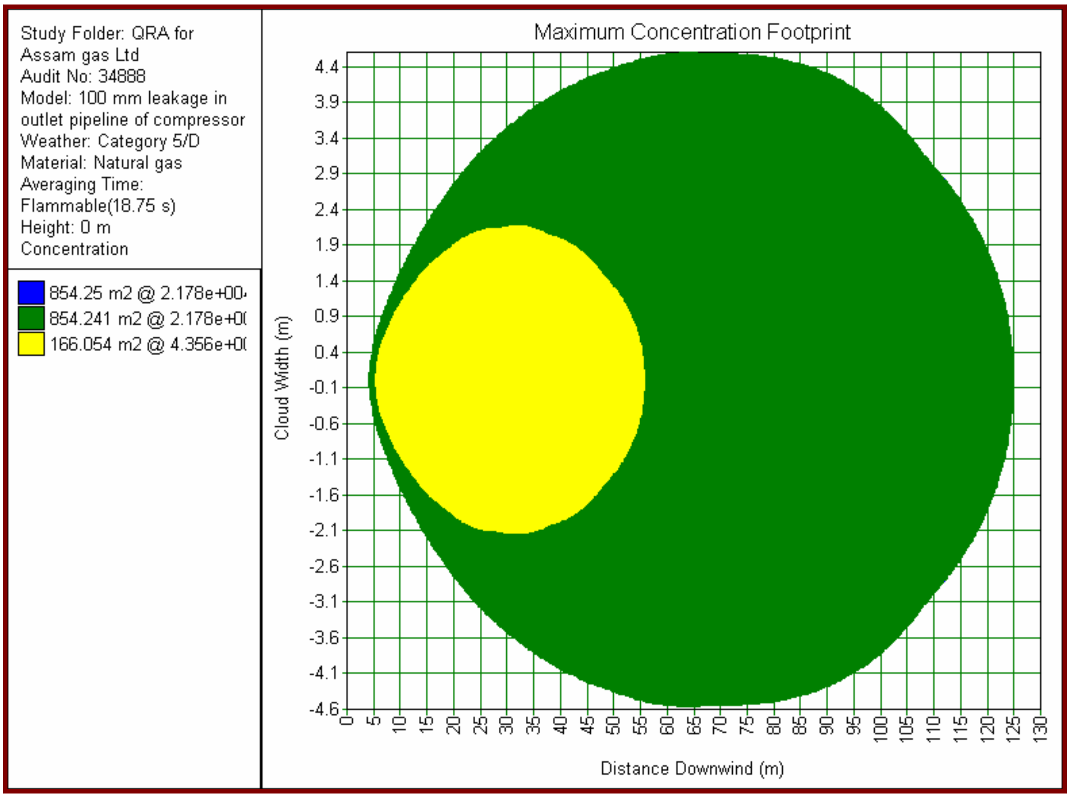
Maximum credible loss Scenario (MCLS): Leakage due to Flange failure or Hose Failure from outlet pipeline of compressor

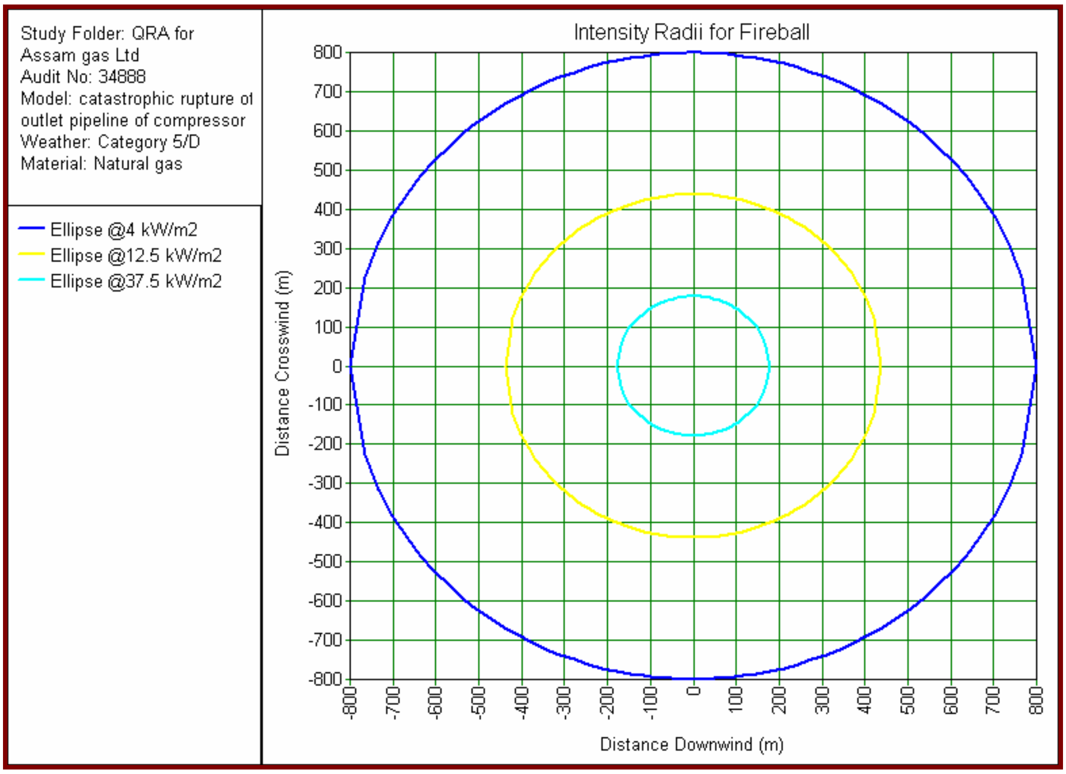
Scenario details	CONCENTRATION AT DISTANCE (M)				
	Concentration in PPM		WEATHER CATEGORY		
			3F	7D	5D
5 mm leakage in outlet pipeline of compressor	UFL	164806	0.50	0.52	0.52
	LFL	43559.7	2.21	2.05	2.13
	LFL (frac)	21779.9	4.08	3.47	3.78
25 mm leakage in outlet pipeline of compressor	UFL	164806	2.50	2.45	2.48
	LFL	43559.7	9.80	8.21	8.84
	LFL (frac)	21779.9	24.67	19.38	21.76
100 mm leakage in outlet pipeline of compressor	UFL	164806	9.92	9.53	9.78
	LFL	43559.7	63.33	61.56	60.99
	LFL (frac)	21779.9	135.12	145.16	140.74

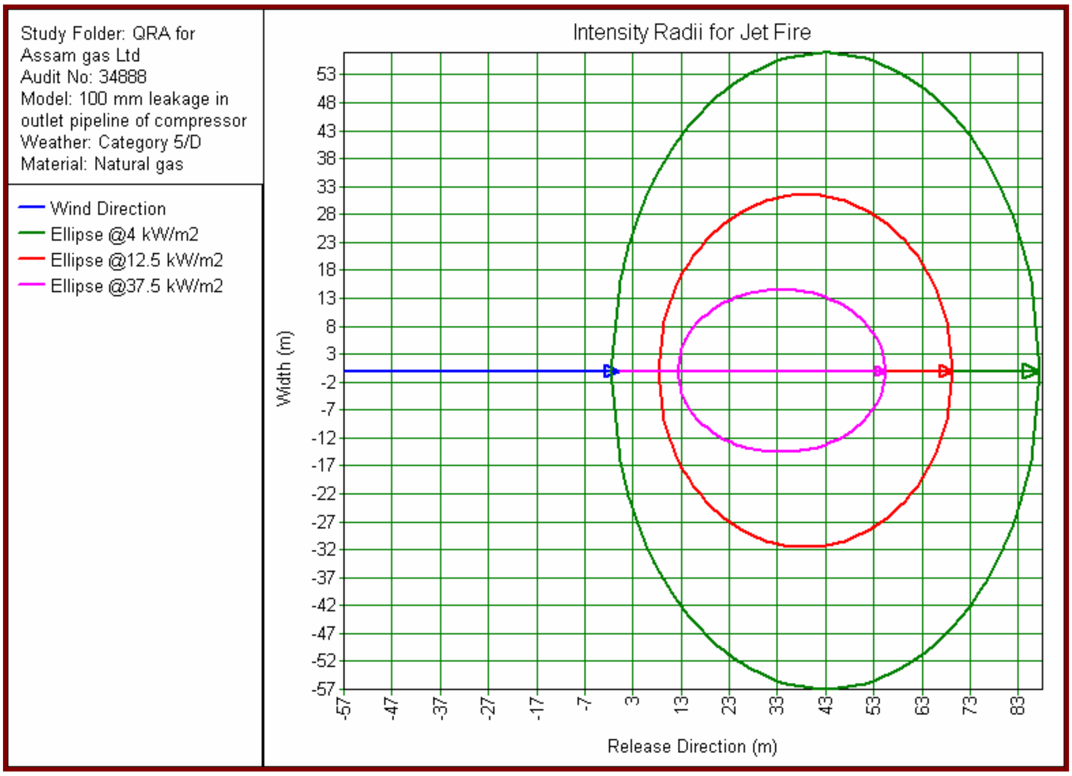
Scenario details	THERMAL DAMAGE DISTANCE BY JET FIRE				MAXIMUM DISTANCE AT OVERPRESSURE LEVEL (M)			
	RADIATION INTENSITY (KW / M2)	WEATHER CATEGORY			OVERPRESSURE (BAR)	WEATHER CATEGORY		
		3F	7D	5D		3F	7D	5D
5 mm leakage in outlet pipeline of compressor	**4**	NR	NR	NR	**0.02068**	NR	NR	NR
	12.5	NR	NR	NR	**0.1379**	NR	NR	NR
	37.5	NR	NR	NR	**0.2068**	NR	NR	NR
25 mm leakage in outlet pipeline of compressor	**4**	21.73	21.96	21.92	**0.02068**	39.52	27.07	37.79
	12.5	17.66	18.57	18.19	**0.1379**	25.06	14.42	24.61
	37.5	13.95	15.19	14.50	**0.2068**	23.91	13.42	23.56

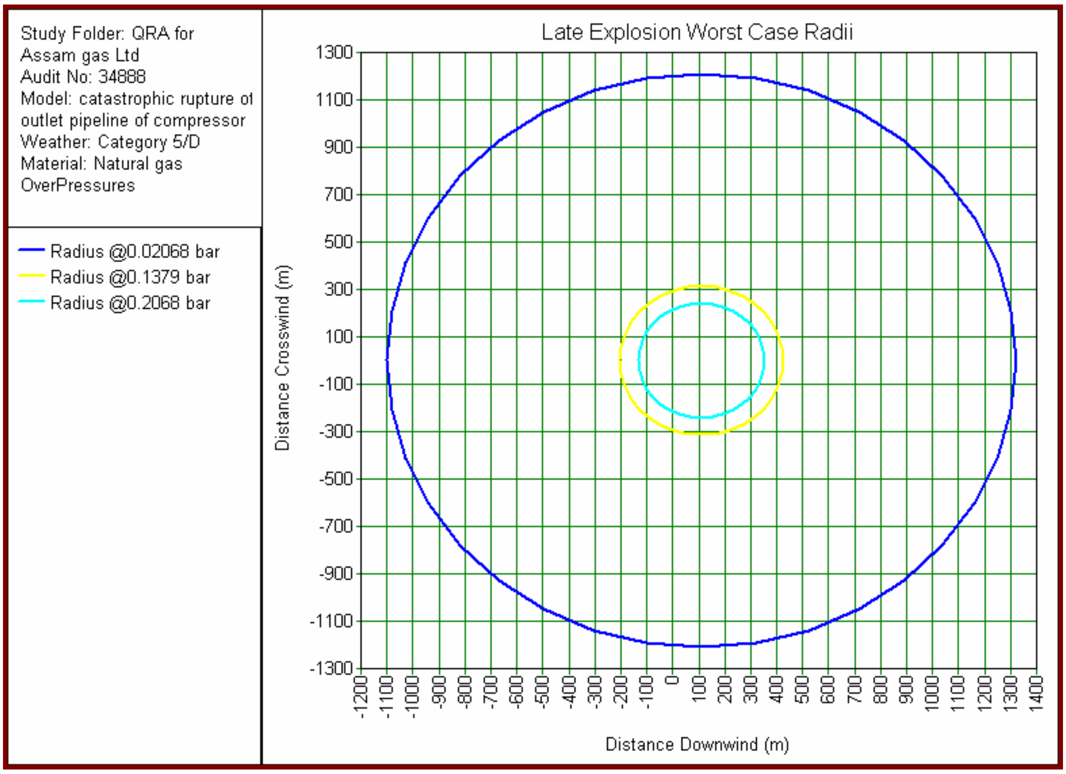
Scenario details	THERMAL DAMAGE DISTANCE BY JET FIRE				MAXIMUM DISTANCE AT OVERPRESSURE LEVEL (M)			
	RADIATION INTENSITY (KW / M2)	WEATHER CATEGORY			OVERPRESSURE (BAR)	WEATHER CATEGORY		
		3F	7D	5D		3F	7D	5D
100 mm leakage in outlet pipeline of compressor	**4**	87.78	87.58	87.46	**0.02068**	237.9	234.92	236.43
	12.5	67.61	71.22	69.39	**0.1379**	157.94	164.58	164.97
	37.5	24.35	59.38	55.43	**0.2068**	151.62	159.02	159.32

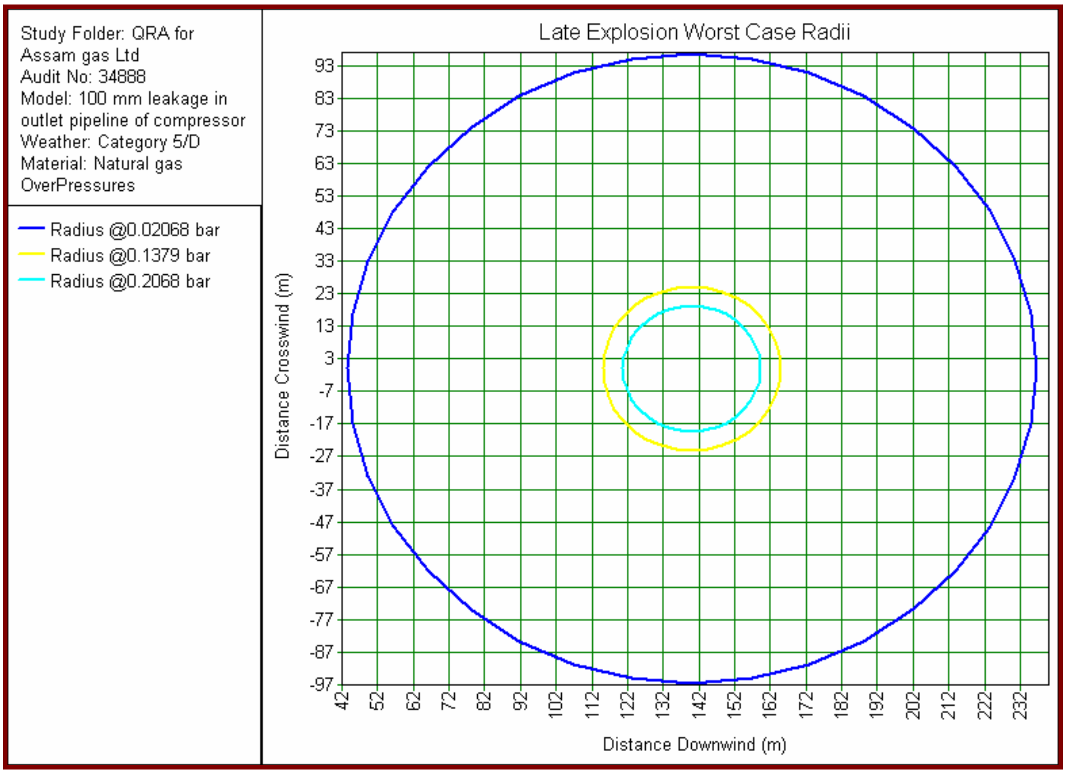



Study Folder: QRA for Assam gas Ltd
Audit No: 34888
Model: 100 mm leakage in outlet pipeline of compressor
Weather: Category 5/D
Material: Natural gas
Averaging Time: Flammable(18.75 s)
Height: 0 m
Concentration
854.25 m2 @ 2.178e+00
854.241 m2 @ 2.178e+0
166.054 m2 @ 4.356e+0
Maximum Concentration Footprint
Cloud Width (m)
Distance Downwind (m)


Study Folder: QRA for Assam gas Ltd
Audit No: 34888
Model: catastrophic rupture of outlet pipeline of compressor
Weather: Category 5/D
Material: Natural gas
Ellipse @4 kW/m2
Ellipse @12.5 kW/m2
Ellipse @37.5 kW/m2
Intensity Radii for Fireball
Distance Crosswind (m)
Distance Downwind (m)


Study Folder: QRA for Assam gas Ltd
Audit No: 34888
Model: 100 mm leakage in outlet pipeline of compressor
Weather: Category 5/D
Material: Natural gas
Wind Direction
Ellipse @4 kW/m2
Ellipse @12.5 kW/m2
Ellipse @37.5 kW/m2
Intensity Radii for Jet Fire
Width (m)
Release Direction (m)


Study Folder: QRA for Assam gas Ltd
Audit No: 34888
Model: catastrophic rupture of outlet pipeline of compressor
Weather: Category 5/D
Material: Natural gas
OverPressures
Radius @0.02068 bar
Radius @0.1379 bar
Radius @0.2068 bar
Late Explosion Worst Case Radii
Distance Crosswind (m)
Distance Downwind (m)


Study Folder: QRA for Assam gas Ltd
Audit No: 34888
Model: 100 mm leakage in outlet pipeline of compressor
Weather: Category 5/D
Material: Natural gas
OverPressures
Radius @0.02068 bar
Radius @0.1379 bar
Radius @0.2068 bar
Late Explosion Worst Case Radii
Distance Crosswind (m)
93
83
73
63
53
43
33
23
13
3
-7
-17
-27
-37
-47
-57
-67
-77
-87
-97
42
52
62
72
82
92
102
112
122
132
142
152
162
172
182
192
202
212
222
232
Distance Downwind (m)

CONSEQUENCE RESULTS COMPRESSOR UNIT 6, 7

Worst Case Scenario (WCS):-100% Catastrophic Rupture in outlet pipeline of compressor

Scenario details	CONCENTRATION AT DISTANCE (M)				
	Concentration in PPM		WEATHER CATEGORY		
			3F	7D	5D
Rupture in outlet pipeline of compressor	UFL	164806	47.01	51.32	48.63
	LFL	43559.7	99.60	131.26	106.39
	LFL (frac)	21779.9	177.40	238.82	170.57

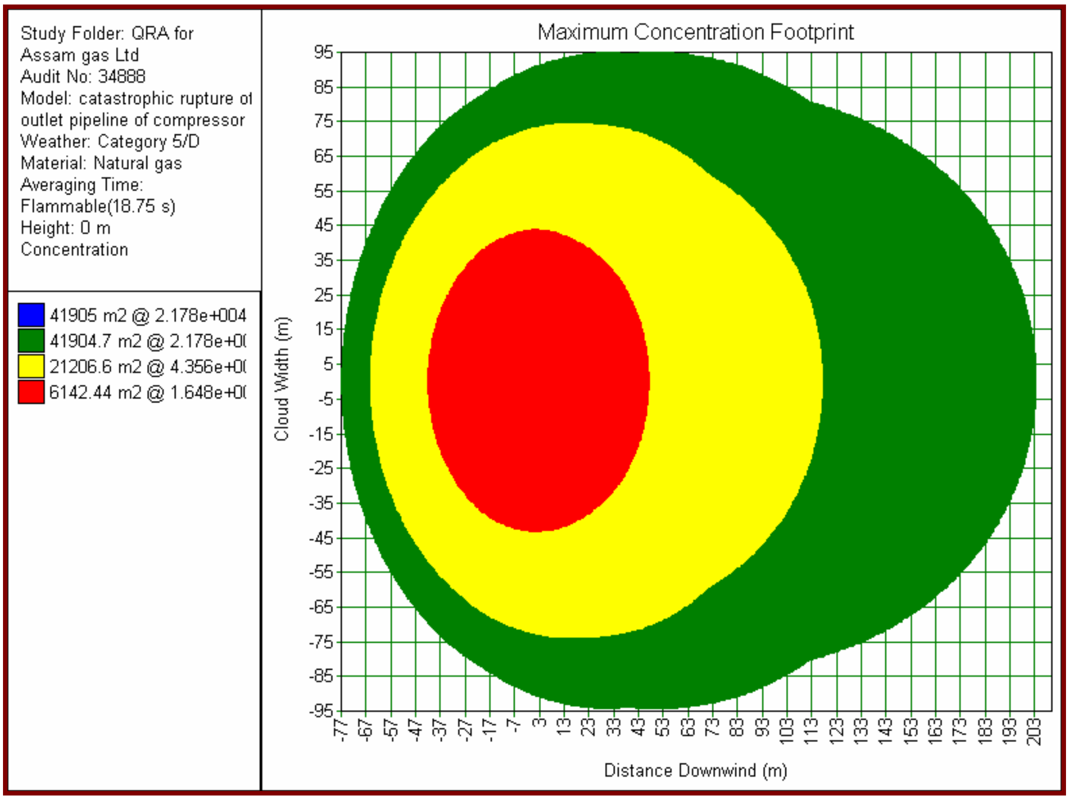
Scenario details	THERMAL DAMAGE DISTANCE BY FIRE BALL				MAXIMUM DISTANCE AT OVERPRESSURE LEVEL (M)			
	RADIATION INTENSITY (KW / M2)	WEATHER CATEGORY			OVERPRESSURE (BAR)	WEATHER CATEGORY		
		3F	7D	5D		3F	7D	5D
Rupture in outlet pipeline of compressor	**4**	852.31	806.79	806.79	**0.02068**	1494.02	1494.02	1494.02
	12.5	467.31	442.05	442.05	**0.1379**	386.84	386.84	386.84
	37.5	196.45	179.04	179.04	**0.2068**	299.33	299.33	299.33

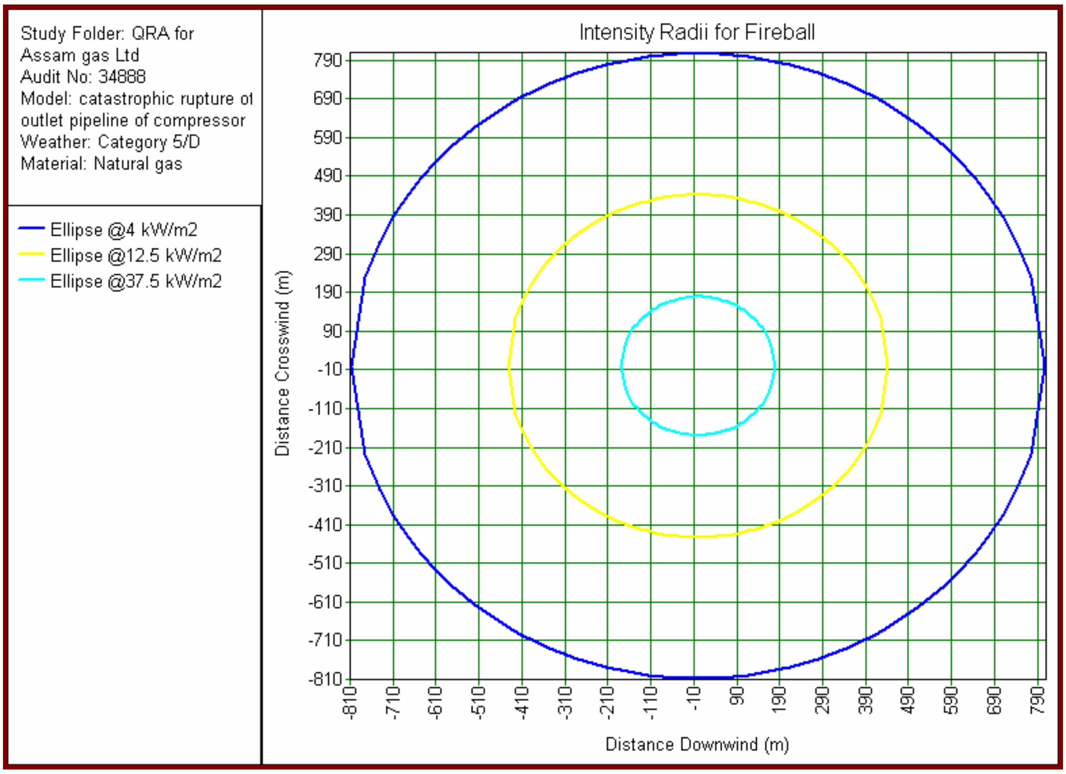
Maximum credible loss Scenario (MCLS): Leakage due to Flange failure or Hose Failure from outlet pipeline of compressor

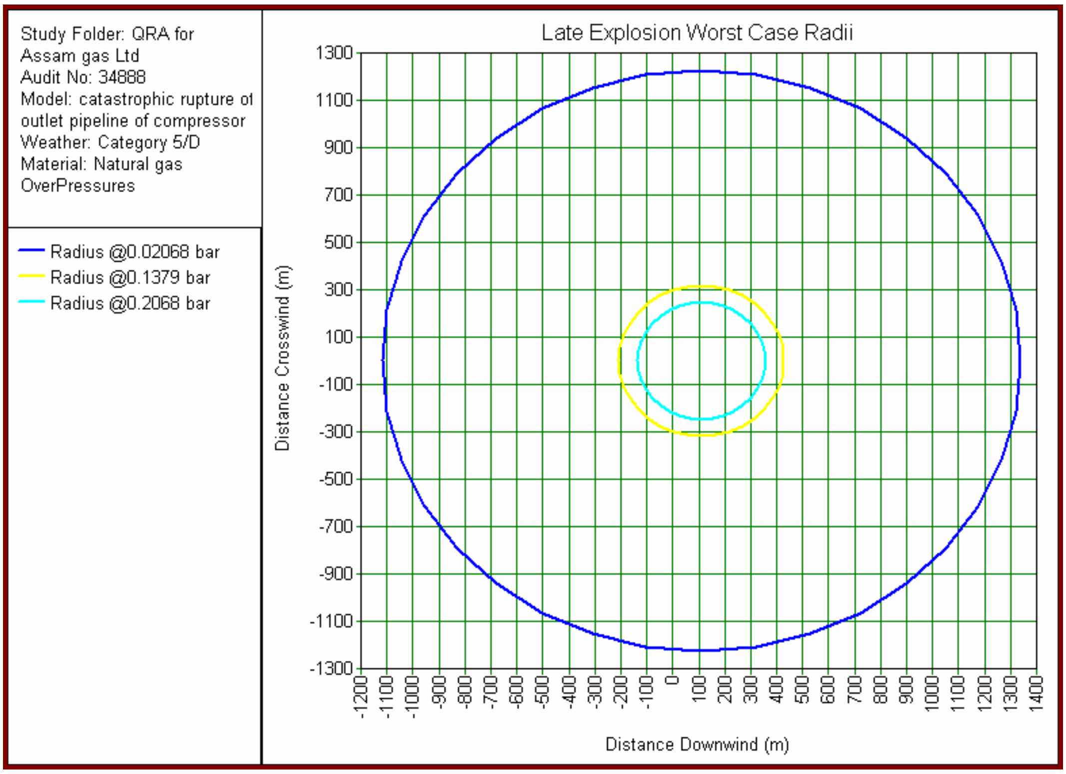
Scenario details	CONCENTRATION AT DISTANCE (M)				
	Concentration in PPM		WEATHER CATEGORY		
			3F	7D	5D
5 mm leakage in outlet pipeline of compressor	UFL	164806	0.53	0.52	0.53
	LFL	43559.7	2.23	2.08	2.16
	LFL (frac)	21779.9	4.14	3.53	3.83
25 mm leakage in outlet pipeline of compressor	UFL	164806	2.52	2.48	2.51
	LFL	43559.7	9.97	8.35	9.01
	LFL (frac)	21779.9	25.33	19.91	22.33
100 mm leakage in outlet pipeline of compressor	UFL	164806	10.09	9.69	9.93
	LFL	43559.7	64.53	62.68	61.73
	LFL (frac)	21779.9	137.29	148.52	141.65

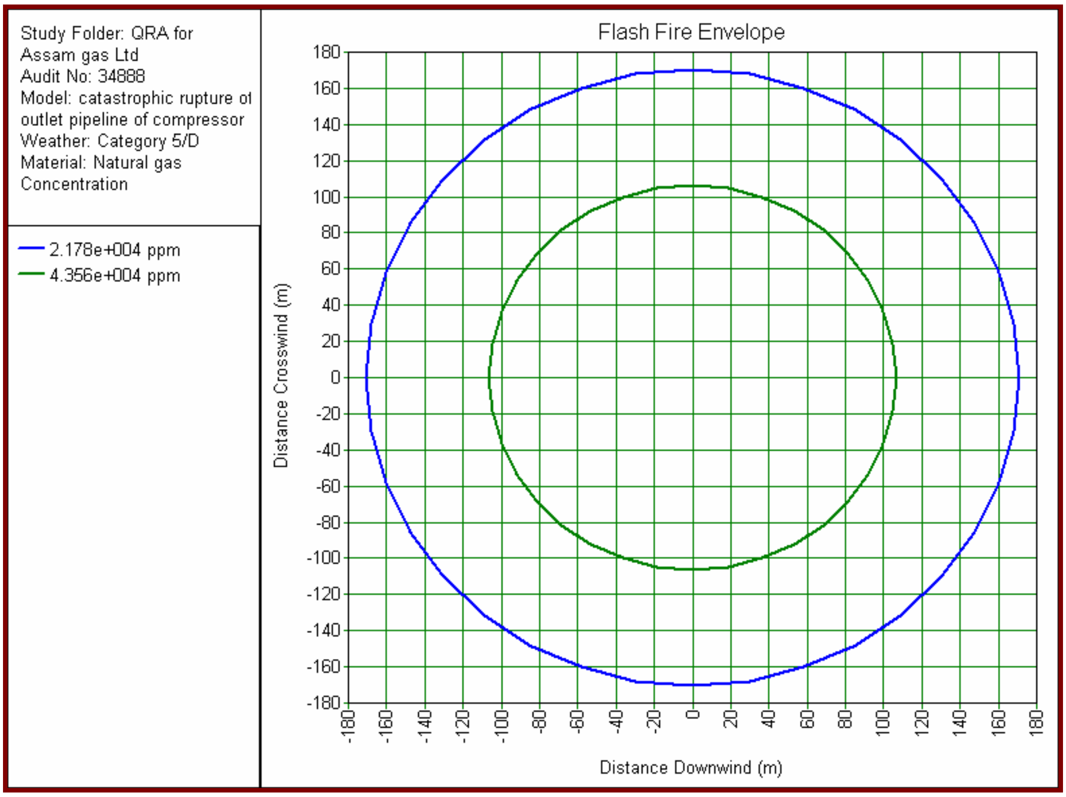
Scenario details	THERMAL DAMAGE DISTANCE BY JET FIRE				MAXIMUM DISTANCE AT OVERPRESSURE LEVEL (M)			
	RADIATION INTENSITY (kW / m2)	WEATHER CATEGORY			OVERPRESSURE (BAR)	WEATHER CATEGORY		
		3F	7D	5D		3F	7D	5D
5 mm leakage in outlet pipeline of compressor	**4**	NR	NR	NR	**0.02068**	NR	NR	NR
	12.5	NR	NR	NR	**0.1379**	NR	NR	NR
	37.5	NR	NR	NR	**0.2068**	NR	NR	NR
25 mm leakage in outlet pipeline of compressor	**4**	22.10	22.34	22.30	**0.02068**	39.84	27.35	38.11
	12.5	17.96	18.89	18.50	**0.1379**	25.14	14.49	24.69
	37.5	14.25	15.54	14.84	**0.2068**	23.98	13.48	23.63

Scenario details	THERMAL DAMAGE DISTANCE BY JET FIRE				MAXIMUM DISTANCE AT OVERPRESSURE LEVEL (M)			
	RADIATION INTENSITY (kW / m2)	WEATHER CATEGORY			OVERPRESSURE (BAR)	WEATHER CATEGORY		
		3F	7D	5D		3F	7D	5D
100 mm leakage in outlet pipeline of compressor	**4**	89.09	88.85	88.73	**0.02068**	239.58	236.92	237.77
	12.5	68.56	72.19	70.35	**0.1379**	158.37	165.10	165.31
	37.5	53.45	60.18	56.15	**0.2068**	151.95	159.42	159.59




Study Folder: QRA for Assam gas Ltd
Audit No: 34888
Model: catastrophic rupture of outlet pipeline of compressor
Weather: Category 5/D
Material: Natural gas
Ellipse @4 kW/m2
Ellipse @12.5 kW/m2
Ellipse @37.5 kW/m2
Intensity Radii for Fireball
Distance Crosswind (m)
Distance Downwind (m)


Study Folder: QRA for Assam gas Ltd
Audit No: 34888
Model: catastrophic rupture of outlet pipeline of compressor
Weather: Category 5/D
Material: Natural gas
OverPressures
Radius @0.02068 bar
Radius @0.1379 bar
Radius @0.2068 bar
Late Explosion Worst Case Radii
Distance Crosswind (m)
Distance Downwind (m)


Study Folder: QRA for Assam gas Ltd
Audit No: 34888
Model: catastrophic rupture of outlet pipeline of compressor
Weather: Category 5/D
Material: Natural gas
Concentration
2.178e+004 ppm
4.356e+004 ppm
Flash Fire Envelope
Distance Crosswind (m)
Distance Downwind (m)

CONSEQUENCE RESULTS COMPRESSOR UNIT 8,9,10,11

Worst Case Scenario (WCS):-100% Catastrophic Rupture

Scenario details	CONCENTRATION AT DISTANCE (M)				
	Concentration in PPM		WEATHER CATEGORY		
			3F	7D	5D
Rupture in outlet pipeline of compressor	UFL	164806	43.89	48.07	45.48
	LFL	43559.7	92.68	125.21	99.73
	LFL (frac)	21779.9	166.42	226.20	161.55

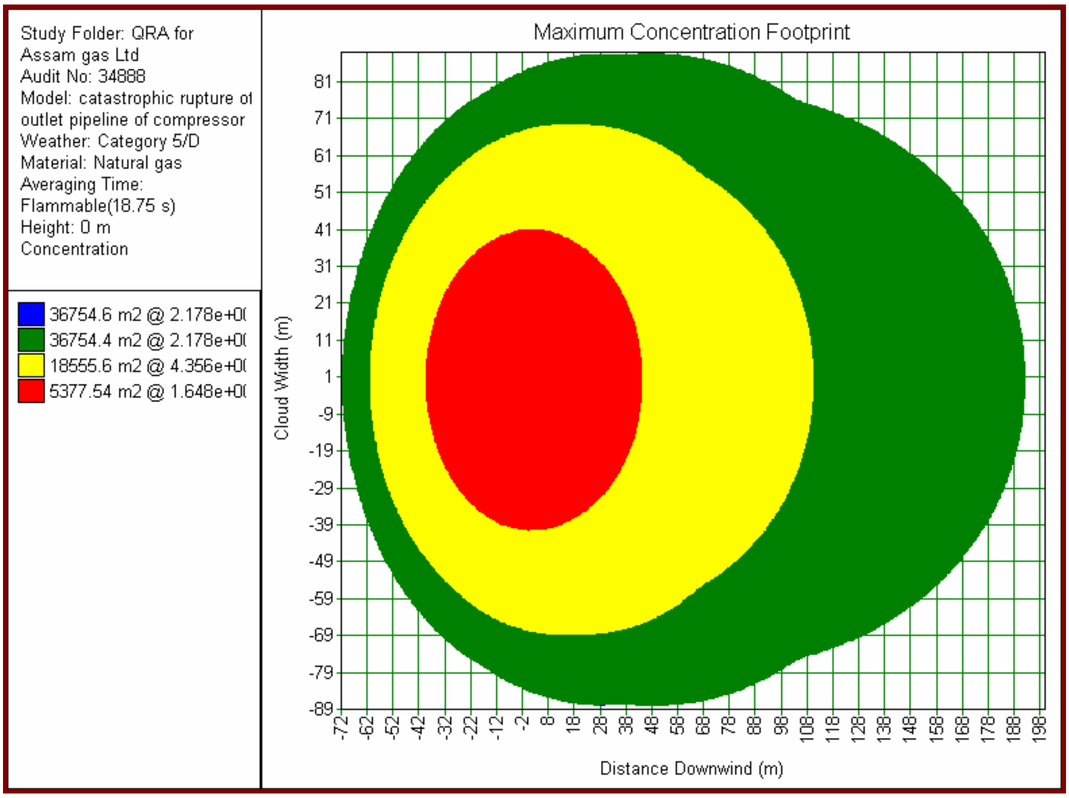
Scenario details	THERMAL DAMAGE DISTANCE BY FIRE BALL				MAXIMUM DISTANCE AT OVERPRESSURE LEVEL (M)			
	RADIATION INTENSITY (KW / M2)	WEATHER CATEGORY			OVERPRESSURE (BAR)	WEATHER CATEGORY		
		3F	7D	5D		3F	7D	5D
Rupture in outlet pipeline of compressor	**4**	789.44	748.14	748.14	**0.02068**	1392.7	1392.7	1392.7
	12.5	431.5	408.53	408.53	**0.1379**	360.61	360.61	360.61
	37.5	178.64	162.62	162.62	**0.2068**	279.03	279.03	279.03

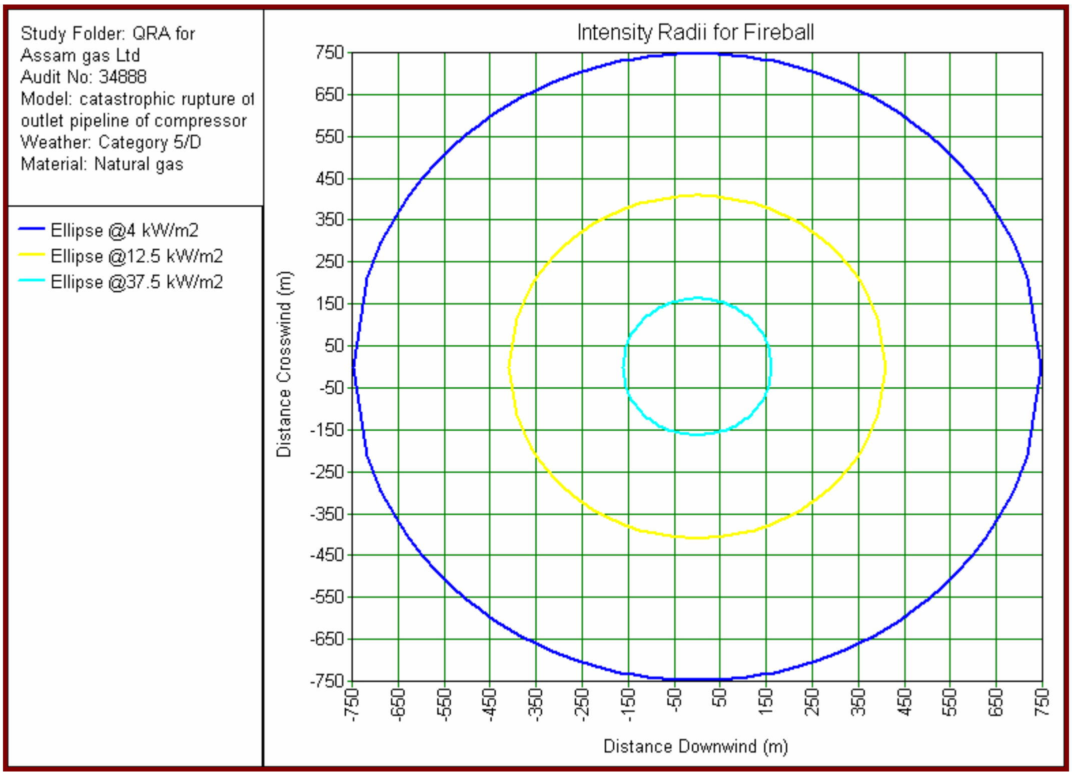
Maximum credible loss Scenario (MCLS): Leakage due to Flange failure or Hose Failure from outlet pipeline of compressor

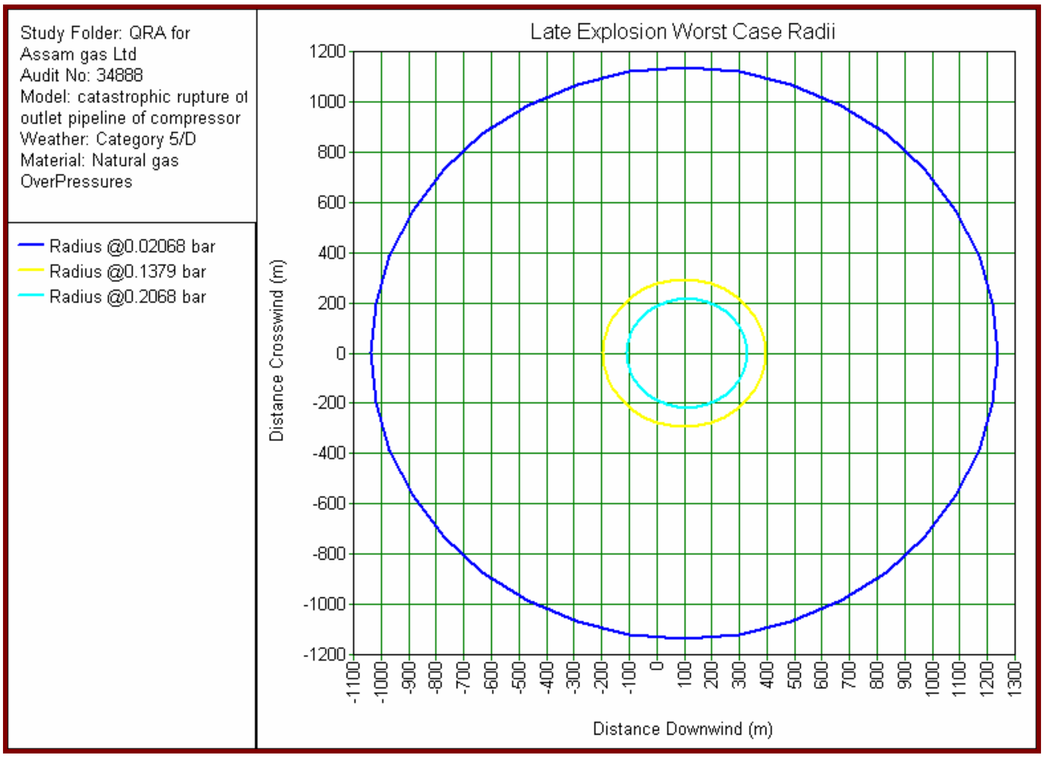
Scenario details	CONCENTRATION AT DISTANCE (M)				
	Concentration in PPM		WEATHER CATEGORY		
			3F	7D	5D
5 mm leakage in outlet pipeline of compressor	UFL	164806	0.44	0.44	0.45
	LFL	43559.7	2.04	1.87	1.96
	LFL (frac)	21779.9	3.76	3.07	3.42
25 mm leakage in outlet pipeline of compressor	UFL	164806	2.36	2.31	2.35
	LFL	43559.7	8.82	7.49	8.06
	LFL (frac)	21779.9	21.17	16.46	18.33
100 mm leakage in outlet pipeline of compressor	UFL	164806	9.13	8.63	8.93
	LFL	43559.7	56.67	54.42	54.68
	LFL (frac)	21779.9	121.81	132.15	128.05

Scenario details	THERMAL DAMAGE DISTANCE BY JET FIRE				MAXIMUM DISTANCE AT OVERPRESSURE LEVEL (M)			
	RADIATION INTENSITY (KW / M2)	WEATHER CATEGORY			OVERPRESSURE (BAR)	WEATHER CATEGORY		
		3F	7D	5D		3F	7D	5D
5 mm leakage in outlet pipeline of compressor	**4**	NR	NR	NR	**0.02068**	NR	NR	NR
	12.5	NR	NR	NR	**0.1379**	NR	NR	NR
	37.5	NR	NR	NR	**0.2068**	NR	NR	NR
25 mm leakage in outlet pipeline of compressor	**4**	19.76	19.94	19.93	**0.02068**	37.70	25.55	26.19
	12.5	16.06	16.84	16.52	**0.1379**	24.58	14.03	14.19
	37.5	12.14	12.49	11.97	**0.2068**	23.55	13.11	13.24
100 mm	**4**	80.83	80.84	80.66	**0.02068**	217.02	215.7	207.8

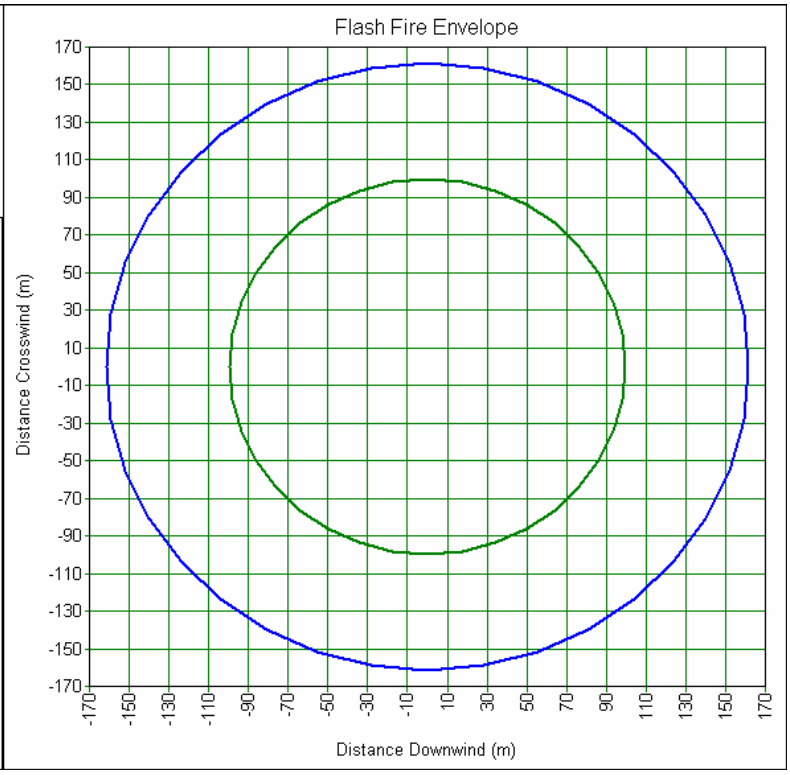
Scenario details	THERMAL DAMAGE DISTANCE BY JET FIRE				MAXIMUM DISTANCE AT OVERPRESSURE LEVEL (M)			
	RADIATION INTENSITY (KW / M2)	WEATHER CATEGORY			OVERPRESSURE (BAR)	WEATHER CATEGORY		
		3F	7D	5D		3F	7D	5D
leakage in outlet pipeline of compressor							4	1
	12.5	62.55	65.97	64.26	**0.1379**	145.12	152.2	142.7 4
	37.5	49.01	55.06	51.53	**0.2068**	139.44	147.1 8	137.5 9




Study Folder: QRA for Assam gas Ltd
Audit No: 34888
Model: catastrophic rupture of outlet pipeline of compressor
Weather: Category 5/D
Material: Natural gas
Ellipse @4 kW/m2
Ellipse @12.5 kW/m2
Ellipse @37.5 kW/m2
Intensity Radii for Fireball
Distance Crosswind (m)
Distance Downwind (m)


Study Folder: QRA for Assam gas Ltd
Audit No: 34888
Model: catastrophic rupture of outlet pipeline of compressor
Weather: Category 5/D
Material: Natural gas
OverPressures
Radius @0.02068 bar
Radius @0.1379 bar
Radius @0.2068 bar
Late Explosion Worst Case Radii
Distance Crosswind (m)
Distance Downwind (m)

Study Folder: QRA for Assam gas Ltd
Audit No: 34888
Model: catastrophic rupture of outlet pipeline of compressor
Weather: Category 5/D
Material: Natural gas
Concentration



CONSEQUENCE RESULTS - AGCL COMPRESSOR STATION TO BVFCL NAMRUP

Worst Case Scenario (WCS):-100% Catastrophic Rupture

Scenario details	CONCENTRATION AT DISTANCE (M)				
	Concentration in PPM		WEATHER CATEGORY		
			3F	7D	5D
Rupture in buried pipeline	UFL	164806	3.77	4.12	3.98
	LFL	43559.7	6.87	9.28	8.30
	LFL (frac)	21779.9	9.67	14.71	12.66

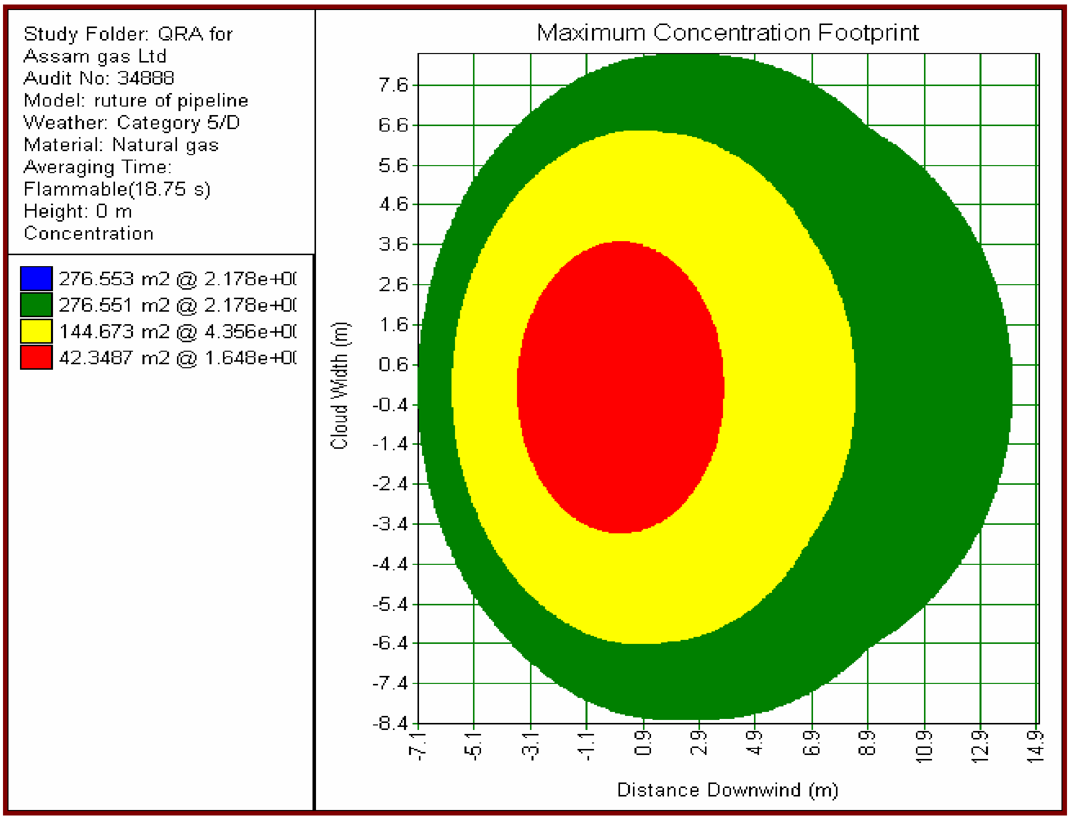
Scenario details	THERMAL DAMAGE DISTANCE BY FIRE BALL				MAXIMUM DISTANCE AT OVERPRESSURE LEVEL (M)			
	RADIATION INTENSITY (kW / m2)	WEATHER CATEGORY			OVERPRESSURE (BAR)	WEATHER CATEGORY		
		3F	7D	5D		3F	7D	5D
Rupture in buried pipeline	**4**	72.55	70.41	70.41	**0.02068**	138.67	138.67	138.67
	12.5	37.03	35.80	35.80	**0.1379**	35.91	35.91	35.91
	37.5	8.02	6.14	6.14	**0.2068**	27.78	27.78	27.78

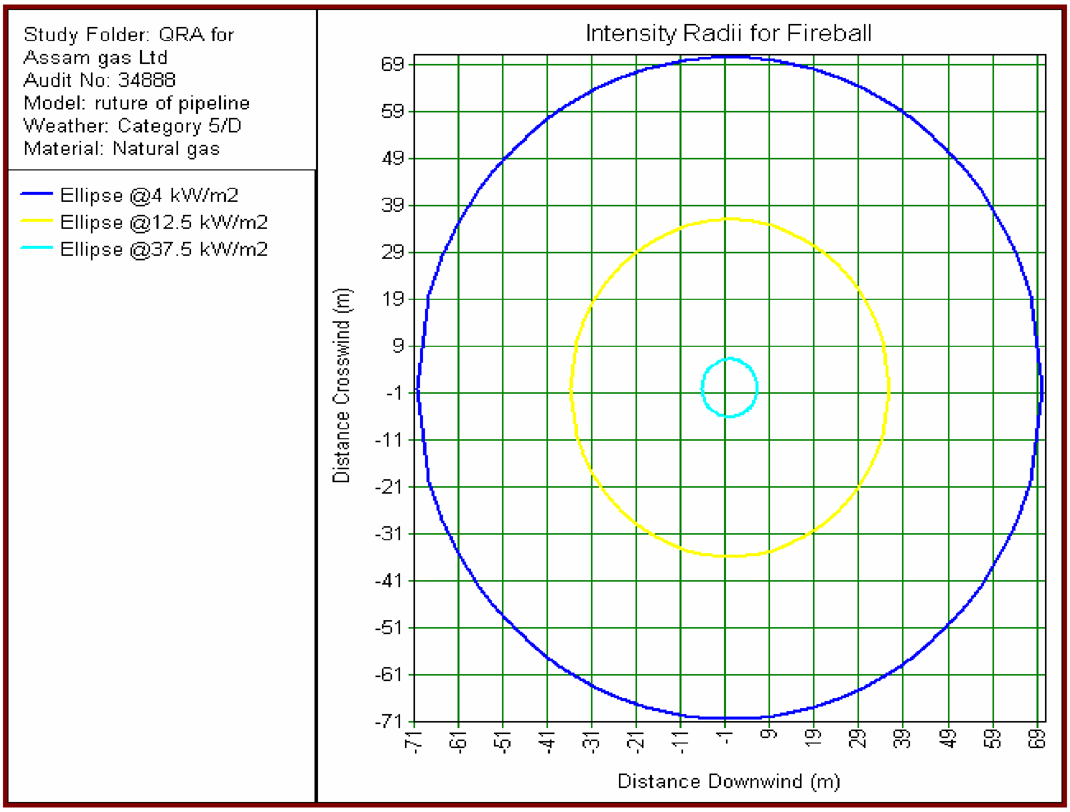
Maximum credible loss Scenario (MCLS): Leakage due to Flange failure or Hose Failure

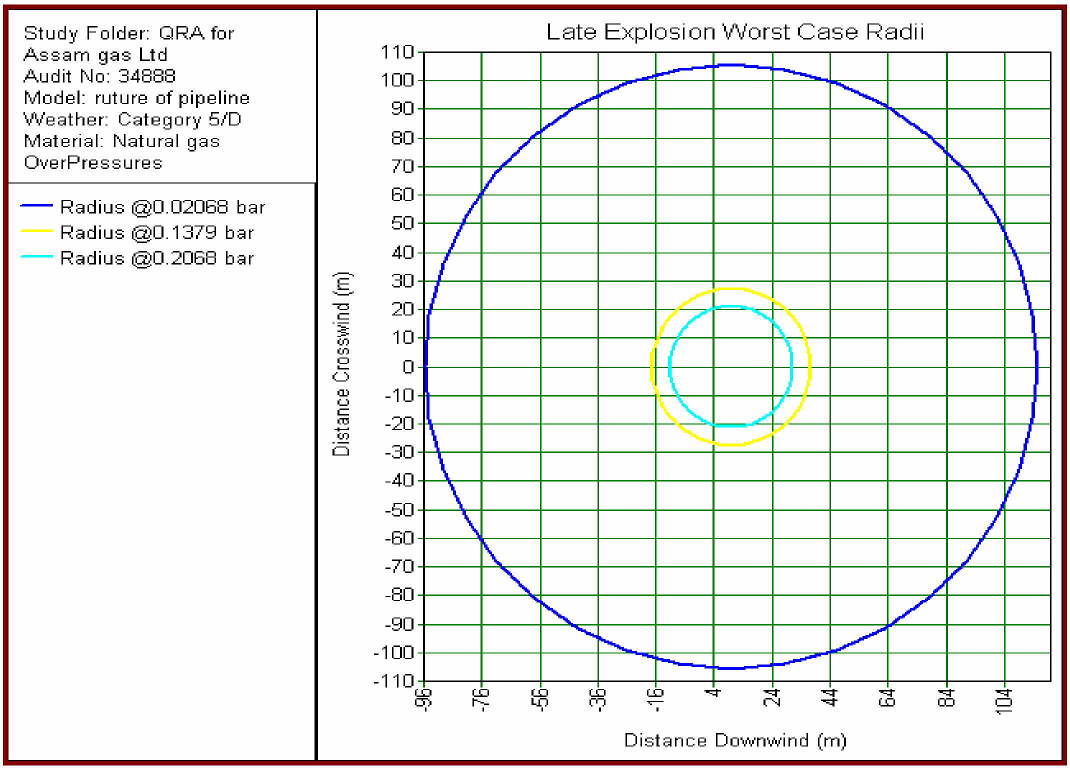
Scenario details	CONCENTRATION AT DISTANCE (M)				
	Concentration in PPM		WEATHER CATEGORY		
			3F	7D	5D
5 mm leakage in buried pipeline	UFL	164806	0.44	0.44	0.44
	LFL	43559.7	2.03	1.85	1.95
	LFL (frac)	21779.9	3.73	3.04	3.39
25 mm leakage in buried pipeline	UFL	164806	2.35	2.30	2.34
	LFL	43559.7	8.77	7.45	8.01
	LFL (frac)	21779.9	20.99	16.30	18.10
100 mm leakage in buried pipeline	UFL	164806	9.06	8.56	8.86
	LFL	43559.7	56.26	53.85	54.22
	LFL (frac)	21779.9	123.32	131.13	127.11

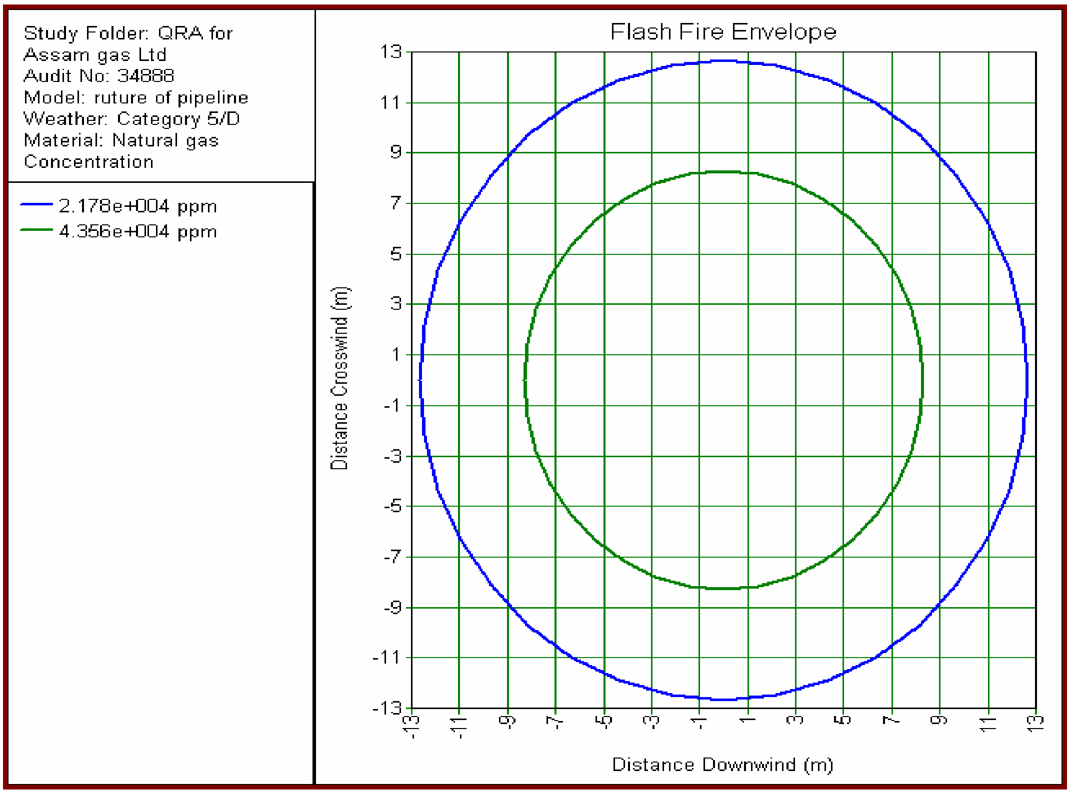
Scenario details	THERMAL DAMAGE DISTANCE BY JET FIRE				MAXIMUM DISTANCE AT OVERPRESSURE LEVEL (M)			
	RADIATION INTENSITY (kW / m2)	WEATHER CATEGORY			OVERPRESSURE (BAR)	WEATHER CATEGORY		
		3F	7D	5D		3F	7D	5D
5 mm leakage in buried pipeline	**4**	NR	NR	NR	**0.02068**	NR	NR	NR
	12.5	NR	NR	NR	**0.1379**	NR	NR	NR
	37.5	NR	NR	NR	**0.2068**	NR	NR	NR
25 mm leakage in buried pipeline	**4**	19.61	19.79	19.78	**0.02068**	37.59	25.45	26.08
	12.5	15.94	16.72	16.40	**0.1379**	24.56	14.00	14.16
	37.5	11.97	12.04	11.61	**0.2068**	23.53	13.10	13.22
100 mm	**4**	72.55	70.41	70.41	**0.02068**	138.67	138.67	138.67

Scenario details	THERMAL DAMAGE DISTANCE BY JET FIRE				MAXIMUM DISTANCE AT OVERPRESSURE LEVEL (M)			
	RADIATION INTENSITY (kW / m2)	WEATHER CATEGORY			OVERPRESSURE (BAR)	WEATHER CATEGORY		
		3F	7D	5D		3F	7D	5D
leakage in buried pipeline	**12.5**	37.03	35.80	35.80	**0.1379**	35.91	35.91	35.91
	37.5	8.02	6.14	6.14	**0.2068**	27.78	27.78	27.78




Study Folder: QRA for Assam gas Ltd
Audit No: 34888
Model: ruture of pipeline
Weather: Category 5/D
Material: Natural gas
Ellipse @4 kW/m2
Ellipse @12.5 kW/m2
Ellipse @37.5 kW/m2
Intensity Radii for Fireball
Distance Crosswind (m)
Distance Downwind (m)


Study Folder: QRA for Assam gas Ltd
Audit No: 34888
Model: ruture of pipeline
Weather: Category 5/D
Material: Natural gas
OverPressures
Radius @0.02068 bar
Radius @0.1379 bar
Radius @0.2068 bar
Late Explosion Worst Case Radii
Distance Crosswind (m)
Distance Downwind (m)


Study Folder: QRA for Assam gas Ltd
Audit No: 34888
Model: ruture of pipeline
Weather: Category 5/D
Material: Natural gas
Concentration
2.178e+004 ppm
4.356e+004 ppm
Flash Fire Envelope
Distance Crosswind (m)
Distance Downwind (m)
13
11
9
7
5
3
1
-1
-3
-5
-7
-9
-11
-13

CONSEQUENCE RESULTS- AGCL COMPRESSOR STATION TO NTPS NAMRUP

Worst Case Scenario (WCS):-100% Catastrophic Rupture

Scenario details	CONCENTRATION AT DISTANCE (M)				
	Concentration in PPM		WEATHER CATEGORY		
			3F	7D	5D
Rupture in buried pipeline	UFL	164806	4.40	4.83	4.69
	LFL	43559.7	8.16	10.88	9.61
	LFL (frac)	21779.9	11.38	19.49	15.13

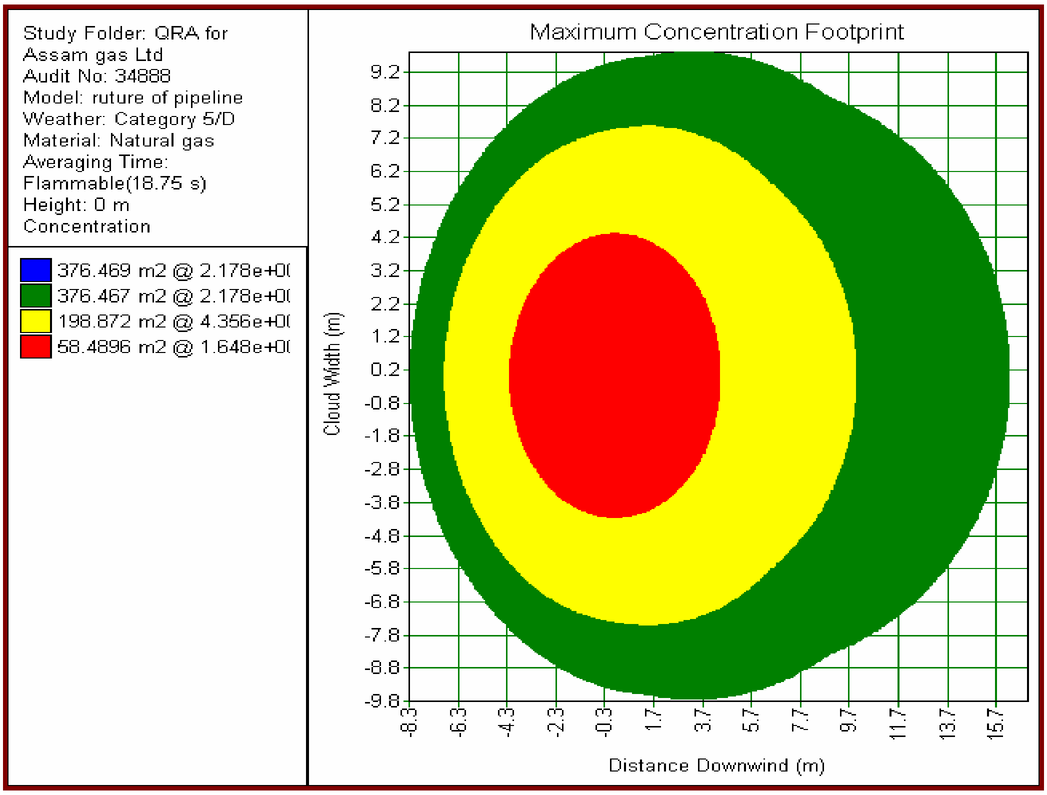
Scenario details	THERMAL DAMAGE DISTANCE BY FIRE BALL				MAXIMUM DISTANCE AT OVERPRESSURE LEVEL (M)			
	RADIATION INTENSITY (KW / M2)	WEATHER CATEGORY			OVERPRESSURE (BAR)	WEATHER CATEGORY		
		3F	7D	5D		3F	7D	5D
Rupture in buried pipeline	**4**	84.51	81.94	81.94	**0.02068**	160.24	160.24	160.24
	12.5	43.37	41.88	41.88	**0.1379**	41.49	41.49	41.49
	37.5	10.46	8.48	8.48	**0.2068**	32.10	32.10	32.10

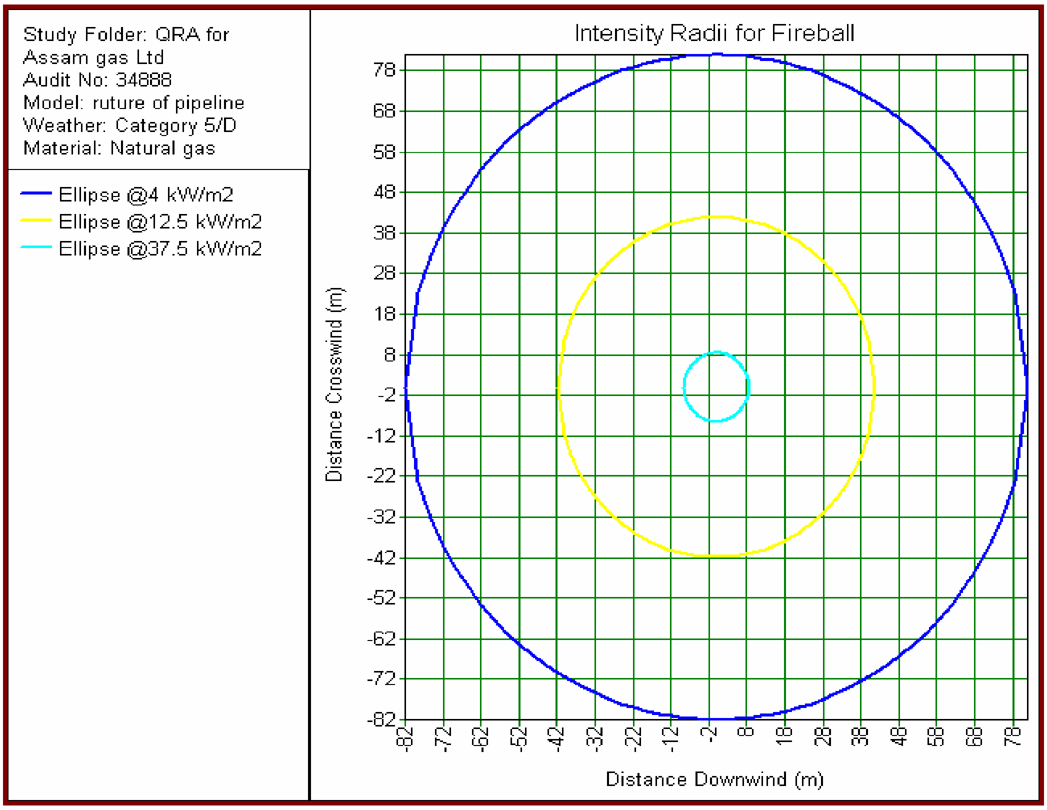
Maximum credible loss Scenario (MCLS): Leakage due to Flange failure or Hose Failure

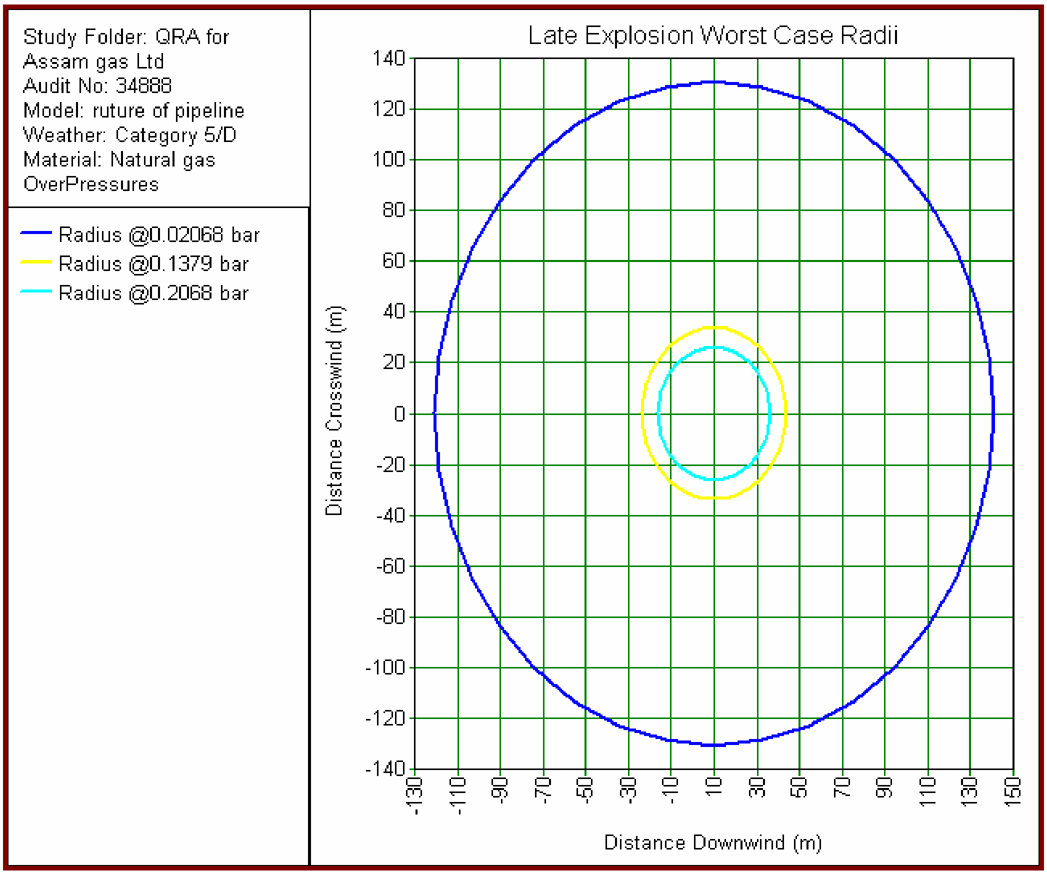
Scenario details	CONCENTRATION AT DISTANCE (M)				
	Concentration in PPM		WEATHER CATEGORY		
			3F	7D	5D
5 mm leakage in buried pipeline	UFL	164806	0.44	0.44	0.44
	LFL	43559.7	2.03	1.85	1.95
	LFL (frac)	21779.9	3.73	3.04	3.39
25 mm leakage in buried pipeline	UFL	164806	2.35	2.30	2.34
	LFL	43559.7	8.77	7.45	8.01
	LFL (frac)	21779.9	20.99	16.30	18.10
100 mm leakage in buried pipeline	UFL	164806	9.06	8.56	8.86
	LFL	43559.7	56.26	53.85	54.22
	LFL (frac)	21779.9	121.14	131.13	127.11

Scenario details	THERMAL DAMAGE DISTANCE BY JET FIRE				MAXIMUM DISTANCE AT OVERPRESSURE LEVEL (M)			
	RADIATION INTENSITY (KW / M2)	WEATHER CATEGORY			OVERPRESSURE (BAR)	WEATHER CATEGORY		
		3F	7D	5D		3F	7D	5D
5 mm leakage in buried pipeline	**4**	NR	NR	NR	**0.02068**	NR	NR	NR
	12.5	NR	NR	NR	**0.1379**	NR	NR	NR
	37.5	NR	NR	NR	**0.2068**	NR	NR	NR
25 mm leakage in buried pipeline	**4**	19.61	19.79	19.78	**0.02068**	37.59	25.45	26.08
	12.5	15.94	16.72	16.40	**0.1379**	24.56	14.00	14.16
	37.5	11.97	12.04	11.61	**0.2068**	23.53	13.10	13.22
100 mm	**4**	84.51	81.94	81.94	**0.02068**	160.24	160.24	160.24

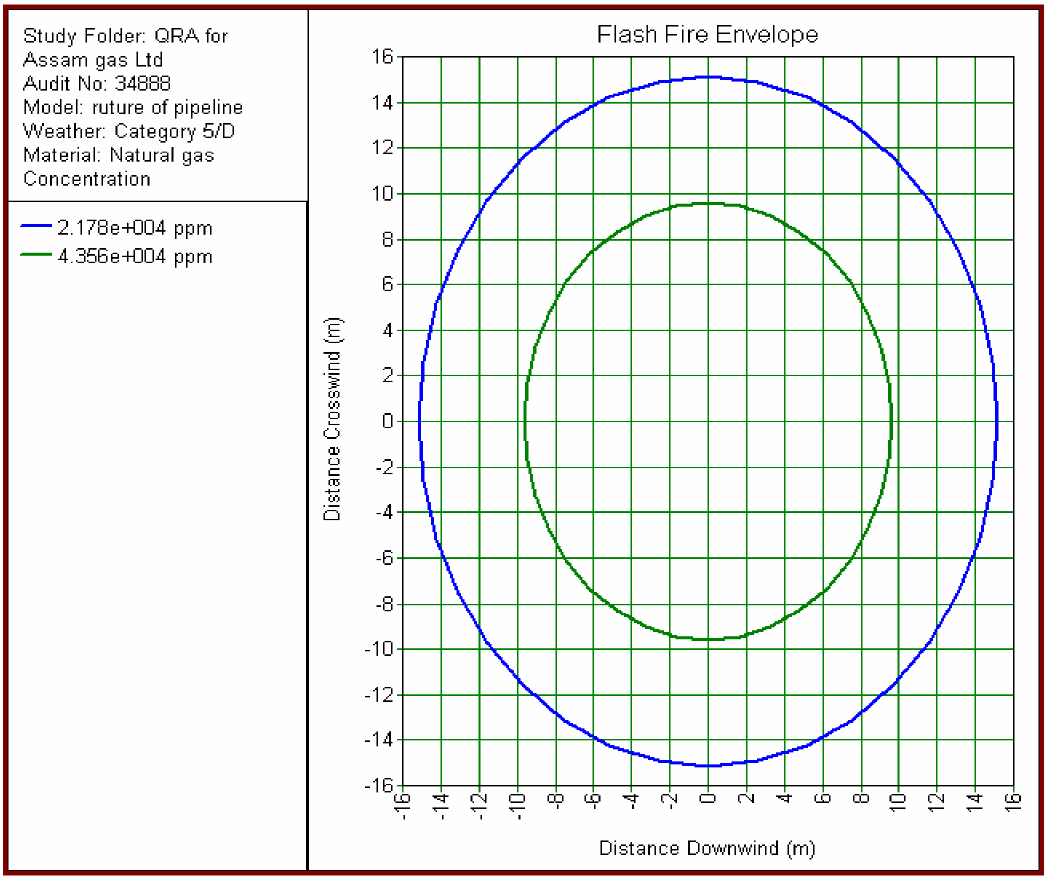
Scenario details	THERMAL DAMAGE DISTANCE BY JET FIRE				MAXIMUM DISTANCE AT OVERPRESSURE LEVEL (M)			
	RADIATION INTENSITY (KW / M2)	WEATHER CATEGORY			OVERPRESSURE (BAR)	WEATHER CATEGORY		
		3F	7D	5D		3F	7D	5D
leakage in buried pipeline	**12.5**	43.37	41.88	41.88	**0.1379**	41.49	41.49	41.49
	37.5	10.46	8.48	8.48	**0.2068**	32.10	32.10	32.10




Study Folder: QRA for Assam gas Ltd
Audit No: 34888
Model: ruture of pipeline
Weather: Category 5/D
Material: Natural gas
Ellipse @4 kW/m2
Ellipse @12.5 kW/m2
Ellipse @37.5 kW/m2
Intensity Radii for Fireball
Distance Crosswind (m)
Distance Downwind (m)
78
68
58
48
38
28
18
8
-2
-12
-22
-32
-42
-52
-62
-72
-82


Study Folder: QRA for Assam gas Ltd
Audit No: 34888
Model: ruture of pipeline
Weather: Category 5/D
Material: Natural gas
OverPressures
Radius @0.02068 bar
Radius @0.1379 bar
Radius @0.2068 bar
Late Explosion Worst Case Radii
Distance Crosswind (m)
Distance Downwind (m)
140
120
100
80
60
40
20
0
-20
-40
-60
-80
-100
-120
-140

Study Folder: QRA for Assam gas Ltd
Audit No: 34888
Model: ruture of pipeline
Weather: Category 5/D
Material: Natural gas
Concentration



CONSEQUENCE RESULTS- AGCL COMPRESSOR STATION TO NTPS NAMRUP

Worst Case Scenario (WCS):-100% Catastrophic Rupture

Scenario details	CONCENTRATION AT DISTANCE (M)				
	Concentration in PPM		WEATHER CATEGORY		
			3F	7D	5D
Rupture in buried pipeline	UFL	164806	3.67	4.01	3.87
	LFL	43559.7	6.71	9.11	8.15
	LFL (frac)	21779.9	9.45	16.25	12.45

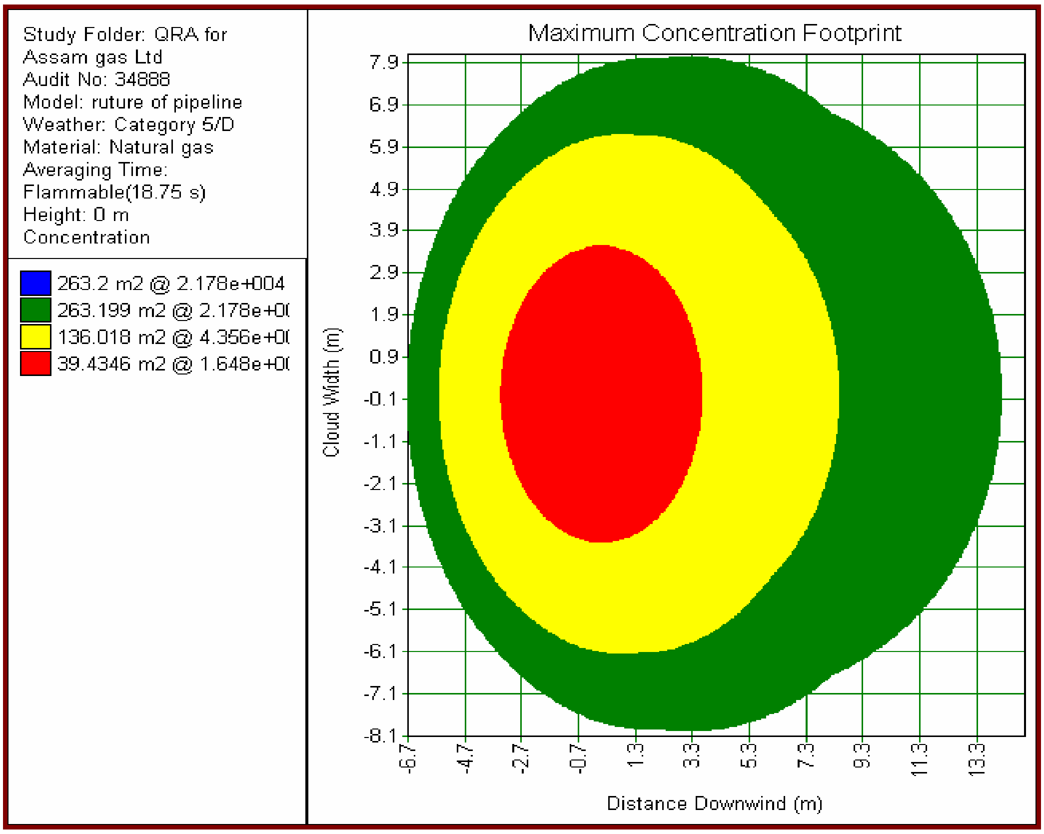
Scenario details	THERMAL DAMAGE DISTANCE BY FIRE BALL				MAXIMUM DISTANCE AT OVERPRESSURE LEVEL (M)			
	RADIATION INTENSITY (KW / M2)	WEATHER CATEGORY			OVERPRESSURE (BAR)	WEATHER CATEGORY		
		3F	7D	5D		3F	7D	5D
Rupture in buried pipeline	**4**	63.907	62.041	62.041	**0.02068**	133.18	133.18	133.18
	12.5	31.6	30.492	30.492	**0.1379**	34.48	34.48	34.48
	37.5	NR	NR	NR	**0.2068**	26.68	26.68	26.68

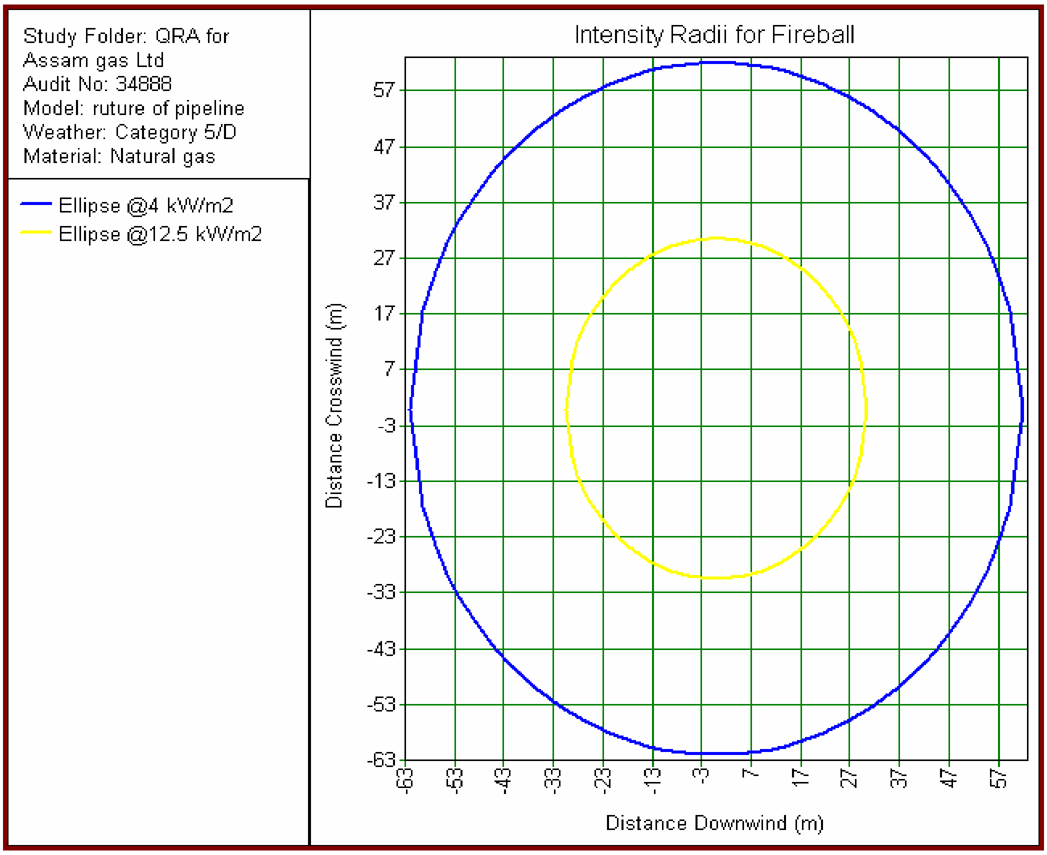
Maximum credible loss Scenario (MCLS): Leakage due to Flange failure or Hose Failure

Scenario details	CONCENTRATION AT DISTANCE (M)				
	Concentration in PPM		WEATHER CATEGORY		
			3F	7D	5D
5 mm leakage in buried pipeline	UFL	164806	0.33	0.33	0.34
	LFL	43559.7	1.48	1.34	1.39
	LFL (frac)	21779.9	2.65	2.42	2.60
25 mm leakage in buried pipeline	UFL	164806	1.92	1.88	1.91
	LFL	43559.7	7.03	5.97	6.57
	LFL (frac)	21779.9	14.32	10.58	12.04
100 mm leakage in buried pipeline	UFL	164806	7.02	6.70	6.89
	LFL	43559.7	41.66	37.30	39.06
	LFL (frac)	21779.9	94.98	96.46	93.56

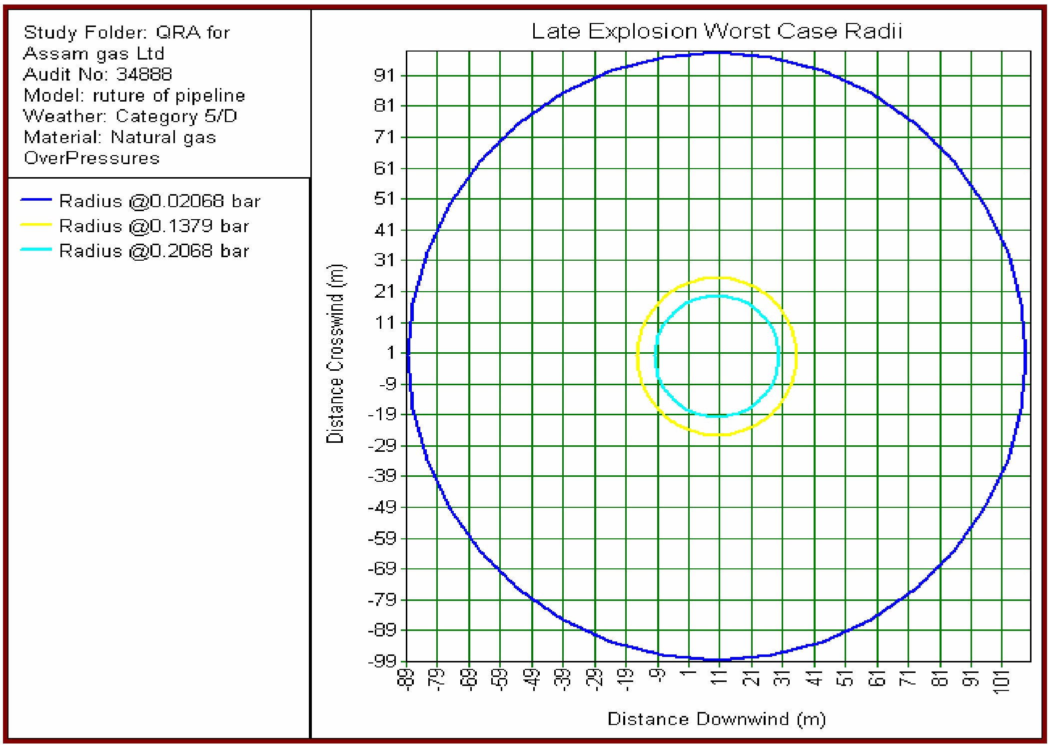
Scenario details	THERMAL DAMAGE DISTANCE BY JET FIRE				MAXIMUM DISTANCE AT OVERPRESSURE LEVEL (M)			
	RADIATION INTENSITY (KW / M2)	WEATHER CATEGORY			OVERPRESSURE (BAR)	WEATHER CATEGORY		
		3F	7D	5D		3F	7D	5D
5 mm leakage in buried pipeline	**4**	NR	NR	NR	**0.02068**	NR	NR	NR
	12.5	NR	NR	NR	**0.1379**	NR	NR	NR
	37.5	NR	NR	NR	**0.2068**	NR	NR	NR
25 mm leakage in buried pipeline	**4**	14.92	14.98	15.02	**0.02068**	24.02	22.09	23.04
	12.5	11.95	12.33	12.17	**0.1379**	13.63	13.13	13.38
	37.5	NR	NR	NR	**0.2068**	12.81	12.42	12.61
100 mm leakage in	**4**	63.91	62.04	62.04	**0.02068**	133.18	133.1 8	133.18

buried pipeline	**12.5**	31.60	30.49	30.49	**0.1379**	34.48	34.48	34.48
	37.5	NR	NR	NR	**0.2068**	26.68	26.68	26.68



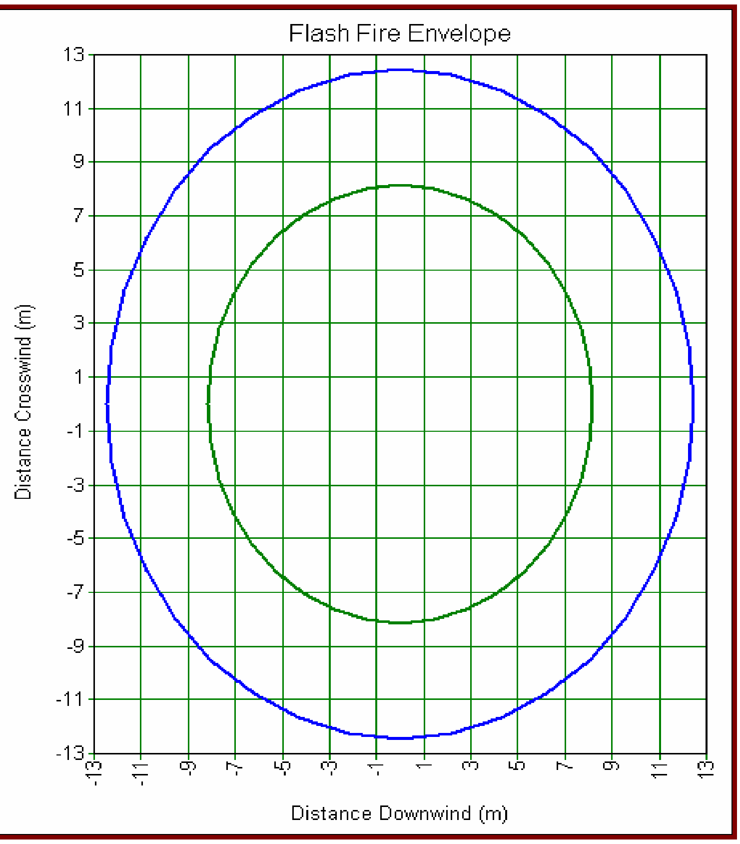


Study Folder: QRA for Assam gas Ltd
Audit No: 34888
Model: rupture of pipeline
Weather: Category 5/D
Material: Natural gas
Ellipse @4 kW/m2
Ellipse @12.5 kW/m2
Intensity Radii for Fireball
Distance Crosswind (m)
Distance Downwind (m)



Study Folder: QRA for Assam gas Ltd
Audit No: 34888
Model: rupture of pipeline
Weather: Category 5/D
Material: Natural gas
OverPressures
Radius @0.02068 bar
Radius @0.1379 bar
Radius @0.2068 bar
Late Explosion Worst Case Radii
Distance Crosswind (m)
Distance Downwind (m)

Study Folder: QRA for Assam gas Ltd
Audit No: 34888
Model: ruture of pipeline
Weather: Category 5/D
Material: Natural gas
Concentration



CONSEQUENCE RESULTS – AGCL TO BVFCL NAMRUP

Worst Case Scenario (WCS):-100% Catastrophic Rupture

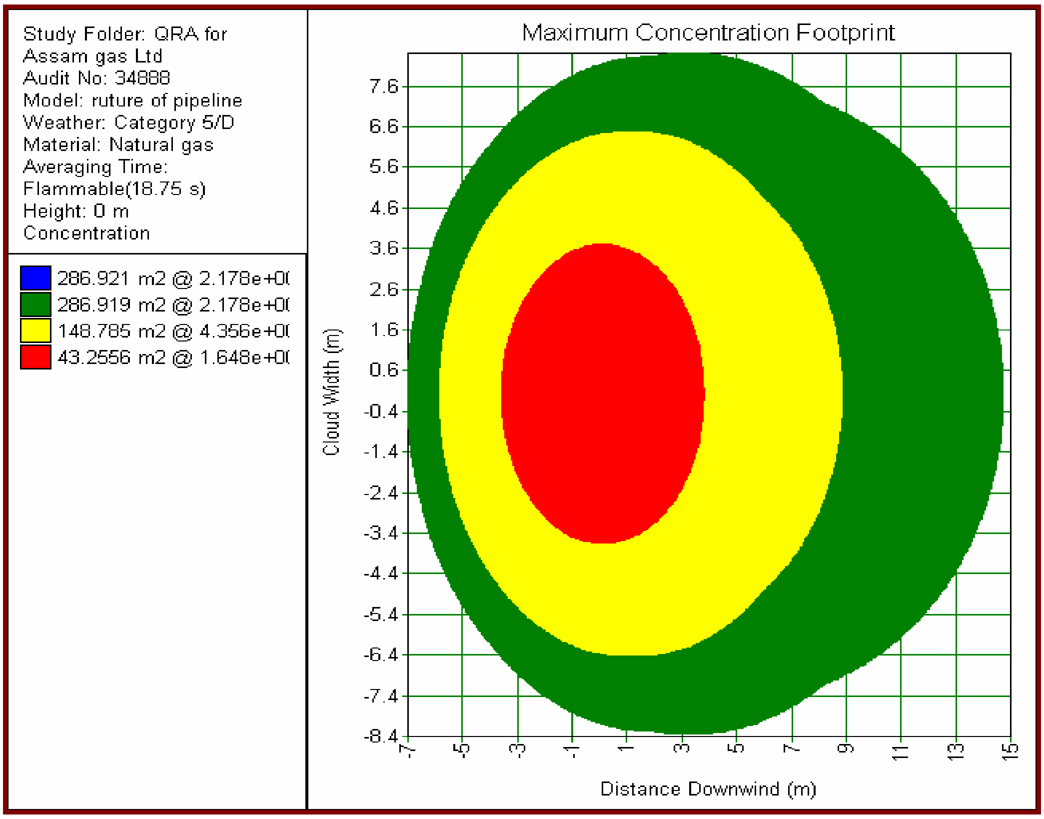
Scenario details	CONCENTRATION AT DISTANCE (M)				
	Concentration in PPM		WEATHER CATEGORY		
			3F	7D	5D
Rupture in buried pipeline going from AGCL to BVFCL Namrup	UFL	164806	3.83	4.19	4.06
	LFL	43559.7	7.03	9.65	8.48
	LFL (frac)	21779.9	9.89	17.70	13.44

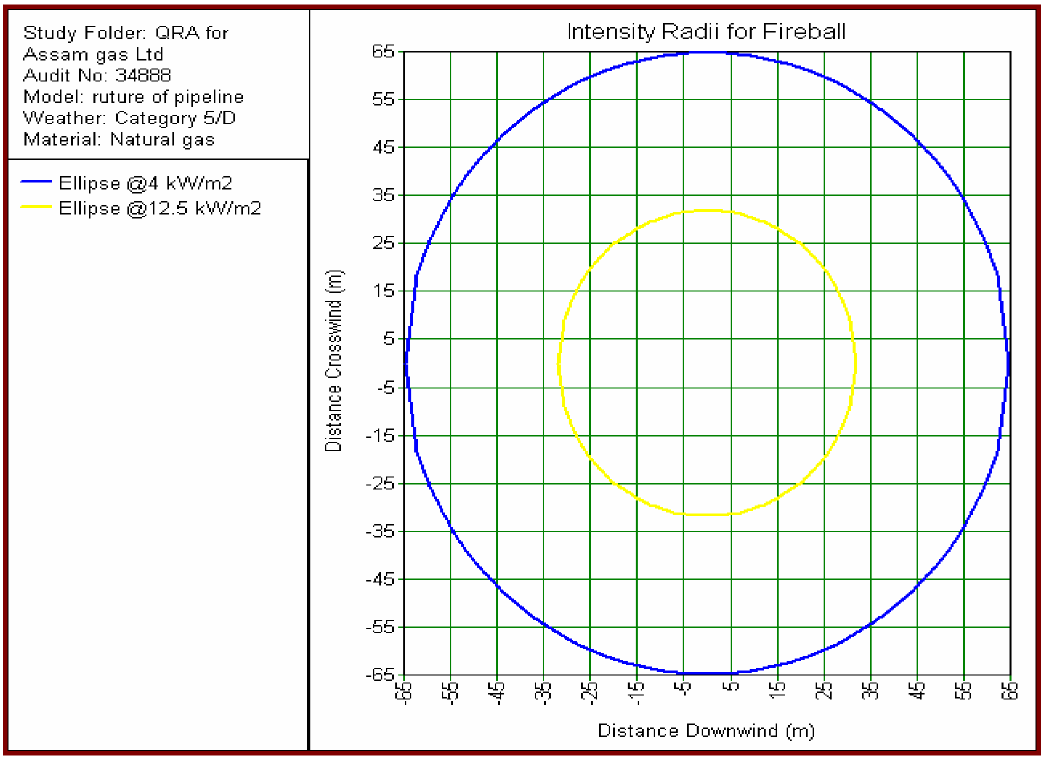
Scenario details	THERMAL DAMAGE DISTANCE BY FIRE BALL				MAXIMUM DISTANCE AT OVERPRESSURE LEVEL (M)			
	RADIATION INTENSITY (KW / M2)	WEATHER CATEGORY			OVERPRESSURE (BAR)	WEATHER CATEGORY		
		3F	7D	5D		3F	7D	5D
Rupture in buried pipeline going from AGCL to BVFCL Namrup	**4**	66.71	64.74	64.74	**0.02068**	138.67	138.67	138.67
	12.5	33.05	31.88	31.88	**0.1379**	35.91	35.91	35.91
	37.5	NR	NR	NR	**0.2068**	27.78	27.78	27.78

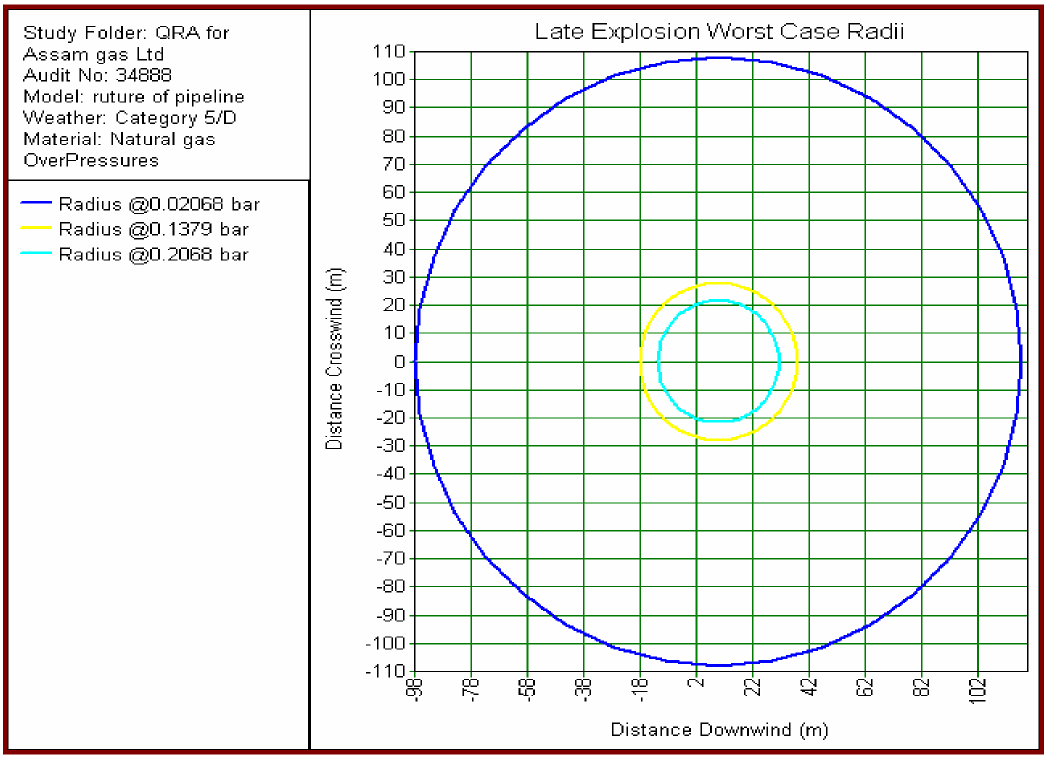
Maximum credible loss Scenario (MCLS): Leakage due to Flange failure or Hose Failure

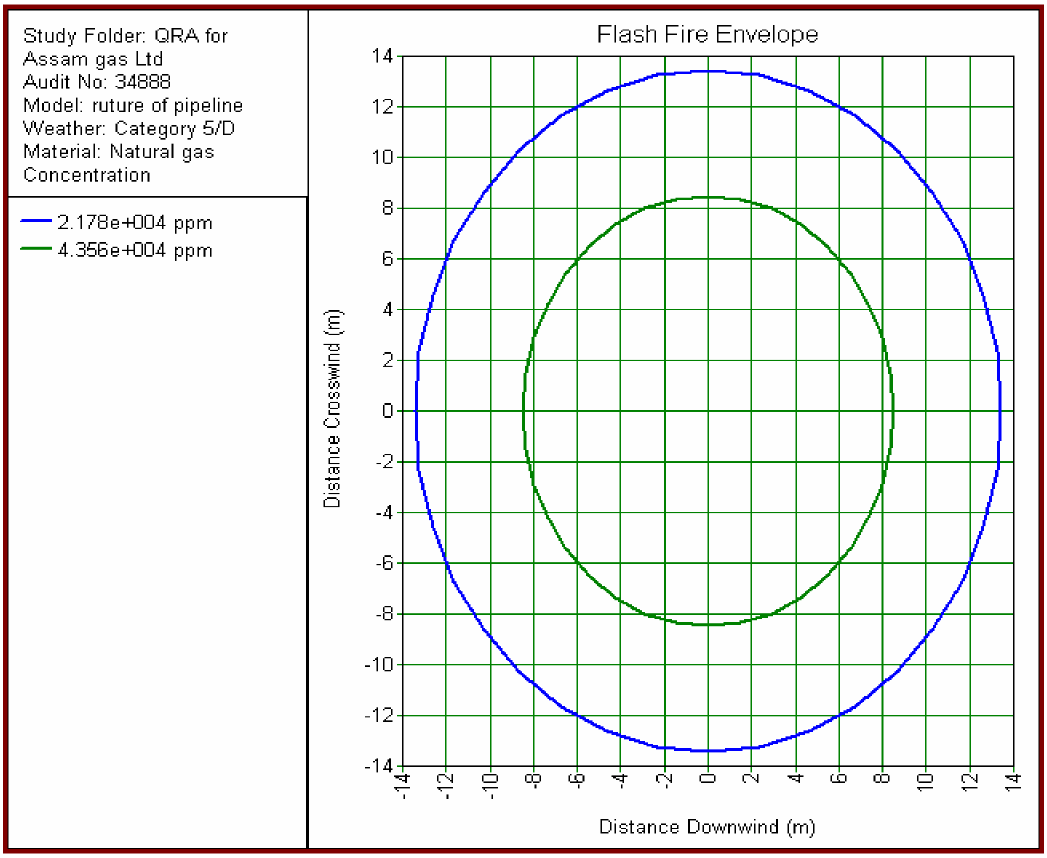
Scenario details	CONCENTRATION AT DISTANCE (M)				
	Concentration in PPM		WEATHER CATEGORY		
			3F	7D	5D
Rupture in buried pipeline going from AGCL to BVFCL Namrup	UFL	164806	0.33	0.33	0.34
	LFL	43559.7	1.48	1.34	1.39
	LFL (frac)	21779.9	2.65	2.42	2.60
Rupture in buried pipeline going from AGCL to BVFCL Namrup	UFL	164806	1.92	1.88	1.91
	LFL	43559.7	7.03	5.97	6.57
	LFL (frac)	21779.9	14.32	10.58	12.04
Rupture in buried pipeline going from AGCL to BVFCL Namrup	UFL	164806	7.02	6.70	6.89
	LFL	43559.7	41.66	37.30	39.06
	LFL (frac)	21779.9	94.98	96.46	93.56

Scenario details	THERMAL DAMAGE DISTANCE BY JET FIRE				MAXIMUM DISTANCE AT OVERPRESSURE LEVEL (M)			
	RADIATION INTENSITY (KW / M2)	WEATHER CATEGORY			OVERPRESSURE (BAR)	WEATHER CATEGORY		
		3F	7D	5D		3F	7D	5D
5 mm leakage in buried pipeline	**4**	NR	NR	NR	**0.02068**	NR	NR	NR
	12.5	NR	NR	NR	**0.1379**	NR	NR	NR
	37.5	NR	NR	NR	**0.2068**	NR	NR	NR
25 mm leakage in buried pipeline	**4**	14.92	14.98	15.02	**0.02068**	24.02	22.09	23.04
	12.5	11.95	12.33	12.17	**0.1379**	13.63	13.13	13.38
	37.5	NR	NR	NR	**0.2068**	12.81	12.42	12.61
100 mm leakage in buried pipeline	**4**	66.71	64.74	64.74	**0.02068**	138.67	138.67	138.67
	12.5	33.05	31.88	31.88	**0.1379**	35.91	35.91	35.91
	37.5	NR	NR	NR	**0.2068**	27.78	27.78	27.78


Study Folder: QRA for Assam gas Ltd
Audit No: 34888
Model: rupture of pipeline
Weather: Category 5/D
Material: Natural gas
Averaging Time: Flammable(18.75 s)
Height: 0 m
Concentration
286.921 m2 @ 2.178e+0(
286.919 m2 @ 2.178e+0(
148.785 m2 @ 4.356e+0(
43.2556 m2 @ 1.648e+0(
Maximum Concentration Footprint
Cloud Width (m)
Distance Downwind (m)


Study Folder: QRA for Assam gas Ltd
Audit No: 34888
Model: rupture of pipeline
Weather: Category 5/D
Material: Natural gas
Ellipse @4 kW/m2
Ellipse @12.5 kW/m2
Intensity Radii for Fireball
Distance Crosswind (m)
Distance Downwind (m)


Study Folder: QRA for Assam gas Ltd
Audit No: 34888
Model: ruture of pipeline
Weather: Category 5/D
Material: Natural gas
OverPressures
Radius @0.02068 bar
Radius @0.1379 bar
Radius @0.2068 bar
Late Explosion Worst Case Radii
Distance Crosswind (m)
Distance Downwind (m)


Study Folder: QRA for Assam gas Ltd
Audit No: 34888
Model: ruture of pipeline
Weather: Category 5/D
Material: Natural gas
Concentration
2.178e+004 ppm
4.356e+004 ppm
Flash Fire Envelope
Distance Crosswind (m)
Distance Downwind (m)

CONSEQUENCE RESULTS – AGCL TO NAMRUP

Worst Case Scenario (WCS):-100% Catastrophic Rupture

Scenario details	CONCENTRATION AT DISTANCE (M)				
	Concentration in PPM		WEATHER CATEGORY		
			3F	7D	5D
Rupture in buried pipeline	UFL	164806	3.79	4.15	4.01
	LFL	43559.7	6.96	9.46	8.40
	LFL (frac)	21779.9	9.78	17.42	13.15

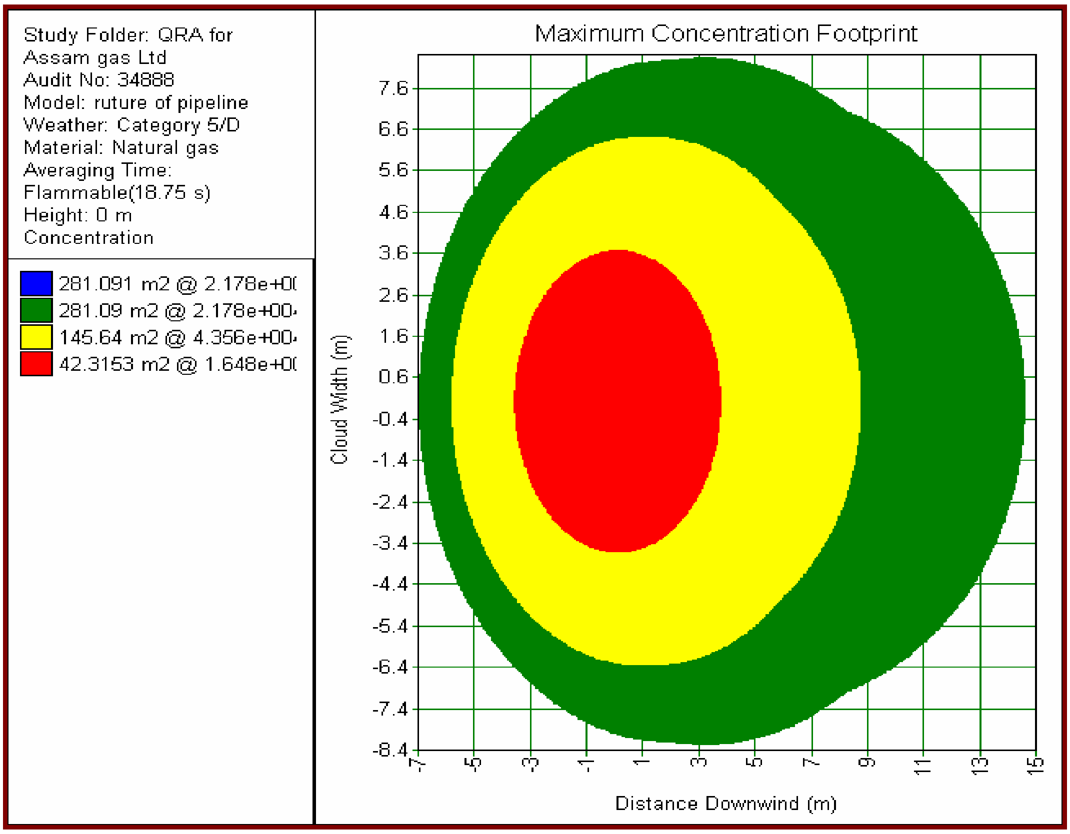
Scenario details	THERMAL DAMAGE DISTANCE BY FIRE BALL				MAXIMUM DISTANCE AT OVERPRESSURE LEVEL (M)			
	RADIATION INTENSITY (KW / M2)	WEATHER CATEGORY			OVERPRESSURE (BAR)	WEATHER CATEGORY		
		3F	7D	5D		3F	7D	5D
Rupture in buried pipeline	**4**	66.03	64.09	64.09	**0.02068**	137.34	137.34	137.34
	12.5	32.69	31.54	31.54	**0.1379**	35.56	35.56	35.56
	37.5	NR	NR	NR	**0.2068**	27.52	27.52	27.52

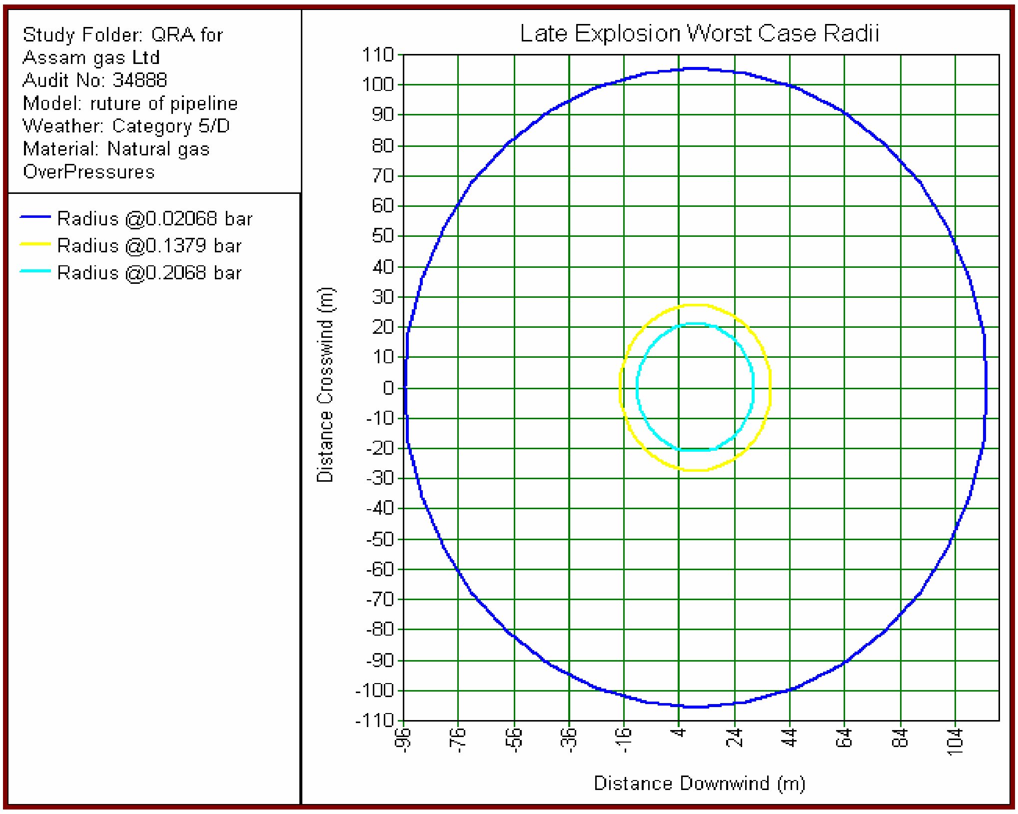
Maximum credible loss Scenario (MCLS): Leakage due to Flange failure or Hose Failure from pipeline

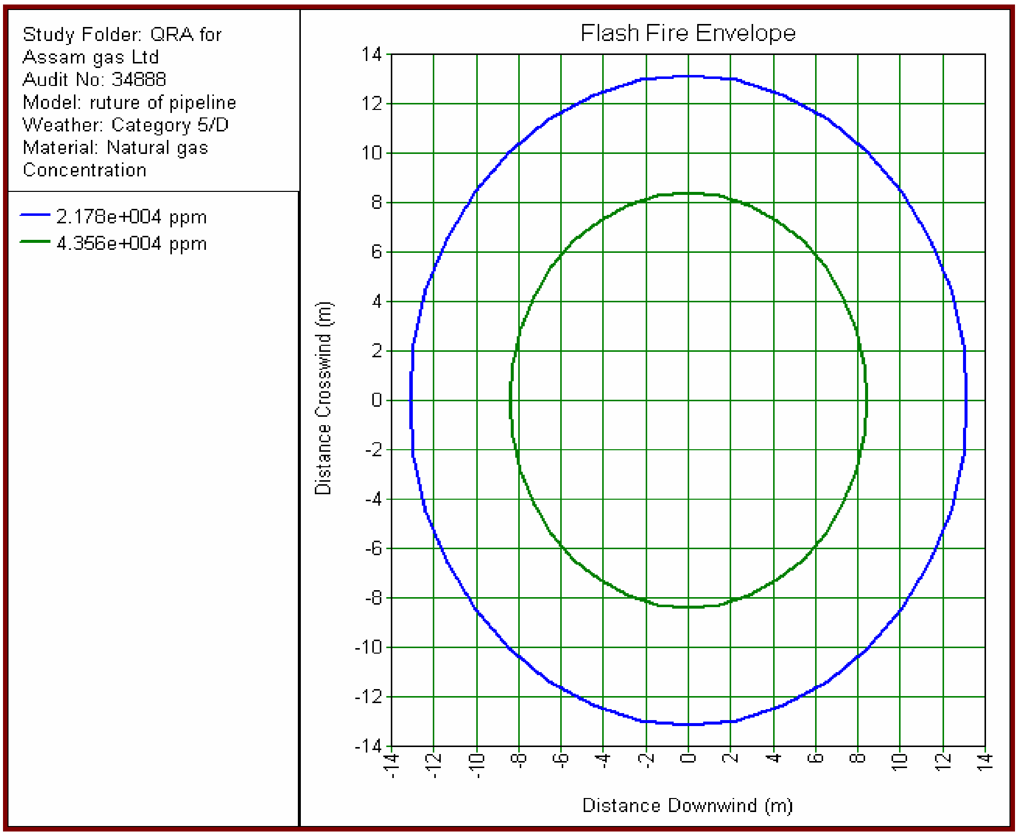
Scenario details	CONCENTRATION AT DISTANCE (M)				
	Concentration in PPM		WEATHER CATEGORY		
			3F	7D	5D
5 mm leakage in buried pipeline	UFL	164806	0.33	0.33	0.34
	LFL	43559.7	1.48	1.34	1.39
	LFL (frac)	21779.9	2.65	2.42	2.60
25 mm leakage in buried pipeline	UFL	164806	1.92	1.88	1.91
	LFL	43559.7	7.03	5.97	6.57
	LFL (frac)	21779.9	14.32	10.58	12.04
100 mm leakage in buried pipeline	UFL	164806	7.02	6.70	6.89
	LFL	43559.7	41.66	37.30	39.06
	LFL (frac)	21779.9	94.98	96.46	93.56

Scenario details	THERMAL DAMAGE DISTANCE BY JET FIRE				MAXIMUM DISTANCE AT OVERPRESSURE LEVEL (M)			
	RADIATION INTENSITY (KW / M2)	WEATHER CATEGORY			OVERPRESSURE (BAR)	WEATHER CATEGORY		
		3F	7D	5D		3F	7D	5D
5 mm leakage in buried pipeline	**4**	NR	NR	NR	**0.02068**	NR	NR	NR
	12.5	NR	NR	NR	**0.1379**	NR	NR	NR
	37.5	NR	NR	NR	**0.2068**	NR	NR	NR
25 mm leakage in buried pipeline	**4**	14.92	14.98	15.02	**0.02068**	24.02	22.09	23.04
	12.5	11.95	12.33	12.17	**0.1379**	13.63	13.13	13.38
	37.5	NR	NR	NR	**0.2068**	12.81	12.42	12.61
100 mm leakage in	**4**	66.03	64.09	64.09	**0.02068**	137.34	137.34	137.34

buried pipeline	**12.5**	32.69	31.54	31.54	**0.1379**	35.56	35.56	35.56
	37.5	NR	NR	NR	**0.2068**	27.52	27.52	27.52




Study Folder: QRA for Assam gas Ltd
Audit No: 34888
Model: ruture of pipeline
Weather: Category 5/D
Material: Natural gas
OverPressures
Radius @0.02068 bar
Radius @0.1379 bar
Radius @0.2068 bar
Late Explosion Worst Case Radii
Distance Crosswind (m)
Distance Downwind (m)


Study Folder: QRA for Assam gas Ltd
Audit No: 34888
Model: ruture of pipeline
Weather: Category 5/D
Material: Natural gas
Concentration
2.178e+004 ppm
4.356e+004 ppm
Flash Fire Envelope
Distance Crosswind (m)
Distance Downwind (m)

CONSEQUENCE RESULTS – DILIAJNAN TO DIBRUGARH

Worst Case Scenario (WCS):-100% Catastrophic Rupture

Scenario details	CONCENTRATION AT DISTANCE (M)				
	Concentration in PPM		WEATHER CATEGORY		
			3F	7D	5D
Rupture in buried pipeline	UFL	164806	3.63	3.96	3.83
	LFL	43559.7	6.62	9.03	8.06
	LFL (frac)	21779.9	9.33	15.49	12.33

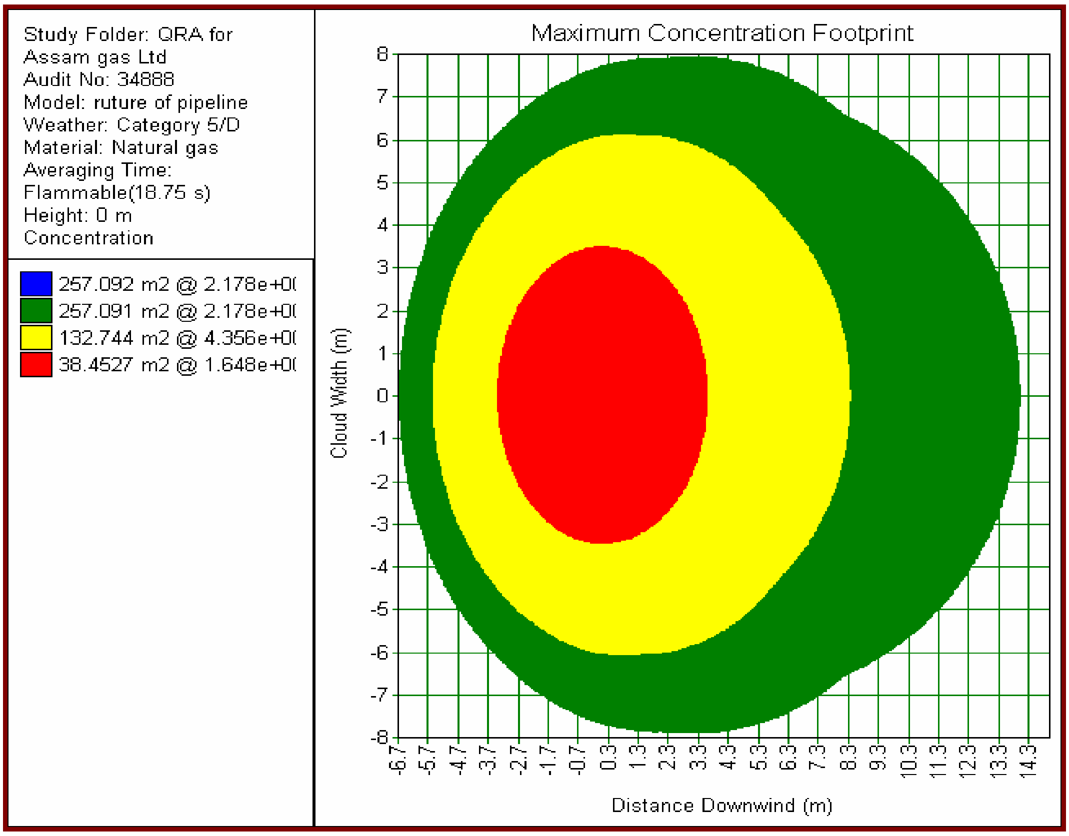
Scenario details	THERMAL DAMAGE DISTANCE BY FIRE BALL				MAXIMUM DISTANCE AT OVERPRESSURE LEVEL (M)			
	RADIATION INTENSITY (KW / M2)	WEATHER CATEGORY			OVERPRESSURE (BAR)	WEATHER CATEGORY		
		3F	7D	5D		3F	7D	5D
Rupture in buried pipeline	**4**	63.17	61.331	61.331	**0.02068**	131.73	131.73	131.73
	12.5	31.22	30.128	30.128	**0.1379**	34.11	34.11	34.11
	37.5	NR	NR	NR	**0.2068**	26.39	26.39	26.39

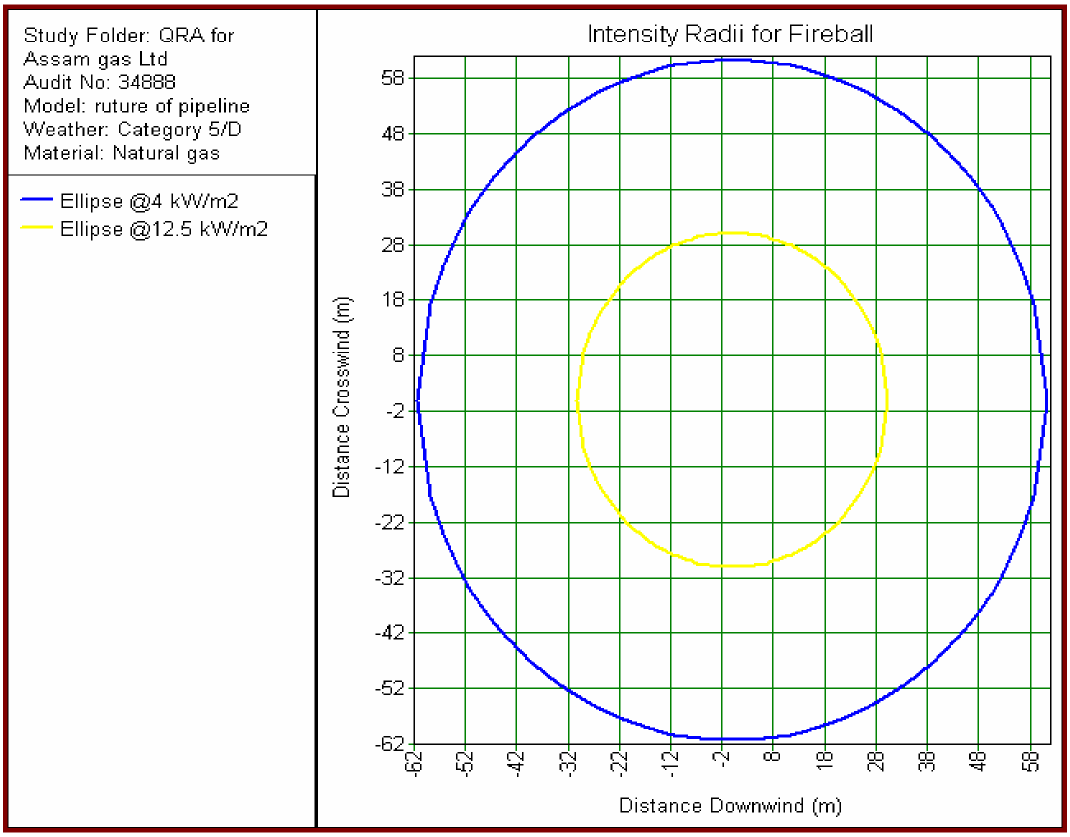
Maximum credible loss Scenario (MCLS): Leakage due to Flange failure or Hose Failure

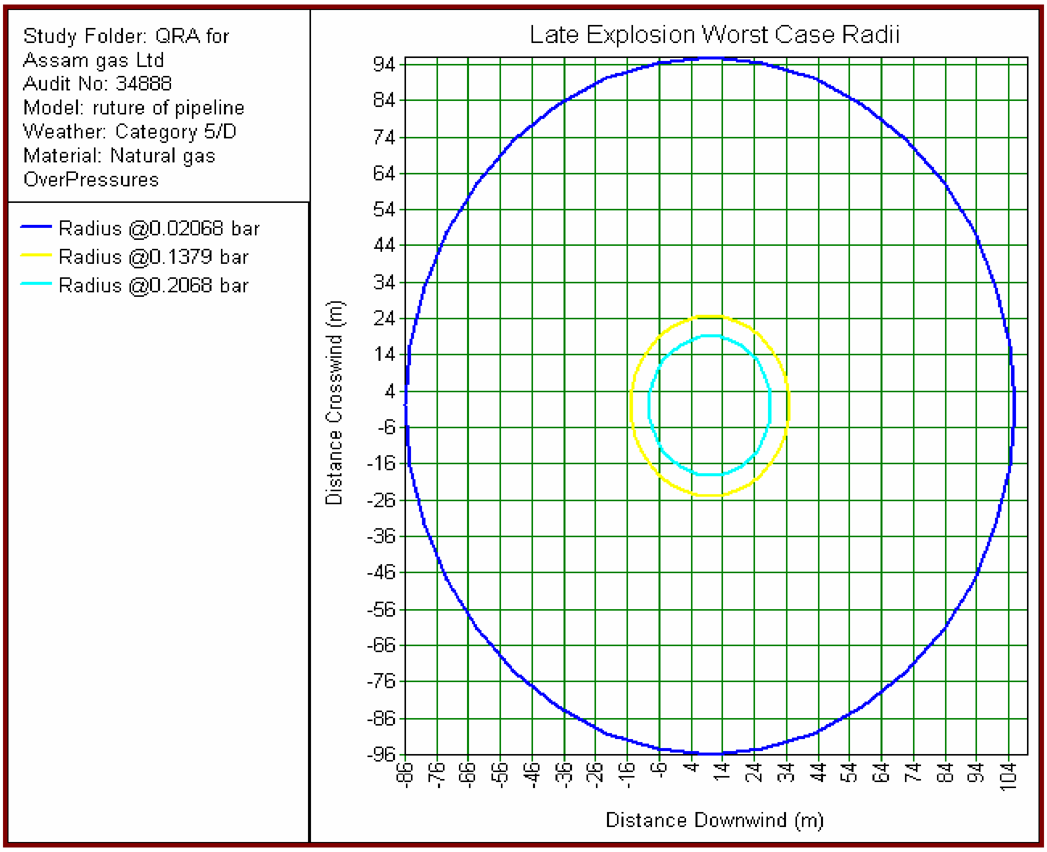
Scenario details	CONCENTRATION AT DISTANCE (M)				
	Concentration in PPM		WEATHER CATEGORY		
			3F	7D	5D
5 mm leakage in buried pipeline	UFL	164806	0.33	0.33	0.34
	LFL	43559.7	1.48	1.34	1.39
	LFL (frac)	21779.9	2.65	2.42	2.60
25 mm leakage in buried pipeline	UFL	164806	1.92	1.88	1.91
	LFL	43559.7	7.03	5.97	6.57
	LFL (frac)	21779.9	14.32	10.58	12.04
100 mm leakage in buried pipeline	UFL	164806	7.02	6.70	6.89
	LFL	43559.7	41.66	37.30	39.06
	LFL (frac)	21779.9	94.98	96.46	93.56

Scenario details	THERMAL DAMAGE DISTANCE BY JET FIRE				MAXIMUM DISTANCE AT OVERPRESSURE LEVEL (M)			
	RADIATION INTENSITY (KW / M2)	WEATHER CATEGORY			OVERPRESSURE (BAR)	WEATHER CATEGORY		
		3F	7D	5D		3F	7D	5D
5 mm leakage in buried pipeline	**4**	NR	NR	NR	**0.02068**	NR	NR	NR
	12.5	NR	NR	NR	**0.1379**	NR	NR	NR
	37.5	NR	NR	NR	**0.2068**	NR	NR	NR
25 mm leakage in buried pipeline	**4**	14.92	14.98	15.02	**0.02068**	24.02	22.09	23.04
	12.5	11.95	12.33	12.17	**0.1379**	13.63	13.13	13.38
	37.5	NR	NR	NR	**0.2068**	12.81	12.42	12.61
100 mm	**4**	63.17	61.33	61.33	**0.02068**	131.73	131.73	131.73

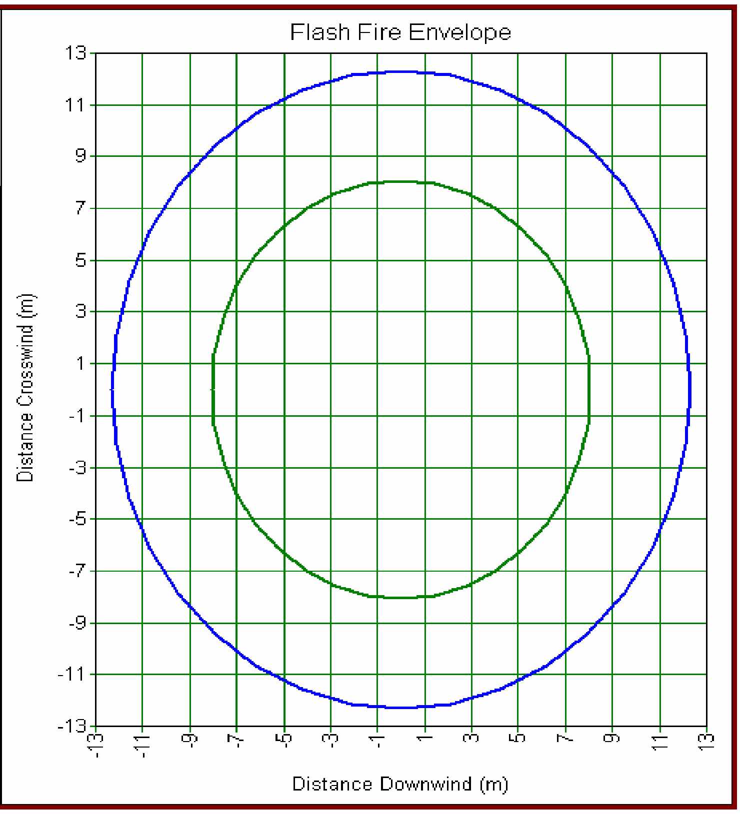
leakage in buried pipeline	**12.5**	31.22	30.13	30.13	**0.1379**	34.11	34.11	34.11
	37.5	NR	NR	NR	**0.2068**	26.39	26.39	26.39




Study Folder: QRA for Assam gas Ltd
Audit No: 34888
Model: ruture of pipeline
Weather: Category 5/D
Material: Natural gas
Ellipse @4 kW/m2
Ellipse @12.5 kW/m2
Intensity Radii for Fireball
Distance Crosswind (m)
Distance Downwind (m)
58
48
38
28
18
8
-2
-12
-22
-32
-42
-52
-62


Study Folder: QRA for Assam gas Ltd
Audit No: 34888
Model: ruture of pipeline
Weather: Category 5/D
Material: Natural gas
OverPressures
Radius @0.02068 bar
Radius @0.1379 bar
Radius @0.2068 bar
Late Explosion Worst Case Radii
Distance Crosswind (m)
Distance Downwind (m)
94
84
74
64
54
44
34
24
14
4
-6
-16
-26
-36
-46
-56
-66
-76
-86
-96
104

Study Folder: QRA for Assam gas Ltd
Audit No: 34888
Model: ruture of pipeline
Weather: Category 5/D
Material: Natural gas
Concentration



CONSEQUENCE RESULTS – KATHALGURI OCS OF OIL TO NEEPCO

Worst Case Scenario (WCS):-100% Catastrophic Rupture

Scenario details	CONCENTRATION AT DISTANCE (M)				
	Concentration in PPM		WEATHER CATEGORY		
			3F	7D	5D
Rupture in buried pipeline	UFL	164806	4.30	4.72	4.58
	LFL	43559.7	7.96	11.38	9.42
	LFL (frac)	21779.9	11.12	20.25	15.92

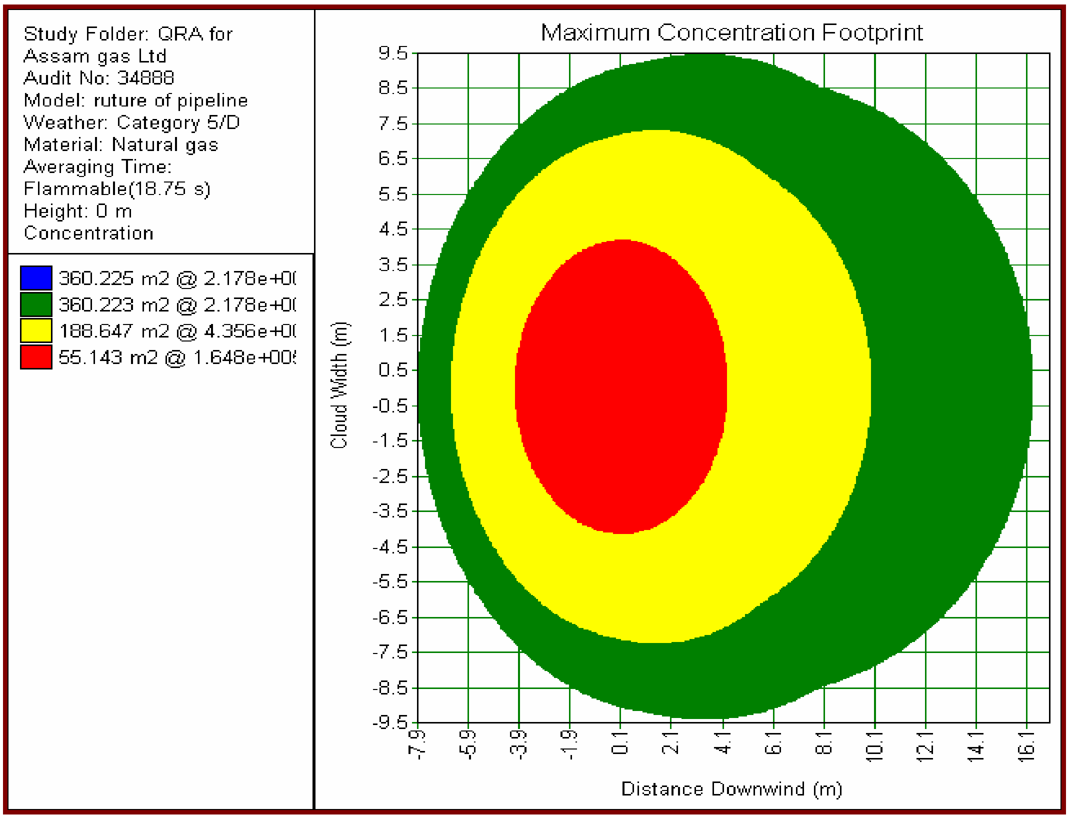
Scenario details	THERMAL DAMAGE DISTANCE BY FIRE BALL				MAXIMUM DISTANCE AT OVERPRESSURE LEVEL (M)			
	RADIATION INTENSITY (KW / M2)	WEATHER CATEGORY			OVERPRESSURE (BAR)	WEATHER CATEGORY		
		3F	7D	5D		3F	7D	5D
Rupture in buried pipeline	**4**	74.851	72.591	72.591	**0.02068**	154.60	154.60	154.60
	12.5	37.259	35.923	35.923	**0.1379**	40.03	40.03	40.03
	37.5	NR	NR	NR	**0.2068**	30.97	30.97	30.97

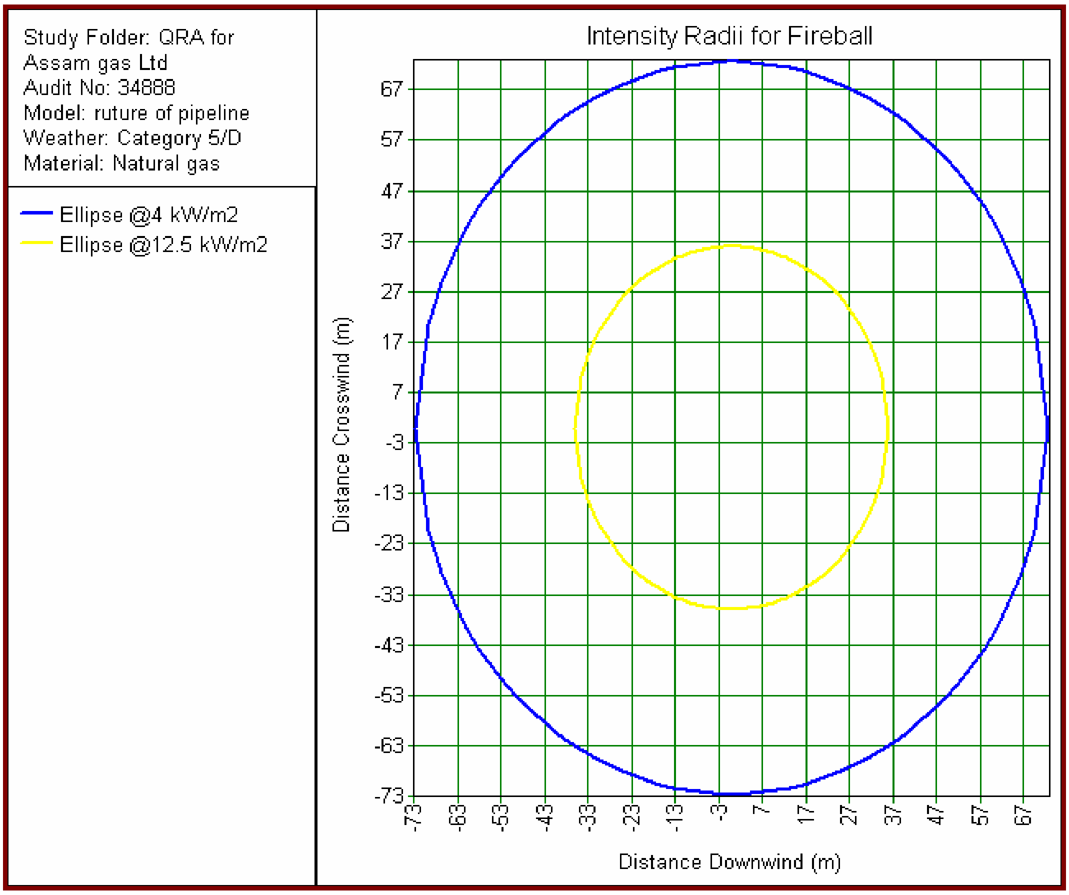
Maximum credible loss Scenario (MCLS): Leakage due to Flange failure or Hose Failure

Scenario details	CONCENTRATION AT DISTANCE (M)				
	Concentration in PPM		WEATHER CATEGORY		
			3F	7D	5D
5 mm leakage in buried pipeline	UFL	164806	0.33	0.33	0.34
	LFL	43559.7	1.48	1.34	1.39
	LFL (frac)	21779.9	2.65	2.42	2.60
25 mm leakage in buried pipeline	UFL	164806	1.92	1.88	1.91
	LFL	43559.7	7.03	5.97	6.57
	LFL (frac)	21779.9	14.32	10.58	12.04
100 mm leakage in buried pipeline	UFL	164806	7.02	6.70	6.89
	LFL	43559.7	41.66	37.30	39.06
	LFL (frac)	21779.9	94.98	96.46	93.56

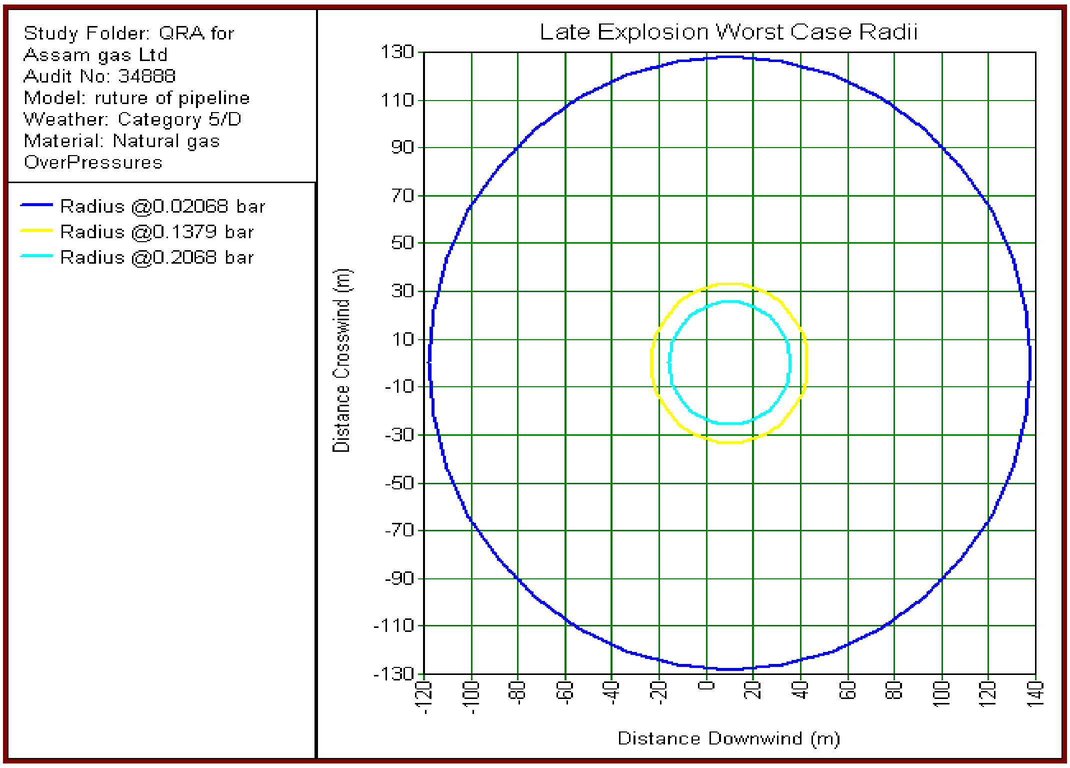
Scenario details	THERMAL DAMAGE DISTANCE BY JET FIRE				MAXIMUM DISTANCE AT OVERPRESSURE LEVEL (M)			
	RADIATION INTENSITY (KW / M2)	WEATHER CATEGORY			OVERPRESSURE (BAR)	WEATHER CATEGORY		
		3F	7D	5D		3F	7D	5D
5 mm leakage in buried pipeline	**4**	NR	NR	NR	**0.02068**	NR	NR	NR
	12.5	NR	NR	NR	**0.1379**	NR	NR	NR
	37.5	NR	NR	NR	**0.2068**	NR	NR	NR
25 mm leakage in buried pipeline	**4**	14.92	14.98	15.02	**0.02068**	24.02	22.09	23.04
	12.5	11.95	12.33	12.17	**0.1379**	13.63	13.13	13.38
	37.5	NR	NR	NR	**0.2068**	12.81	12.42	12.61

100 mm leakage in buried pipeline	**4**	74.85	72.59	72.59	**0.02068**	154.60	154.60	154.60
	12.5	37.26	35.92	35.92	**0.1379**	40.03	40.03	40.03
	37.5	NR	NR	NR	**0.2068**	30.97	30.97	30.97

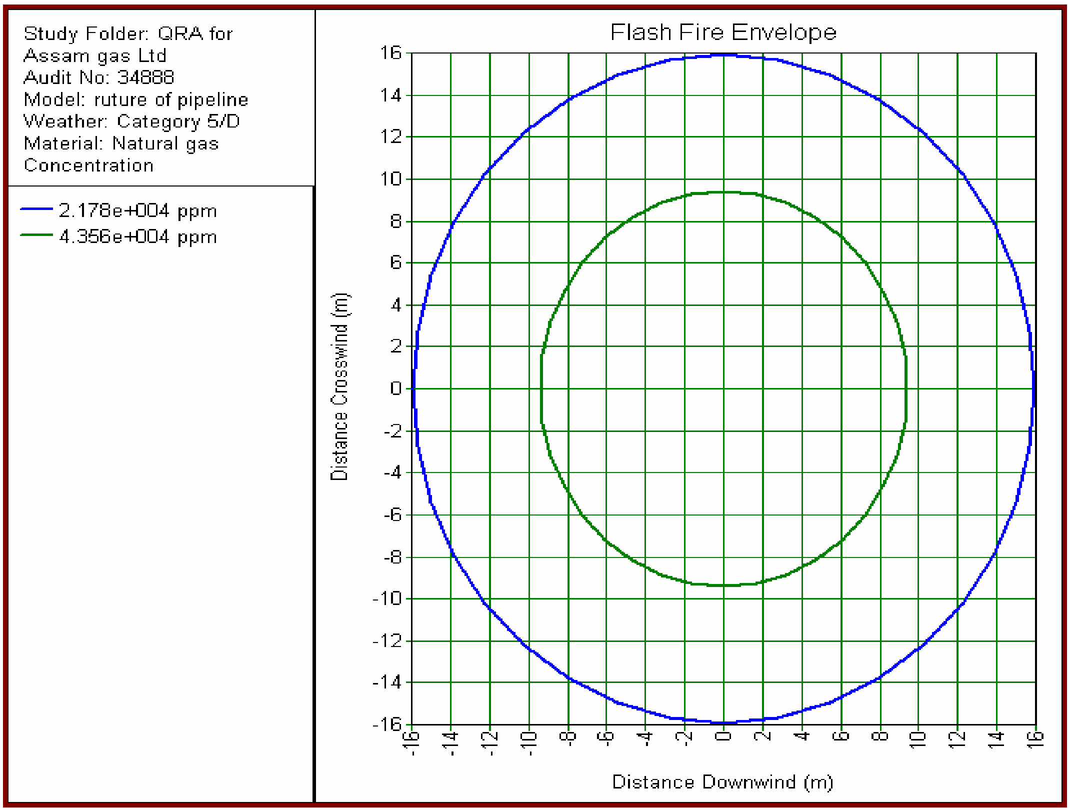




Study Folder: QRA for Assam gas Ltd
Audit No: 34888
Model: ruture of pipeline
Weather: Category 5/D
Material: Natural gas
Ellipse @4 kW/m2
Ellipse @12.5 kW/m2
Intensity Radii for Fireball
Distance Crosswind (m)
67
57
47
37
27
17
7
-3
-13
-23
-33
-43
-53
-63
-73
-73
-63
-53
-43
-33
-23
-13
-3
7
17
27
37
47
57
67
Distance Downwind (m)



Study Folder: QRA for Assam gas Ltd
Audit No: 34888
Model: ruture of pipeline
Weather: Category 5/D
Material: Natural gas
OverPressures
Radius @0.02068 bar
Radius @0.1379 bar
Radius @0.2068 bar
Late Explosion Worst Case Radii
Distance Crosswind (m)
130
110
90
70
50
30
10
-10
-30
-50
-70
-90
-110
-130
-120
-100
-80
-60
-40
-20
0
20
40
60
80
100
120
140
Distance Downwind (m)


Study Folder: QRA for Assam gas Ltd
Audit No: 34888
Model: ruture of pipeline
Weather: Category 5/D
Material: Natural gas
Concentration
2.178e+004 ppm
4.356e+004 ppm
Flash Fire Envelope
Distance Crosswind (m)
Distance Downwind (m)
16
14
12
10
8
6
4
2
0
-2
-4
-6
-8
-10
-12
-14
-16

CONSEQUENCE RESULTS – KUSIJAN TO DOOMDOOMA

Worst Case Scenario (WCS):-100% Catastrophic Rupture

Scenario details	CONCENTRATION AT DISTANCE (M)				
	Concentration in PPM		WEATHER CATEGORY		
			3F	7D	5D
Rupture in buried pipeline	UFL	164806	3.42	3.73	3.59
	LFL	43559.7	6.20	8.59	7.63
	LFL (frac)	21779.9	8.77	14.37	11.77

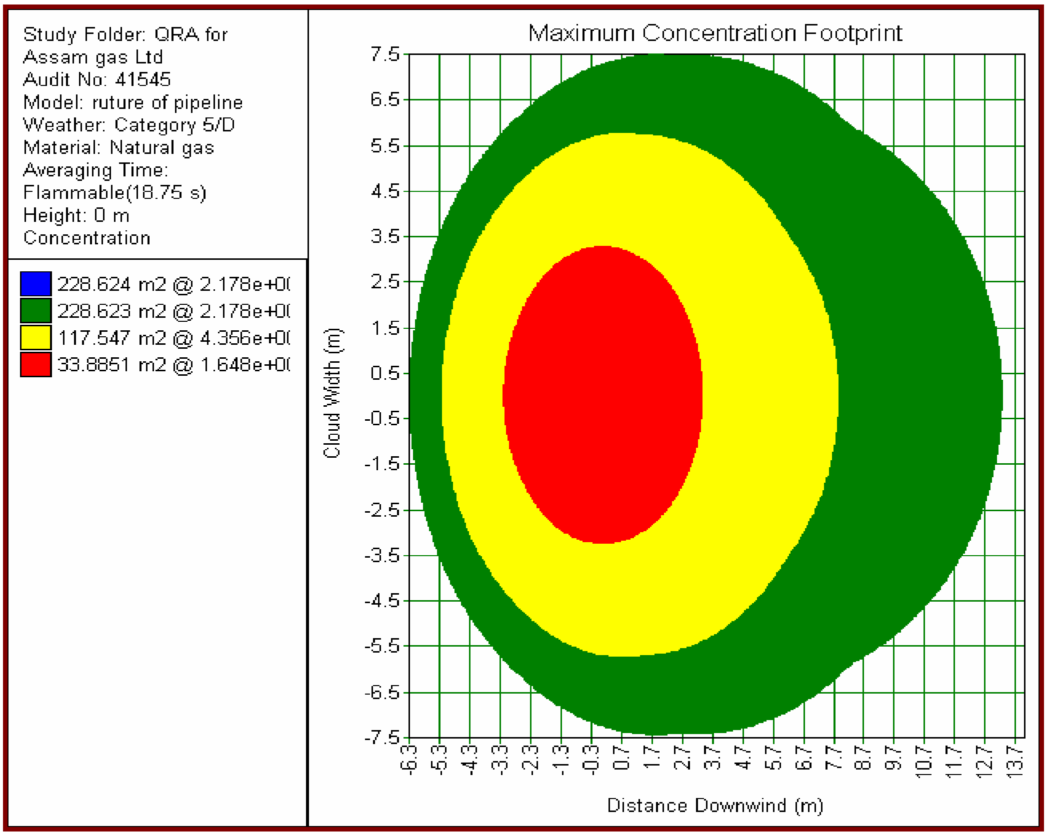
Scenario details	THERMAL DAMAGE DISTANCE BY FIRE BALL				MAXIMUM DISTANCE AT OVERPRESSURE LEVEL (M)			
	RADIATION INTENSITY (KW / M2)	WEATHER CATEGORY			OVERPRESSURE (BAR)	WEATHER CATEGORY		
		3F	7D	5D		3F	7D	5D
Rupture in buried pipeline	**4**	59.64	57.92	57.92	**0.02068**	124.78	124.78	124.78
	12.5	29.40	28.38	28.38	**0.1379**	32.309	32.309	32.309
	37.5	NR	NR	NR	**0.2068**	25	25	25

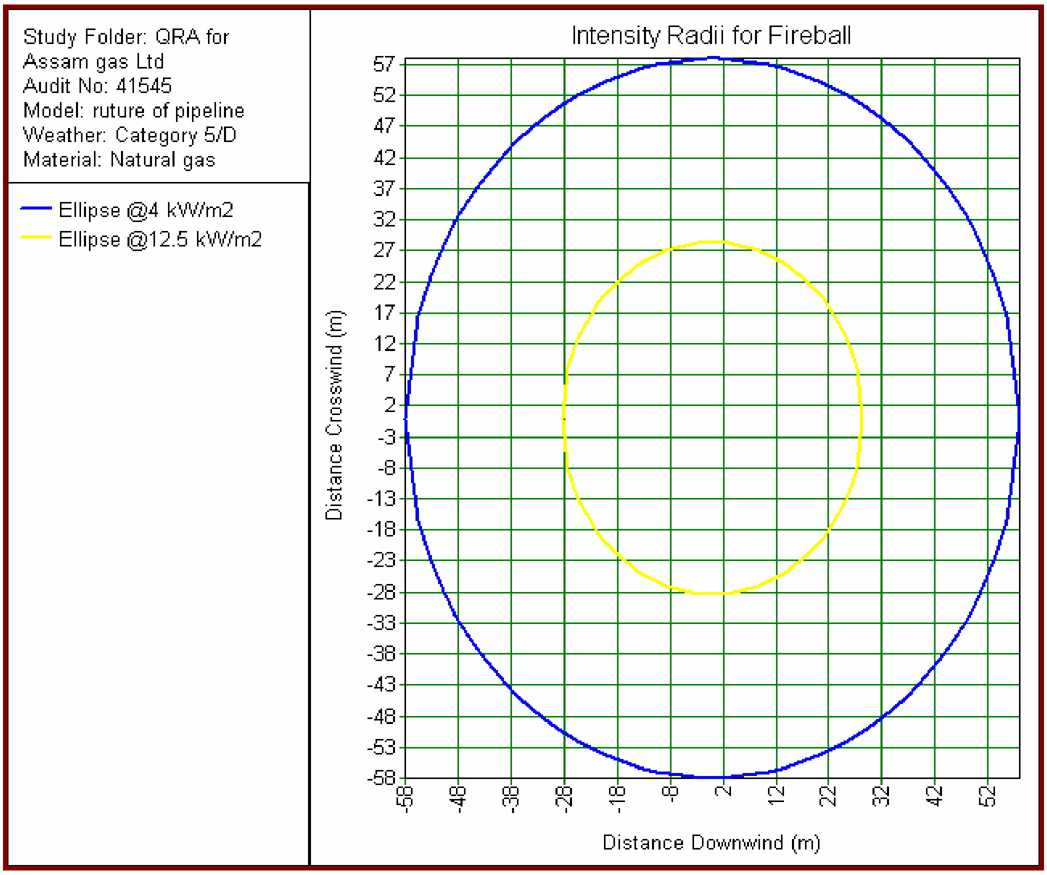
Maximum credible loss Scenario (MCLS): Leakage due to Flange failure or Hose Failure

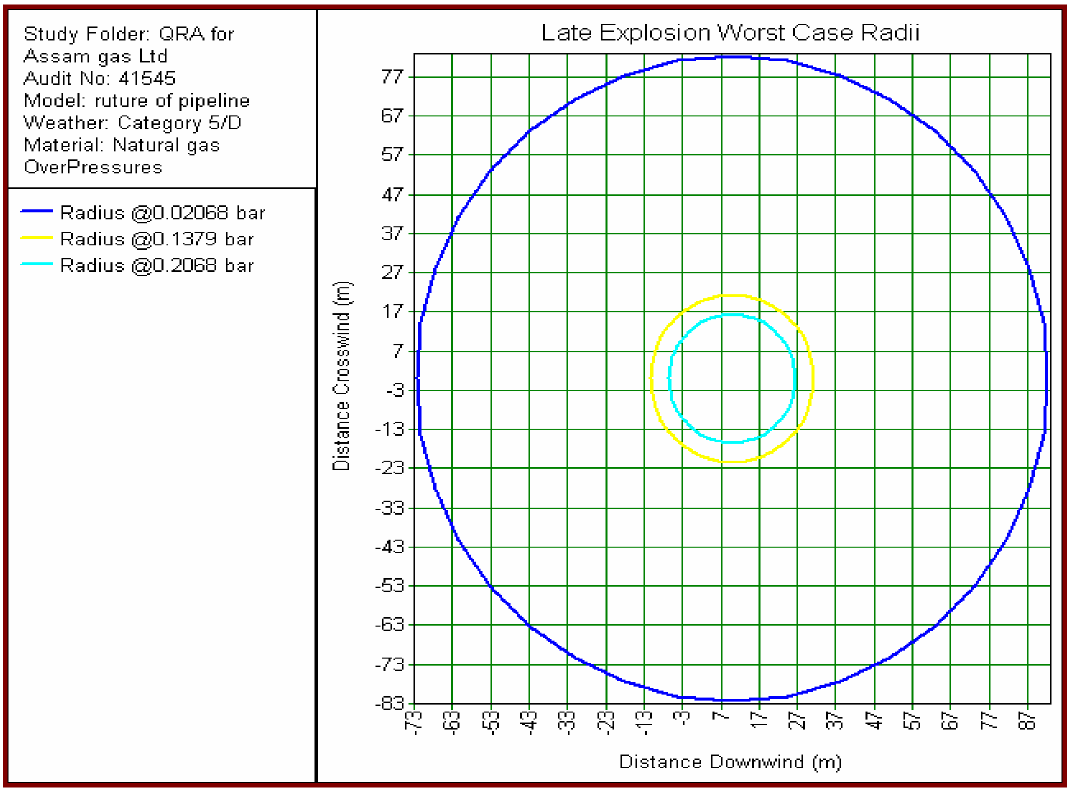
Scenario details	CONCENTRATION AT DISTANCE (M)				
	Concentration in PPM		WEATHER CATEGORY		
			3F	7D	5D
5 mm leakage in buried pipeline	UFL	164806	0.33	0.33	0.34
	LFL	43559.7	1.48	1.34	1.39
	LFL (frac)	21779.9	2.65	2.42	2.60
25 mm leakage in buried pipeline	UFL	164806	1.92	1.88	1.91
	LFL	43559.7	7.03	5.97	6.57
	LFL (frac)	21779.9	14.32	10.58	12.04
100 mm leakage in buried pipeline	UFL	164806	7.02	6.70	6.89
	LFL	43559.7	41.66	37.30	39.06
	LFL (frac)	21779.9	94.98	96.46	93.56

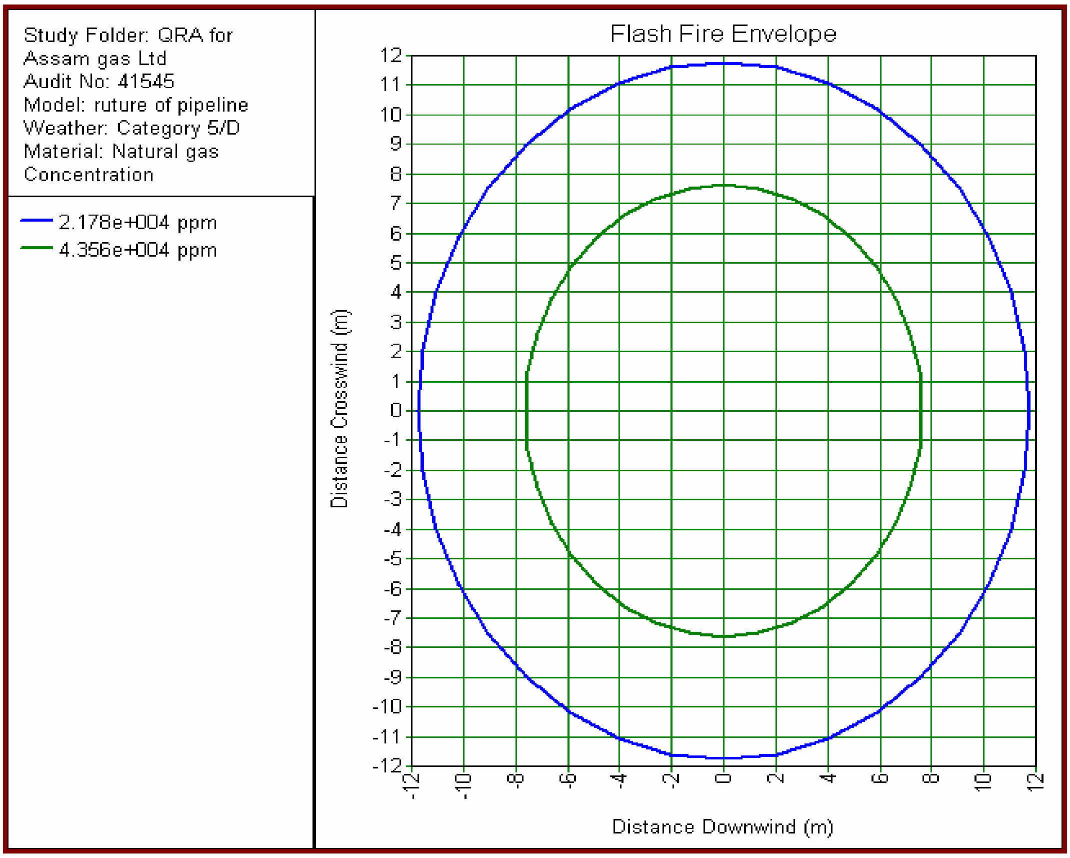
Scenario details	THERMAL DAMAGE DISTANCE BY JET FIRE				MAXIMUM DISTANCE AT OVERPRESSURE LEVEL (M)			
	RADIATION INTENSITY (KW / M2)	WEATHER CATEGORY			OVERPRESSURE (BAR)	WEATHER CATEGORY		
		3F	7D	5D		3F	7D	5D
5 mm leakage in buried pipeline	**4**	NR	NR	NR	**0.02068**	NR	NR	NR
	12.5	NR	NR	NR	**0.1379**	NR	NR	NR
	37.5	NR	NR	NR	**0.2068**	NR	NR	NR
25 mm leakage in buried pipeline	**4**	14.92	14.98	15.02	**0.02068**	24.02	22.09	23.04
	12.5	11.95	12.33	12.17	**0.1379**	13.63	13.13	13.38
	37.5	NR	NR	NR	**0.2068**	12.81	12.42	12.61
100 mm	**4**	59.64	57.92	57.92	**0.02068**	124.78	124.78	124.78

Scenario details	THERMAL DAMAGE DISTANCE BY JET FIRE				MAXIMUM DISTANCE AT OVERPRESSURE LEVEL (M)			
	RADIATION INTENSITY (KW / M2)	WEATHER CATEGORY			OVERPRESSURE (BAR)	WEATHER CATEGORY		
		3F	7D	5D		3F	7D	5D
leakage in buried pipeline	**12.5**	29.40	28.38	28.38	**0.1379**	32.31	32.31	32.31
	37.5	NR	NR	NR	**0.2068**	25.00	25.00	25.00




Study Folder: QRA for Assam gas Ltd
Audit No: 41545
Model: ruture of pipeline
Weather: Category 5/D
Material: Natural gas
Ellipse @4 kW/m2
Ellipse @12.5 kW/m2
Intensity Radii for Fireball
Distance Crosswind (m)
Distance Downwind (m)


Study Folder: QRA for Assam gas Ltd
Audit No: 41545
Model: ruture of pipeline
Weather: Category 5/D
Material: Natural gas
OverPressures
Radius @0.02068 bar
Radius @0.1379 bar
Radius @0.2068 bar
Late Explosion Worst Case Radii
Distance Crosswind (m)
Distance Downwind (m)


Study Folder: QRA for Assam gas Ltd
Audit No: 41545
Model: ruture of pipeline
Weather: Category 5/D
Material: Natural gas
Concentration
2.178e+004 ppm
4.356e+004 ppm
Flash Fire Envelope
Distance Crosswind (m)
Distance Downwind (m)
12
11
10
9
8
7
6
5
4
3
2
1
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
-10
-11
-12
-12
-10
-8
-6
-4
-2
0
2
4
6
8
10
12

CONSEQUENCE RESULTS – LAKWA TO GOLAGHAT

Worst Case Scenario (WCS):-100% Catastrophic Rupture

Scenario details	CONCENTRATION AT DISTANCE (M)				
	Concentration in PPM		WEATHER CATEGORY		
			3F	7D	5D
Rupture in buried pipeline	UFL	164806	3.45	3.79	3.65
	LFL	43559.7	6.33	8.98	7.78
	LFL (frac)	21779.9	8.94	16.71	12.52

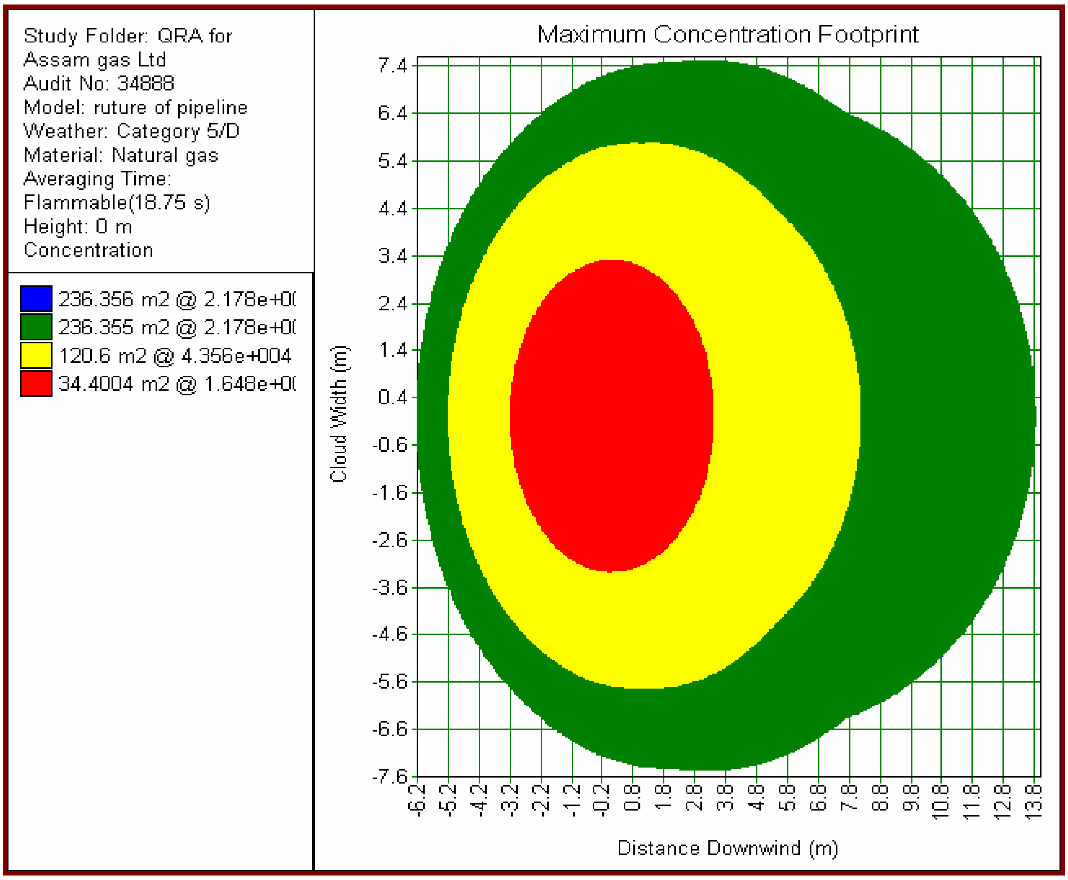
Scenario details	THERMAL DAMAGE DISTANCE BY FIRE BALL				MAXIMUM DISTANCE AT OVERPRESSURE LEVEL (M)			
	RADIATION INTENSITY (KW / M2)	WEATHER CATEGORY			OVERPRESSURE (BAR)	WEATHER CATEGORY		
		3F	7D	5D		3F	7D	5D
Rupture in buried pipeline	**4**	56.42	54.80	54.80	**0.02068**	124.78	124.78	124.78
	12.5	27.14	26.15	26.15	**0.1379**	32.31	32.31	32.31
	37.5	NR	NR	NR	**0.2068**	25.00	25.00	25.00

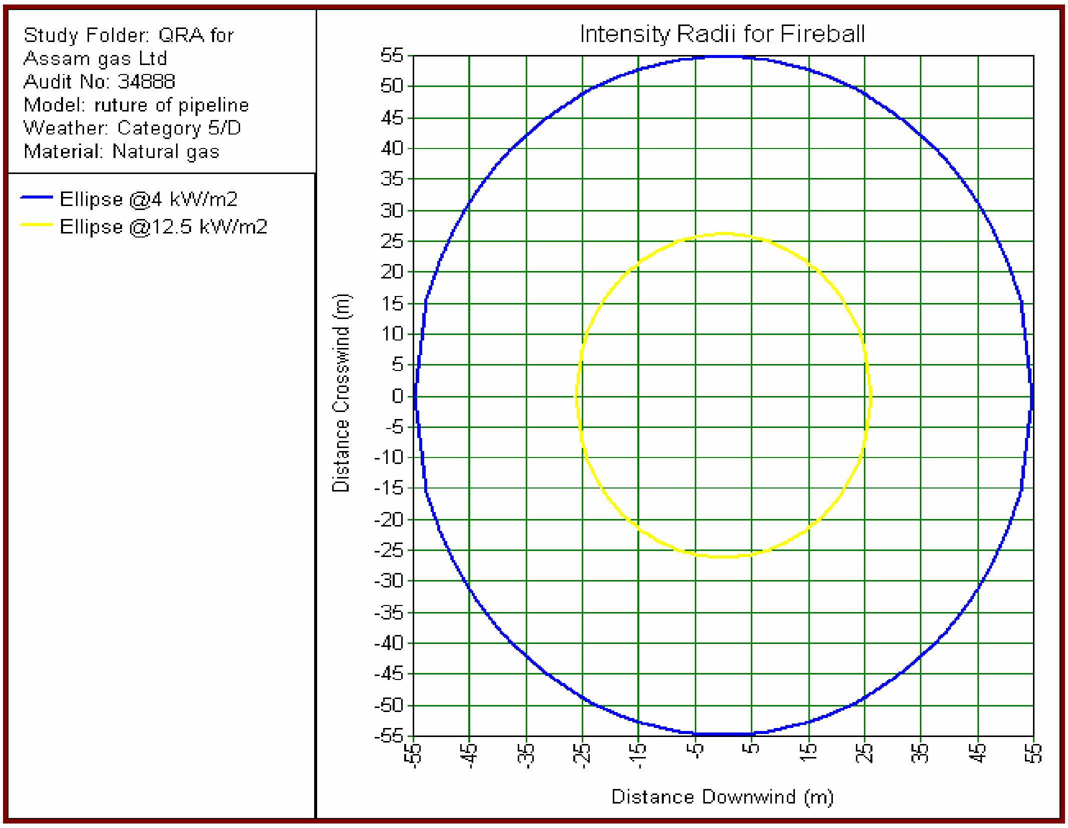
Maximum credible loss Scenario (MCLS): Leakage due to Flange failure or Hose Failure

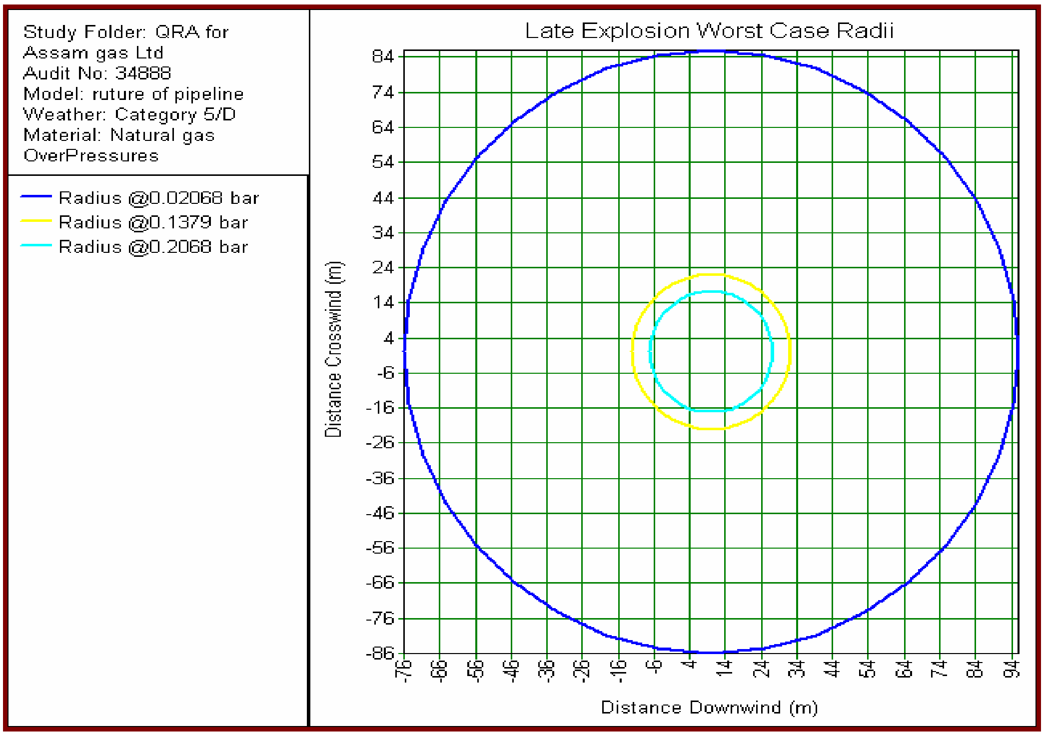
Scenario details	CONCENTRATION AT DISTANCE (M)				
	Concentration in PPM		WEATHER CATEGORY		
			3F	7D	5D
5 mm leakage in buried pipeline	UFL	164806	0.27	0.27	0.27
	LFL	43559.7	1.27	1.20	1.24
	LFL (frac)	21779.9	2.40	2.16	2.28
25 mm leakage in buried pipeline	UFL	164806	1.53	1.56	1.60
	LFL	43559.7	5.85	5.10	5.46
	LFL (frac)	21779.9	11.34	8.34	9.46
100 mm leakage in buried pipeline	UFL	164806	6.00	5.68	5.88
	LFL	43559.7	32.14	29.86	30.60
	LFL (frac)	21779.9	76.62	77.89	76.63

Scenario details	THERMAL DAMAGE DISTANCE BY JET FIRE				MAXIMUM DISTANCE AT OVERPRESSURE LEVEL (M)			
	RADIATION INTENSITY (KW / M2)	WEATHER CATEGORY			OVERPRESSURE (BAR)	WEATHER CATEGORY		
		3F	7D	5D		3F	7D	5D
5 mm leakage in buried pipeline	**4**	NR	NR	NR	**0.02068**	NR	NR	NR
	12.5	NR	NR	NR	**0.1379**	NR	NR	NR
	37.5	NR	NR	NR	**0.2068**	NR	NR	NR
25 mm leakage in buried pipeline	**4**	12.46	12.45	12.52	**0.02068**	NR	NR	NR
	12.5	9.84	10.18	10.07	**0.1379**	NR	NR	NR
	37.5	NR	NR	NR	**0.2068**	NR	NR	NR
100 mm	**4**	53.80	54.22	54.01	**0.02068**	124.78	124.78	124.78

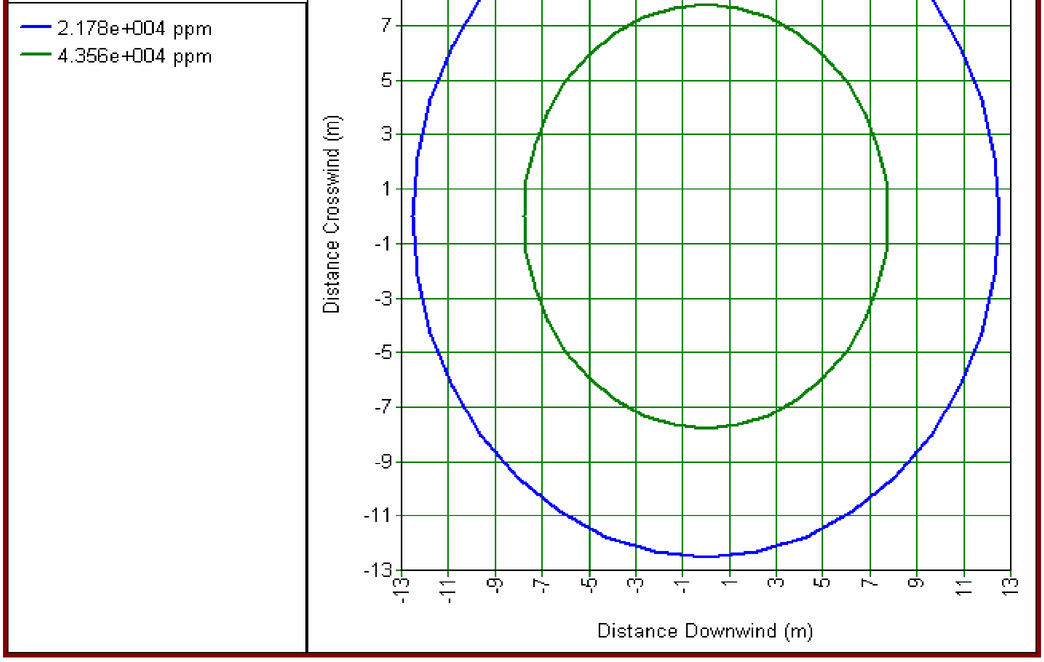
leakage in buried pipeline	**12.5**	42.44	44.91	43.75	**0.1379**	32.31	32.31	32.31
	37.5	33.81	37.08	35.67	**0.2068**	25.00	25.00	25.00




Study Folder: QRA for Assam gas Ltd
Audit No: 34888
Model: ruture of pipeline
Weather: Category 5/D
Material: Natural gas
Ellipse @4 kW/m2
Ellipse @12.5 kW/m2
Intensity Radii for Fireball
Distance Crosswind (m)
Distance Downwind (m)


Study Folder: QRA for Assam gas Ltd
Audit No: 34888
Model: ruture of pipeline
Weather: Category 5/D
Material: Natural gas
OverPressures
Radius @0.02068 bar
Radius @0.1379 bar
Radius @0.2068 bar
Late Explosion Worst Case Radii
Distance Crosswind (m)
Distance Downwind (m)

Study Folder: QRA for Assam gas Ltd
Audit No: 34888
Model: ruture of pipeline
Weather: Category 5/D
Material: Natural gas
Concentration



CONSEQUENCE RESULTS – LAKWA TO NAMRUP

Worst Case Scenario (WCS):-100% Catastrophic Rupture

Scenario details	CONCENTRATION AT DISTANCE (M)				
	Concentration in PPM		WEATHER CATEGORY		
			3F	7D	5D
Rupture in buried pipeline	UFL	164806	3.88	4.26	4.13
	LFL	43559.7	7.18	10.94	8.94
	LFL (frac)	21779.9	10.08	20.41	15.38

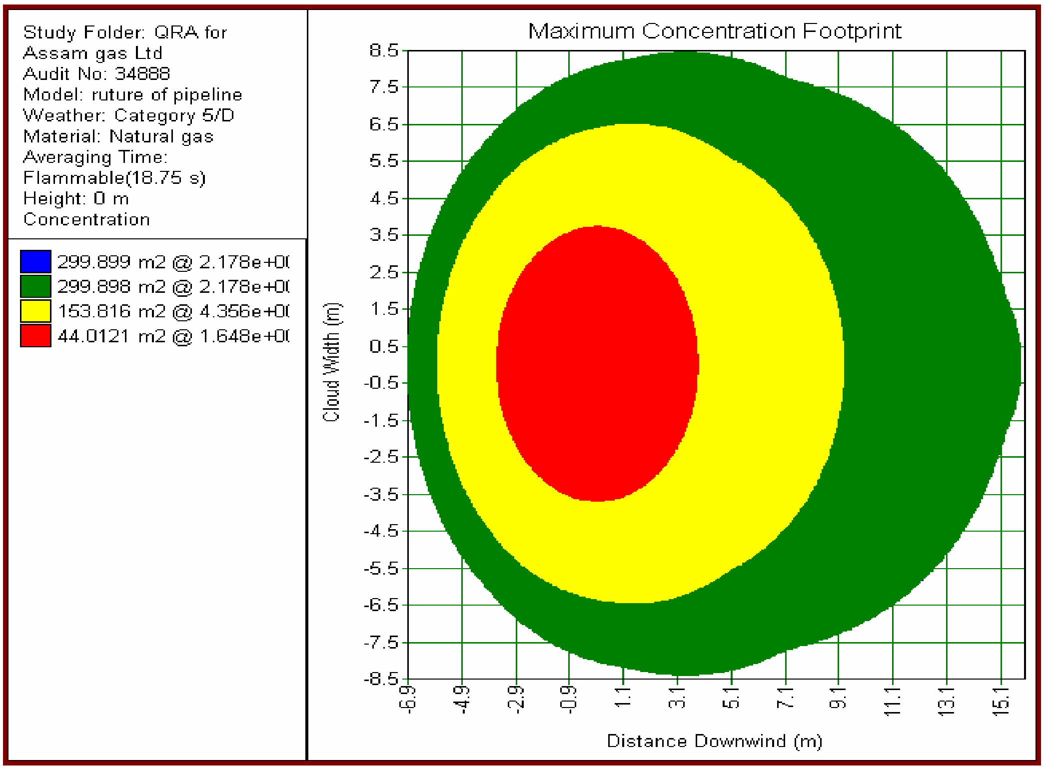
Scenario details	THERMAL DAMAGE DISTANCE BY FIRE BALL				MAXIMUM DISTANCE AT OVERPRESSURE LEVEL (M)			
	RADIATION INTENSITY (kW / m2)	WEATHER CATEGORY			OVERPRESSURE (BAR)	WEATHER CATEGORY		
		3F	7D	5D		3F	7D	5D
Rupture in buried pipeline	**4**	61.66	59.84	59.84	**0.02068**	138.67	138.67	138.67
	12.5	29.49	28.37	28.37	**0.1379**	35.91	35.91	35.91
	37.5	61.66	59.84	59.84	**0.2068**	27.78	27.78	27.78

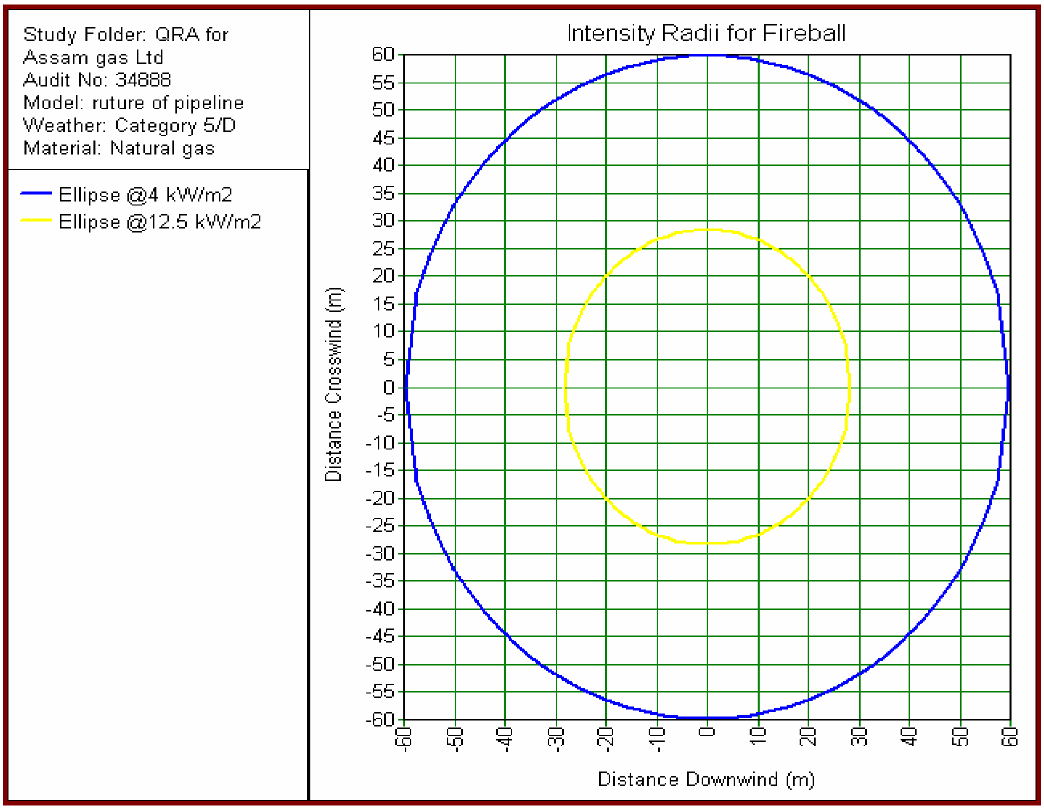
Maximum credible loss Scenario (MCLS): Leakage due to Flange failure or Hose Failure

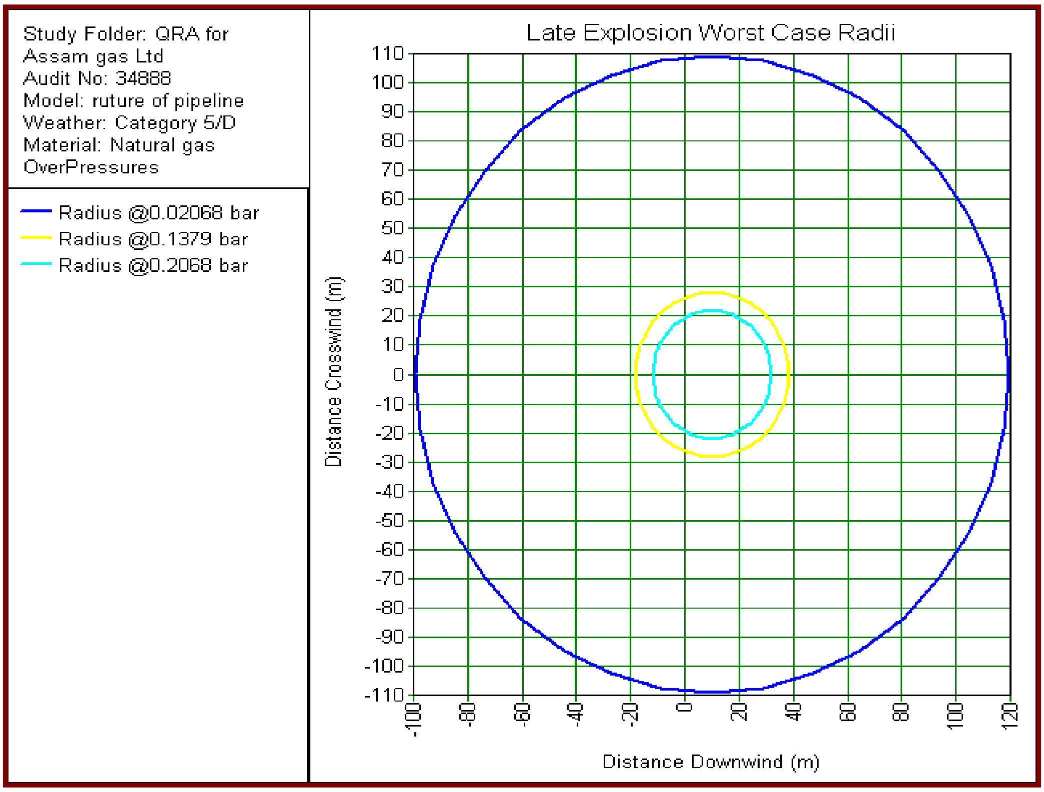
Scenario details	CONCENTRATION AT DISTANCE (M)				
	Concentration in PPM		WEATHER CATEGORY		
			3F	7D	5D
5 mm leakage in buried pipeline	UFL	164806	0.24	0.24	0.24
	LFL	43559.7	1.20	1.14	1.18
	LFL (frac)	21779.9	2.29	2.04	2.17
25 mm leakage in buried pipeline	UFL	164806	1.42	1.42	1.46
	LFL	43559.7	5.58	4.93	5.11
	LFL (frac)	21779.9	10.22	7.70	8.70
100 mm leakage in buried pipeline	UFL	164806	5.54	5.22	5.42
	LFL	43559.7	29.50	27.11	27.96
	LFL (frac)	21779.9	71.21	72.88	70.39

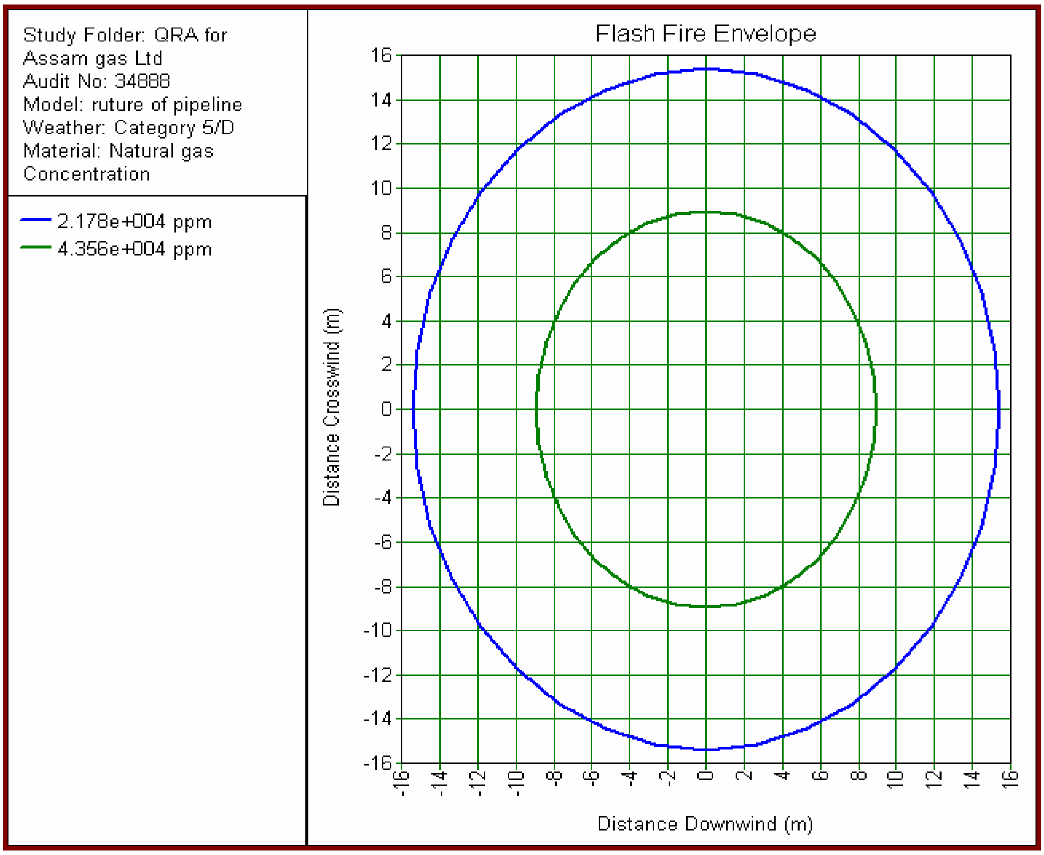
Scenario details	THERMAL DAMAGE DISTANCE BY JET FIRE				MAXIMUM DISTANCE AT OVERPRESSURE LEVEL (M)			
	RADIATION INTENSITY (KW / M2)	WEATHER CATEGORY			OVERPRESSURE (BAR)	WEATHER CATEGORY		
		3F	7D	5D		3F	7D	5D
5 mm leakage in buried pipeline	**4**	NR	NR	NR	**0.02068**	NR	NR	NR
	12.5	NR	NR	NR	**0.1379**	NR	NR	NR
	37.5	NR	NR	NR	**0.2068**	NR	NR	NR
25 mm leakage in buried pipeline	**4**	11.53	11.49	11.57	**0.02068**	NR	NR	NR
	12.5	9.11	9.36	9.30	**0.1379**	NR	NR	NR
	37.5	NR	NR	NR	**0.2068**	NR	NR	NR
100 mm	**4**	61.663	59.842	59.842	**0.02068**	138.67	138.67	138.67

leakage in buried pipeline	**12.5**	29.49	28.374	28.374	**0.1379**	35.91	35.91	35.91
	37.5	61.663	59.842	59.842	**0.2068**	27.78	27.78	27.78




Study Folder: QRA for Assam gas Ltd
Audit No: 34888
Model: ruture of pipeline
Weather: Category 5/D
Material: Natural gas
Ellipse @4 kW/m2
Ellipse @12.5 kW/m2
Intensity Radii for Fireball
Distance Crosswind (m)
Distance Downwind (m)


Study Folder: QRA for Assam gas Ltd
Audit No: 34888
Model: ruture of pipeline
Weather: Category 5/D
Material: Natural gas
OverPressures
Radius @0.02068 bar
Radius @0.1379 bar
Radius @0.2068 bar
Late Explosion Worst Case Radii
Distance Crosswind (m)
Distance Downwind (m)


Study Folder: QRA for Assam gas Ltd
Audit No: 34888
Model: ruture of pipeline
Weather: Category 5/D
Material: Natural gas
Concentration
2.178e+004 ppm
4.356e+004 ppm
Flash Fire Envelope
Distance Crosswind (m)
Distance Downwind (m)
16
14
12
10
8
6
4
2
0
-2
-4
-6
-8
-10
-12
-14
-16

CONSEQUENCE RESULTS – LPG_SEPERATION STATION TO AGCL- DULIAJAN

Worst Case Scenario (WCS):-100% Catastrophic Rupture

Scenario details	CONCENTRATION AT DISTANCE (M)				
	Concentration in PPM		WEATHER CATEGORY		
			3F	7D	5D
Rupture in buried pipeline	UFL	164806	4.98	5.40	5.26
	LFL	43559.7	9.13	13.16	11.01
	LFL (frac)	21779.9	12.68	23.99	18.41

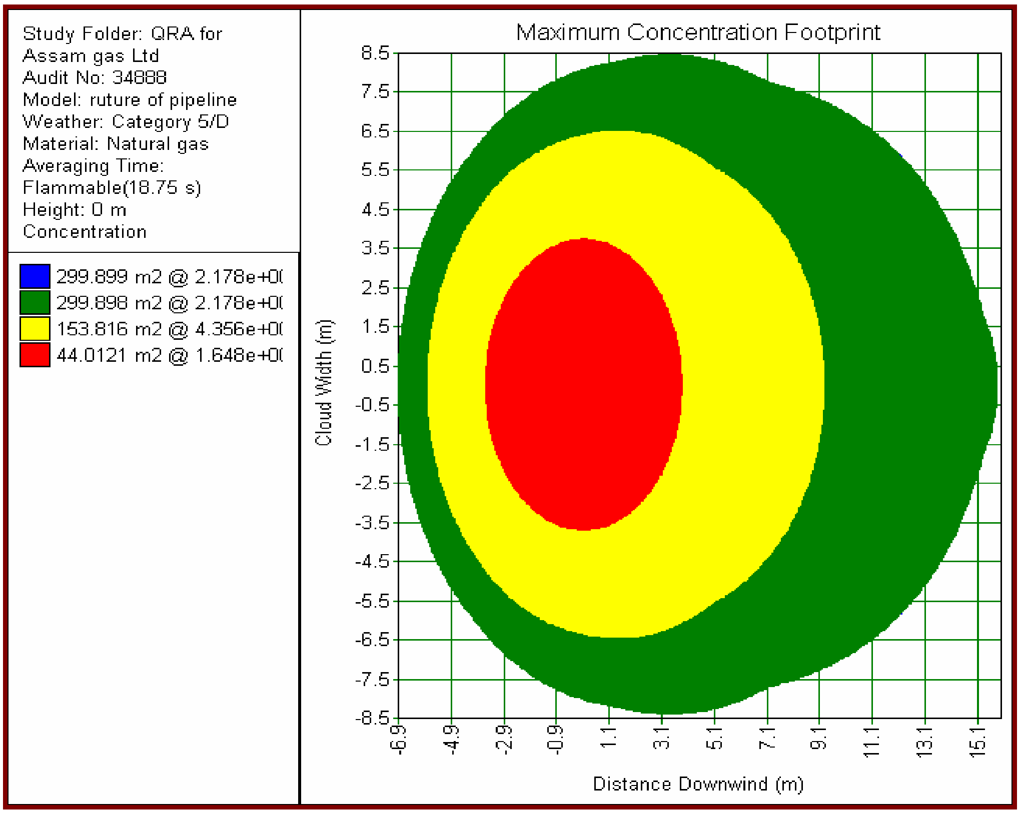
Scenario details	THERMAL DAMAGE DISTANCE BY FIRE BALL				MAXIMUM DISTANCE AT OVERPRESSURE LEVEL (M)			
	RADIATION INTENSITY (KW / M2)	WEATHER CATEGORY			OVERPRESSURE (BAR)	WEATHER CATEGORY		
		3F	7D	5D		3F	7D	5D
Rupture in buried pipeline	**4**	85.608	82.948	82.948	**0.02068**	175.55	175.55	175.55
	12.5	42.847	41.28	41.28	**0.1379**	45.45	45.45	45.45
	37.5	NR	NR	NR	**0.2068**	35.17	35.17	35.17

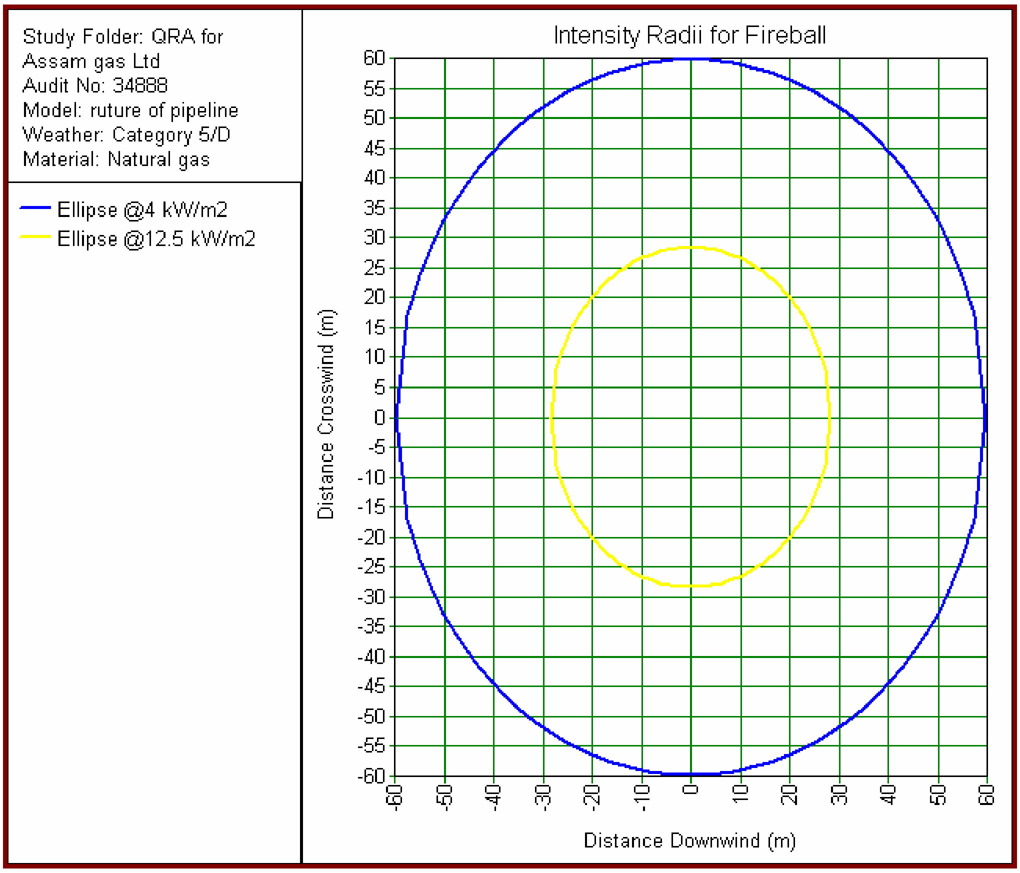
Maximum credible loss Scenario (MCLS): Leakage due to Flange failure or Hose Failure

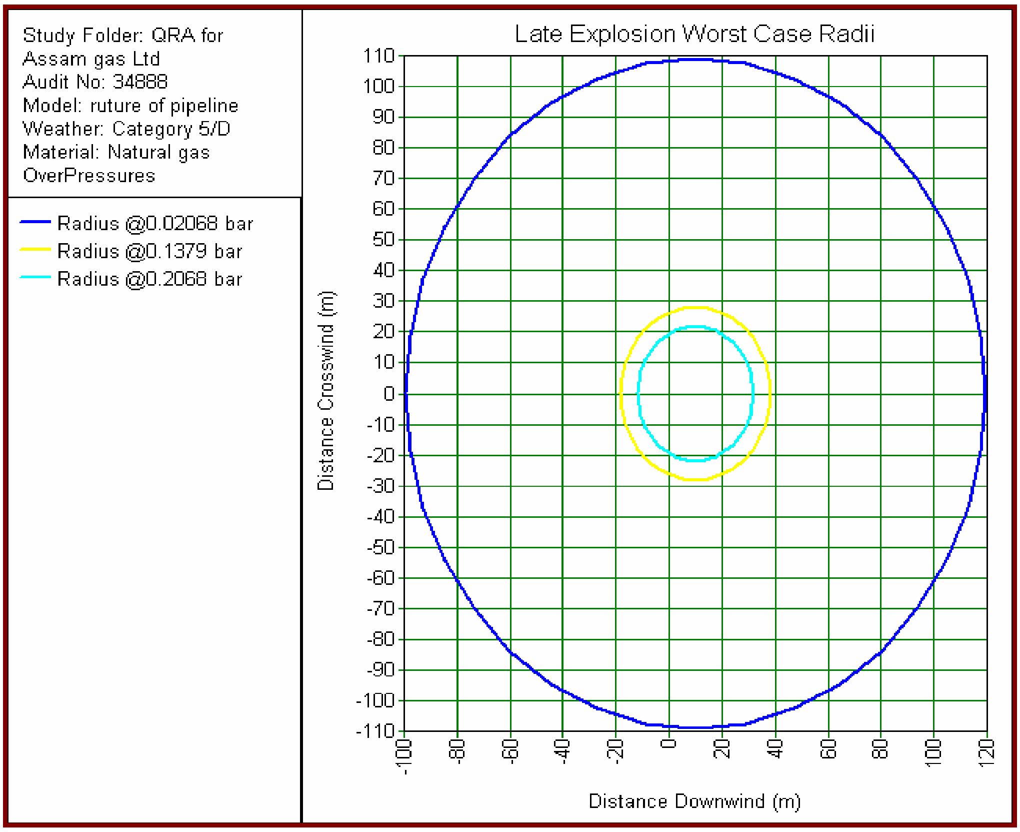
Scenario details	CONCENTRATION AT DISTANCE (M)				
	Concentration in PPM		WEATHER CATEGORY		
			3F	7D	5D
5 mm leakage in buried pipeline	UFL	164806	0.33	0.33	0.34
	LFL	43559.7	1.48	1.34	1.39
	LFL (frac)	21779.9	2.65	2.42	2.60
25 mm leakage in buried pipeline	UFL	164806	1.92	1.88	1.91
	LFL	43559.7	7.03	5.97	6.57
	LFL (frac)	21779.9	14.32	10.58	12.04
100 mm leakage in buried pipeline	UFL	164806	7.02	6.70	6.89
	LFL	43559.7	41.66	37.30	39.06
	LFL (frac)	21779.9	94.98	96.46	93.56

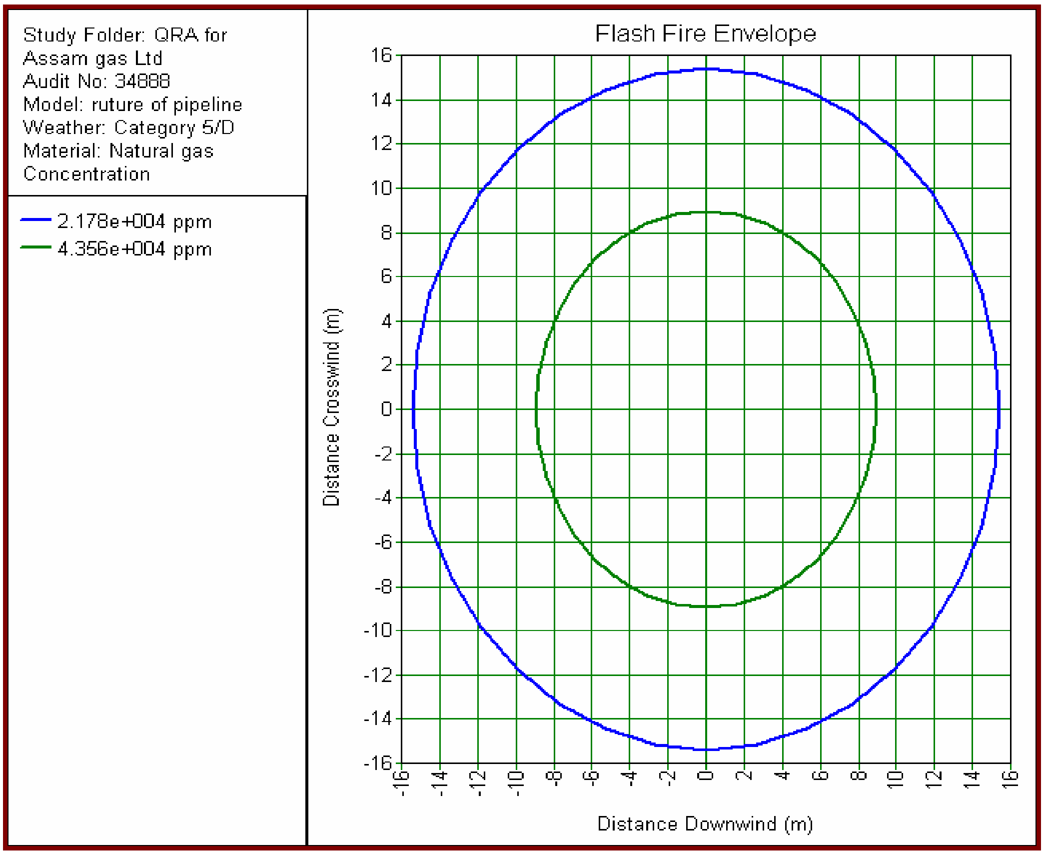
Scenario details	THERMAL DAMAGE DISTANCE BY JET FIRE				MAXIMUM DISTANCE AT OVERPRESSURE LEVEL (M)			
	RADIATION INTENSITY (KW / M2)	WEATHER CATEGORY			OVERPRESSURE (BAR)	WEATHER CATEGORY		
		3F	7D	5D		3F	7D	5D
5 mm leakage in buried pipeline	**4**	NR	NR	NR	**0.02068**	NR	NR	NR
	12.5	NR	NR	NR	**0.1379**	NR	NR	NR
	37.5	NR	NR	NR	**0.2068**	NR	NR	NR
25 mm leakage in buried pipeline	**4**	14.92	14.98	15.02	**0.02068**	24.02	22.09	23.04
	12.5	11.95	12.33	12.17	**0.1379**	13.63	13.13	13.38
	37.5	14.92	14.98	15.02	**0.2068**	12.81	12.42	12.61
100 mm	**4**	63.19	63.54	63.31	**0.02068**	175.55	175.55	175.55

leakage in buried pipeline	**12.5**	49.50	52.35	50.98	**0.1379**	45.45	45.45	45.45
	37.5	39.19	43.32	41.32	**0.2068**	35.17	35.17	35.17




Study Folder: QRA for Assam gas Ltd
Audit No: 34888
Model: ruture of pipeline
Weather: Category 5/D
Material: Natural gas
Ellipse @4 kW/m2
Ellipse @12.5 kW/m2
Intensity Radii for Fireball
Distance Crosswind (m)
Distance Downwind (m)


Study Folder: QRA for Assam gas Ltd
Audit No: 34888
Model: ruture of pipeline
Weather: Category 5/D
Material: Natural gas
OverPressures
Radius @0.02068 bar
Radius @0.1379 bar
Radius @0.2068 bar
Late Explosion Worst Case Radii
Distance Crosswind (m)
Distance Downwind (m)


Study Folder: QRA for Assam gas Ltd
Audit No: 34888
Model: ruture of pipeline
Weather: Category 5/D
Material: Natural gas
Concentration
2.178e+004 ppm
4.356e+004 ppm
Flash Fire Envelope
Distance Crosswind (m)
Distance Downwind (m)
16
14
12
10
8
6
4
2
0
-2
-4
-6
-8
-10
-12
-14
-16

CONSEQUENCE RESULTS – DULIAJAN TO AGCL COMPRESSOR AREA

Worst Case Scenario (WCS):-100% Catastrophic Rupture

Scenario details	CONCENTRATION AT DISTANCE (M)				
	Concentration in PPM		WEATHER CATEGORY		
			3F	7D	5D
Rupture in buried pipeline	UFL	164806	3.83	4.19	4.06
	LFL	43559.7	7.03	9.65	8.48
	LFL (frac)	21779.9	9.89	17.70	13.44

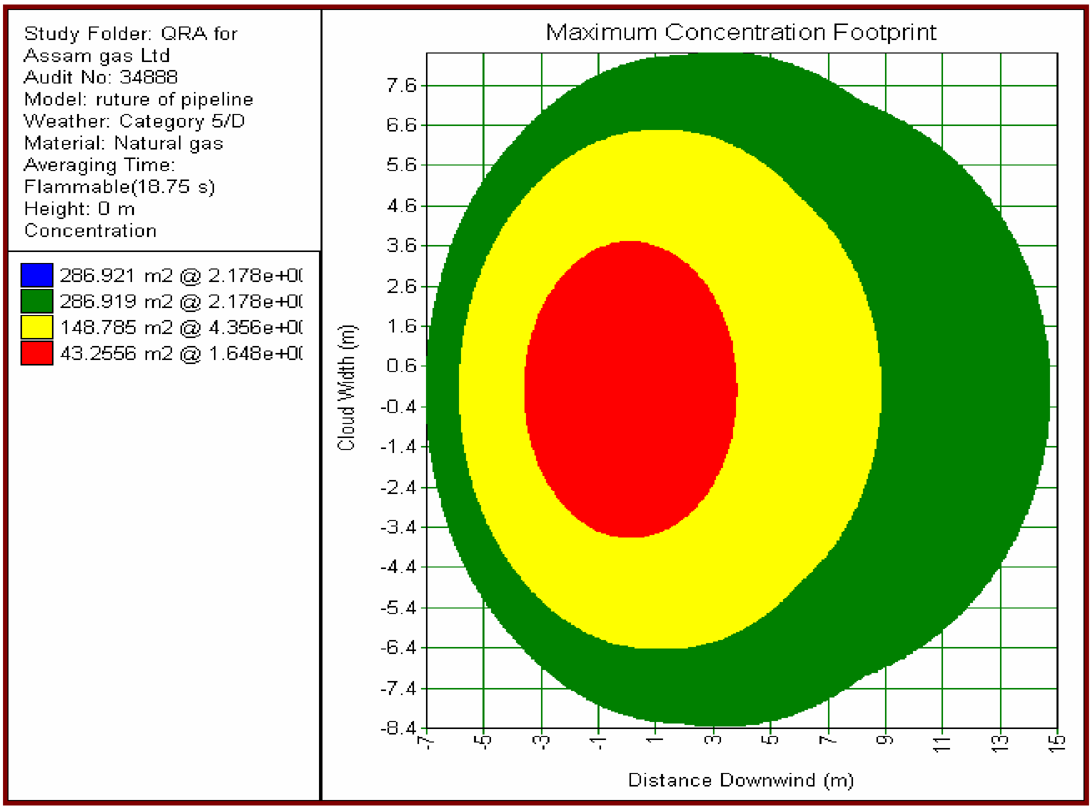
Scenario details	THERMAL DAMAGE DISTANCE BY FIRE BALL				MAXIMUM DISTANCE AT OVERPRESSURE LEVEL (M)			
	RADIATION INTENSITY (KW / M2)	WEATHER CATEGORY			OVERPRESSURE (BAR)	WEATHER CATEGORY		
		3F	7D	5D		3F	7D	5D
Rupture in buried pipeline	**4**	66.71	64.74	64.74	**0.02068**	138.67	138.67	138.67
	12.5	33.05	31.88	31.88	**0.1379**	35.91	35.91	35.91
	37.5	NR	NR	NR	**0.2068**	27.78	27.78	27.78

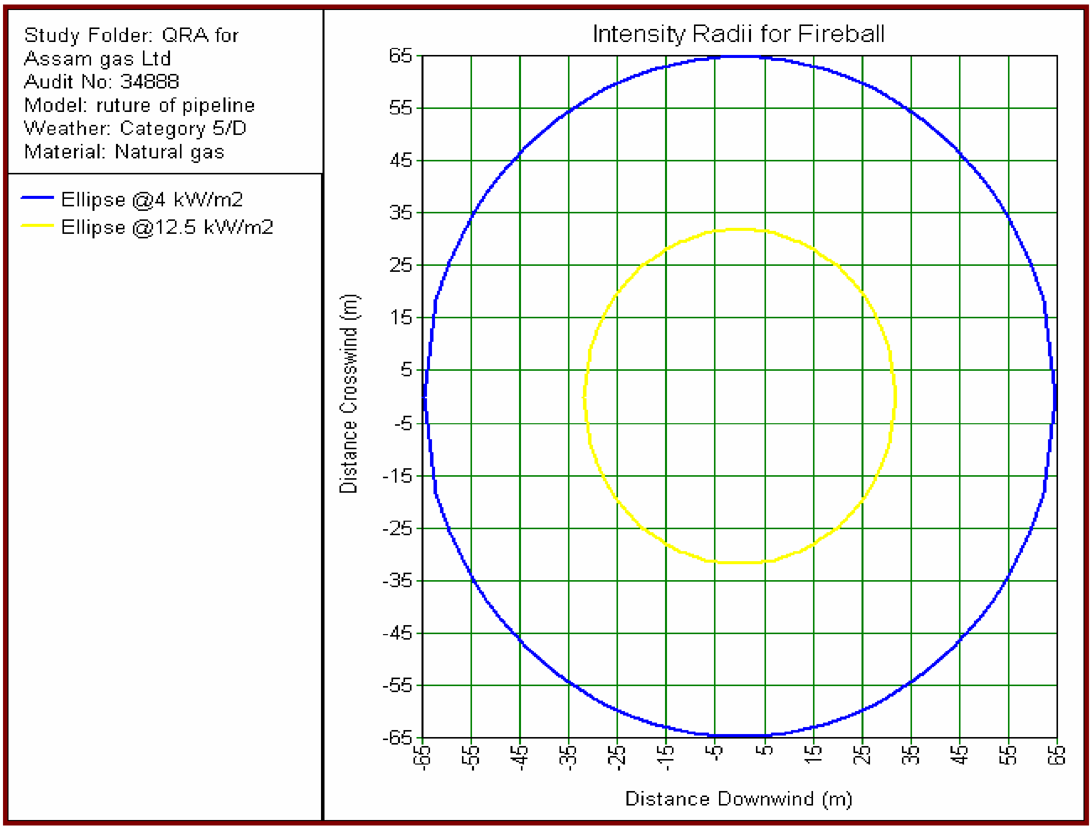
Maximum credible loss Scenario (MCLS): Leakage due to Flange failure or Hose Failure

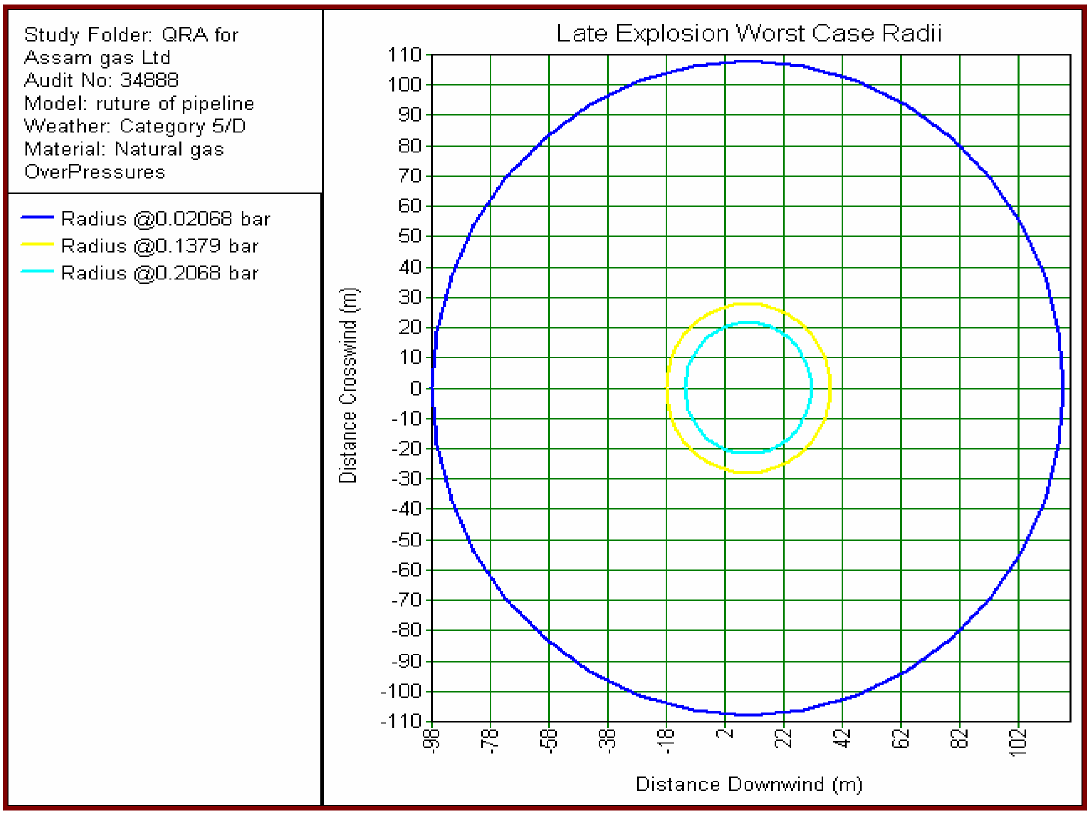
Scenario details	CONCENTRATION AT DISTANCE (M)				
	Concentration in PPM		WEATHER CATEGORY		
			3F	7D	5D
5 mm leakage in buried pipeline	UFL	164806	0.33	0.33	0.34
	LFL	43559.7	1.48	1.34	1.39
	LFL (frac)	21779.9	2.65	2.42	2.60
25 mm leakage in buried pipeline	UFL	164806	1.92	1.88	1.91
	LFL	43559.7	7.03	5.97	6.57
	LFL (frac)	21779.9	14.32	10.58	12.04
100 mm leakage in buried pipeline	UFL	164806	1.00	1.00	1.00
	LFL	43559.7	1.34	1.11	1.15
	LFL (frac)	21779.9	4.05	2.05	2.19

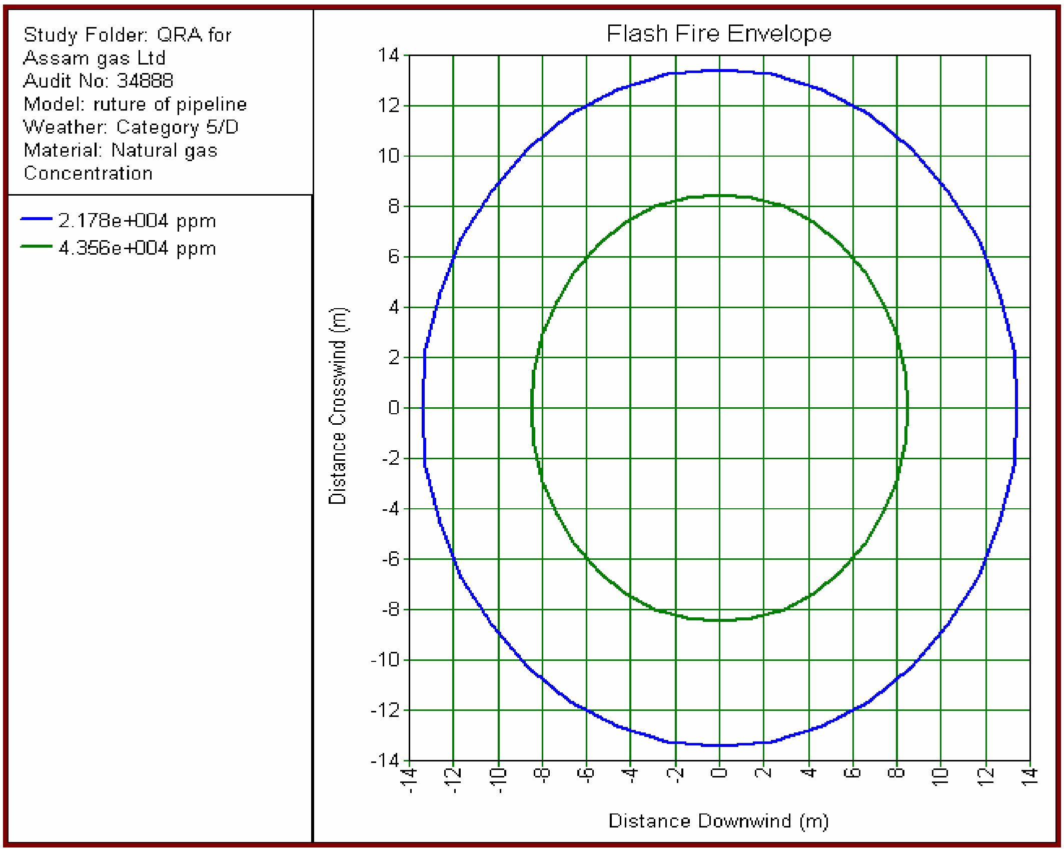
Scenario details	THERMAL DAMAGE DISTANCE BY JET FIRE				MAXIMUM DISTANCE AT OVERPRESSURE LEVEL (M)			
	RADIATION INTENSITY (KW / M2)	WEATHER CATEGORY			OVERPRESSURE (BAR)	WEATHER CATEGORY		
		3F	7D	5D		3F	7D	5D
5 mm leakage in buried pipeline	**4**	NR	NR	NR	**0.02068**	NR	NR	NR
	12.5	NR	NR	NR	**0.1379**	NR	NR	NR
	37.5	NR	NR	NR	**0.2068**	NR	NR	NR
25 mm leakage in buried pipeline	**4**	14.92	14.98	15.02	**0.02068**	24.02	22.09	23.04
	12.5	11.95	12.33	12.17	**0.1379**	13.63	13.13	13.38
	37.5	NR	NR	NR	**0.2068**	12.81	12.42	12.61
100 mm	**4**	63.19	63.54	63.31	**0.02068**	138.67	138.67	138.67

leakage in buried pipeline	**12.5**	49.50	52.35	50.98	**0.1379**	35.91	35.91	35.91
	37.5	39.19	43.32	41.32	**0.2068**	27.78	27.78	27.78




Study Folder: QRA for Assam gas Ltd
Audit No: 34888
Model: ruture of pipeline
Weather: Category 5/D
Material: Natural gas
Ellipse @4 kW/m2
Ellipse @12.5 kW/m2
Intensity Radii for Fireball
Distance Crosswind (m)
Distance Downwind (m)
65
55
45
35
25
15
5
-5
-15
-25
-35
-45
-55
-65


Study Folder: QRA for Assam gas Ltd
Audit No: 34888
Model: ruture of pipeline
Weather: Category 5/D
Material: Natural gas
OverPressures
Radius @0.02068 bar
Radius @0.1379 bar
Radius @0.2068 bar
Late Explosion Worst Case Radii
Distance Crosswind (m)
Distance Downwind (m)
-98
-78
-58
-38
-18
2
22
42
62
82
102


Study Folder: QRA for Assam gas Ltd
Audit No: 34888
Model: ruture of pipeline
Weather: Category 5/D
Material: Natural gas
Concentration
2.178e+004 ppm
4.356e+004 ppm
Flash Fire Envelope
Distance Crosswind (m)
Distance Downwind (m)
14
12
10
8
6
4
2
0
-2
-4
-6
-8
-10
-12
-14

CONSEQUENCE RESULTS – LPG,DULAJAN TO BVFCL NAMRUP

Worst Case Scenario (WCS):-100% Catastrophic Rupture

Scenario details	CONCENTRATION AT DISTANCE (M)				
	Concentration in PPM		WEATHER CATEGORY		
			3F	7D	5D
Rupture in buried pipeline	UFL	164806	3.83	4.19	4.06
	LFL	43559.7	7.03	9.65	8.48
	LFL (frac)	21779.9	9.89	17.70	13.44

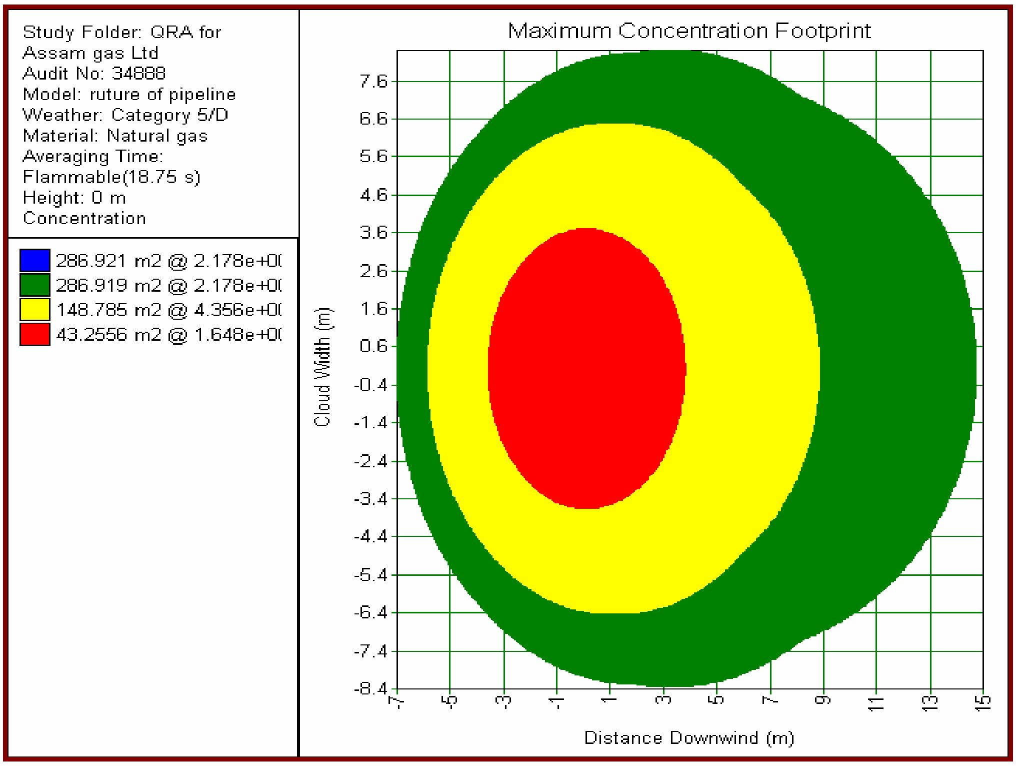
Scenario details	THERMAL DAMAGE DISTANCE BY FIRE BALL				MAXIMUM DISTANCE AT OVERPRESSURE LEVEL (M)			
	RADIATION INTENSITY (KW / M2)	WEATHER CATEGORY			OVERPRESSURE (BAR)	WEATHER CATEGORY		
		3F	7D	5D		3F	7D	5D
Rupture in buried pipeline	**4**	66.708	64.743	64.743	**0.02068**	138.67	138.67	138.67
	12.5	33.046	31.881	31.881	**0.1379**	35.91	35.91	35.91
	37.5	NR	NR	NR	**0.2068**	27.78	27.78	27.78

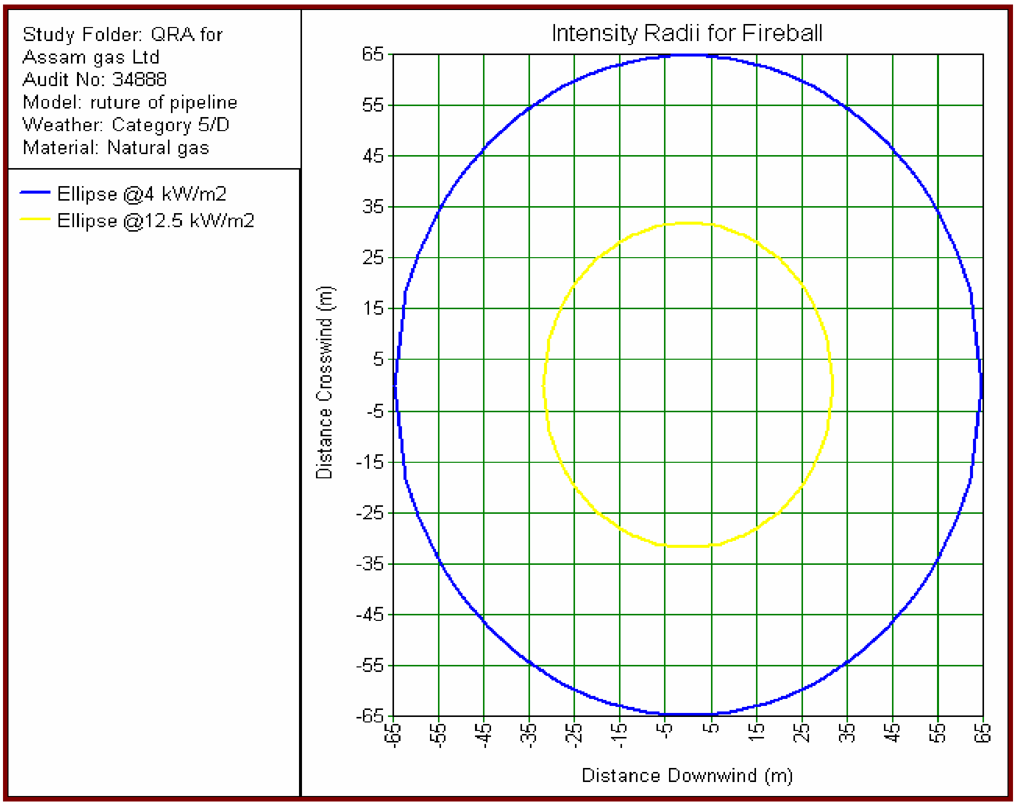
Maximum credible loss Scenario (MCLS): Leakage due to Flange failure or Hose Failure

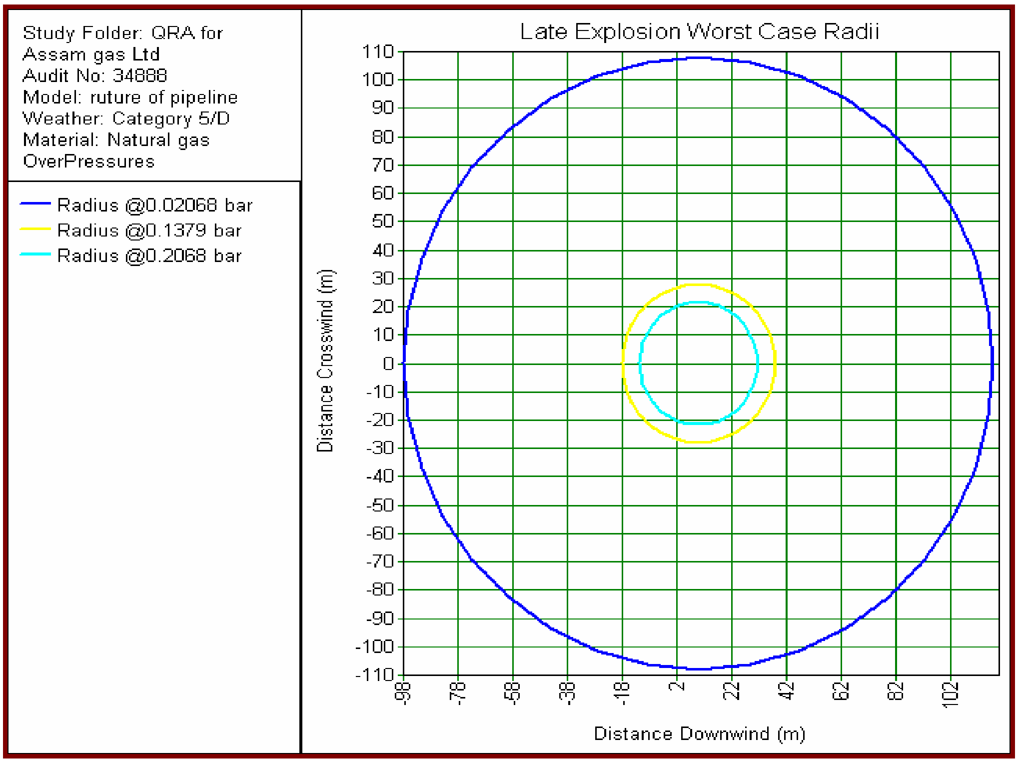
Scenario details	CONCENTRATION AT DISTANCE (M)				
	Concentration in PPM		WEATHER CATEGORY		
			3F	7D	5D
5 mm leakage in buried pipeline	UFL	164806	0.33	0.33	0.34
	LFL	43559.7	1.48	1.34	1.39
	LFL (frac)	21779.9	2.65	2.42	2.60
25 mm leakage in buried pipeline	UFL	164806	1.92	1.88	1.91
	LFL	43559.7	7.03	5.97	6.57
	LFL (frac)	21779.9	14.32	10.58	12.04
100 mm leakage in buried pipeline	UFL	164806	7.02	6.70	6.89
	LFL	43559.7	41.66	37.30	39.06
	LFL (frac)	21779.9	94.98	96.46	93.56

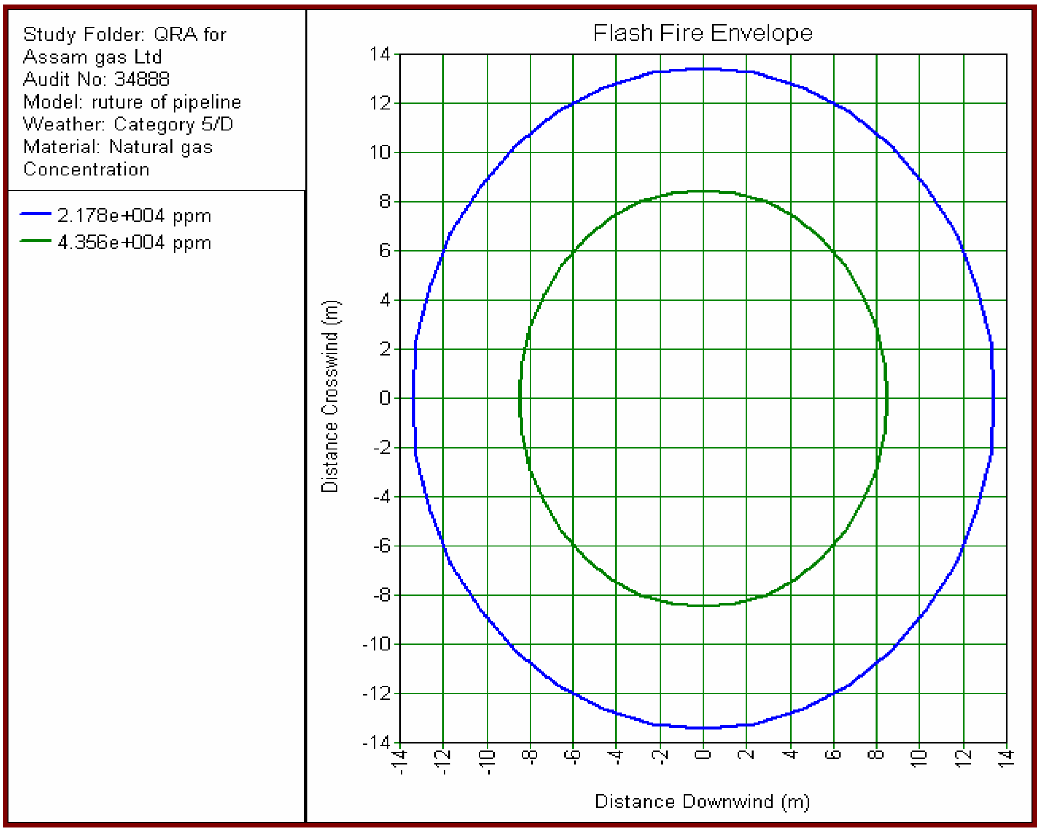
Scenario details	THERMAL DAMAGE DISTANCE BY JET FIRE				MAXIMUM DISTANCE AT OVERPRESSURE LEVEL (M)			
	RADIATION INTENSITY (KW / M2)	WEATHER CATEGORY			OVERPRESSURE (BAR)	WEATHER CATEGORY		
		3F	7D	5D		3F	7D	5D
5 mm leakage in buried pipeline	**4**	NR	NR	NR	**0.02068**	NR	NR	NR
	12.5	NR	NR	NR	**0.1379**	NR	NR	NR
	37.5	NR	NR	NR	**0.2068**	NR	NR	NR
25 mm leakage in buried pipeline	**4**	14.92	14.982	15.023	**0.02068**	24.02	22.09	23.04
	12.5	11.951	12.329	12.171	**0.1379**	13.63	13.13	13.38
	37.5	NR	NR	NR	**0.2068**	12.81	12.42	12.61
100 mm	**4**	63.189	63.543	63.313	**0.02068**	138.67	138.67	138.67

leakage in buried pipeline	**12.5**	49.503	52.354	50.984	**0.1379**	35.906	35.906	35.906
	37.5	39.189	43.32	41.317	**0.2068**	27.783	27.783	27.783




Study Folder: QRA for Assam gas Ltd
Audit No: 34888
Model: ruture of pipeline
Weather: Category 5/D
Material: Natural gas
Ellipse @4 kW/m2
Ellipse @12.5 kW/m2
Intensity Radii for Fireball
Distance Crosswind (m)
Distance Downwind (m)


Study Folder: QRA for Assam gas Ltd
Audit No: 34888
Model: ruture of pipeline
Weather: Category 5/D
Material: Natural gas
OverPressures
Radius @0.02068 bar
Radius @0.1379 bar
Radius @0.2068 bar
Late Explosion Worst Case Radii
Distance Crosswind (m)
Distance Downwind (m)


Study Folder: QRA for Assam gas Ltd
Audit No: 34888
Model: ruture of pipeline
Weather: Category 5/D
Material: Natural gas
Concentration
2.178e+004 ppm
4.356e+004 ppm
Flash Fire Envelope
Distance Crosswind (m)
Distance Downwind (m)
14
12
10
8
6
4
2
0
-2
-4
-6
-8
-10
-12
-14

CONSEQUENCE RESULTS – TENGAKHAT TO TINSUKIA

Worst Case Scenario (WCS):-100% Catastrophic Rupture

Scenario details	CONCENTRATION AT DISTANCE (M)				
	Concentration in PPM		WEATHER CATEGORY		
			3F	7D	5D
Rupture in buried pipeline	UFL	164806	2.96	3.19	3.10
	LFL	43559.7	5.36	7.57	6.61
	LFL (frac)	21779.9	7.43	12.99	10.43

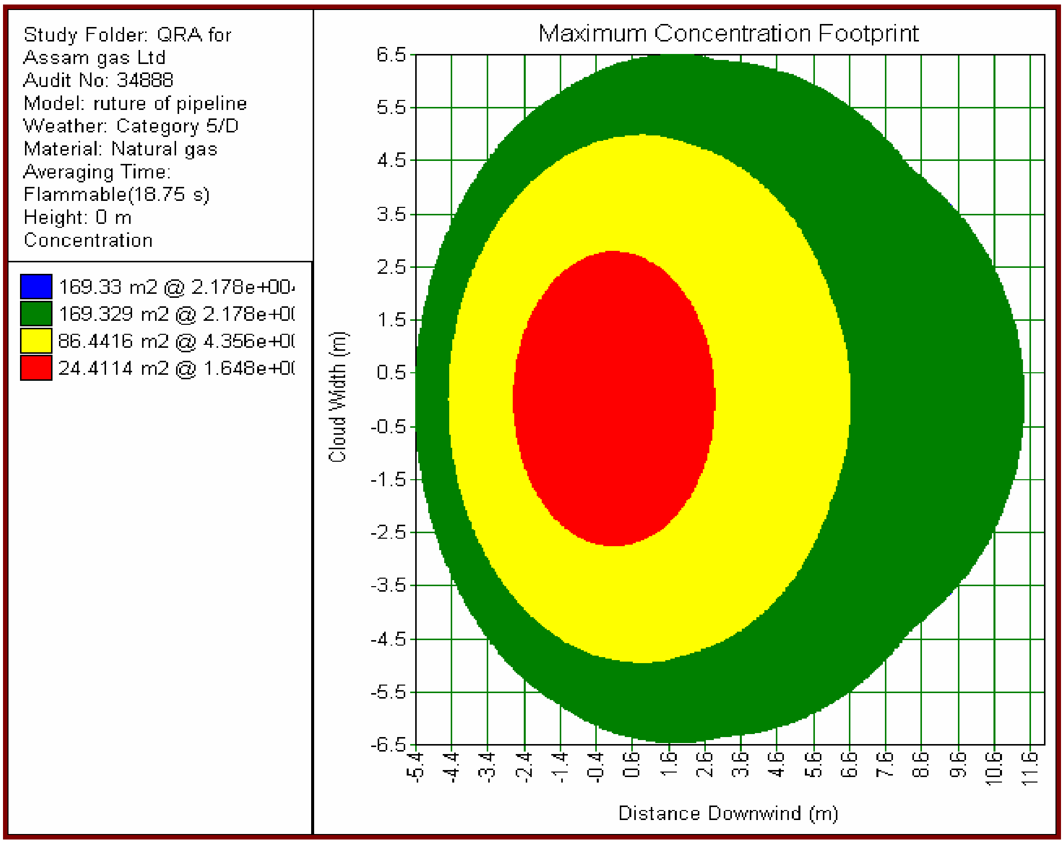
Scenario details	THERMAL DAMAGE DISTANCE BY FIRE BALL				MAXIMUM DISTANCE AT OVERPRESSURE LEVEL (M)			
	RADIATION INTENSITY (KW / M2)	WEATHER CATEGORY			OVERPRESSURE (BAR)	WEATHER CATEGORY		
		3F	7D	5D		3F	7D	5D
Rupture in buried pipeline	**4**	51.659	50.217	50.217	**0.02068**	109.01	109.01	109.01
	12.5	25.303	24.441	24.441	**0.1379**	28.22	28.22	28.22
	37.5	NR	NR	NR	**0.2068**	21.84	21.84	21.84

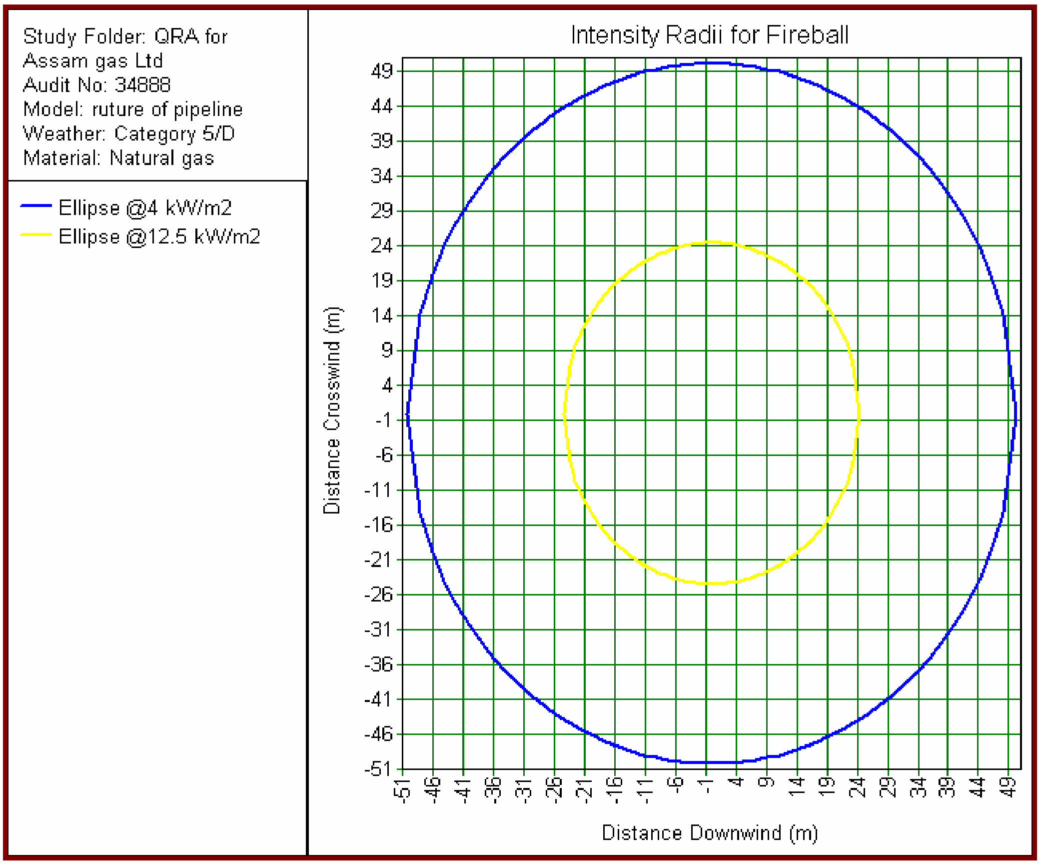
Maximum credible loss Scenario (MCLS): Leakage due to Flange failure or Hose Failure

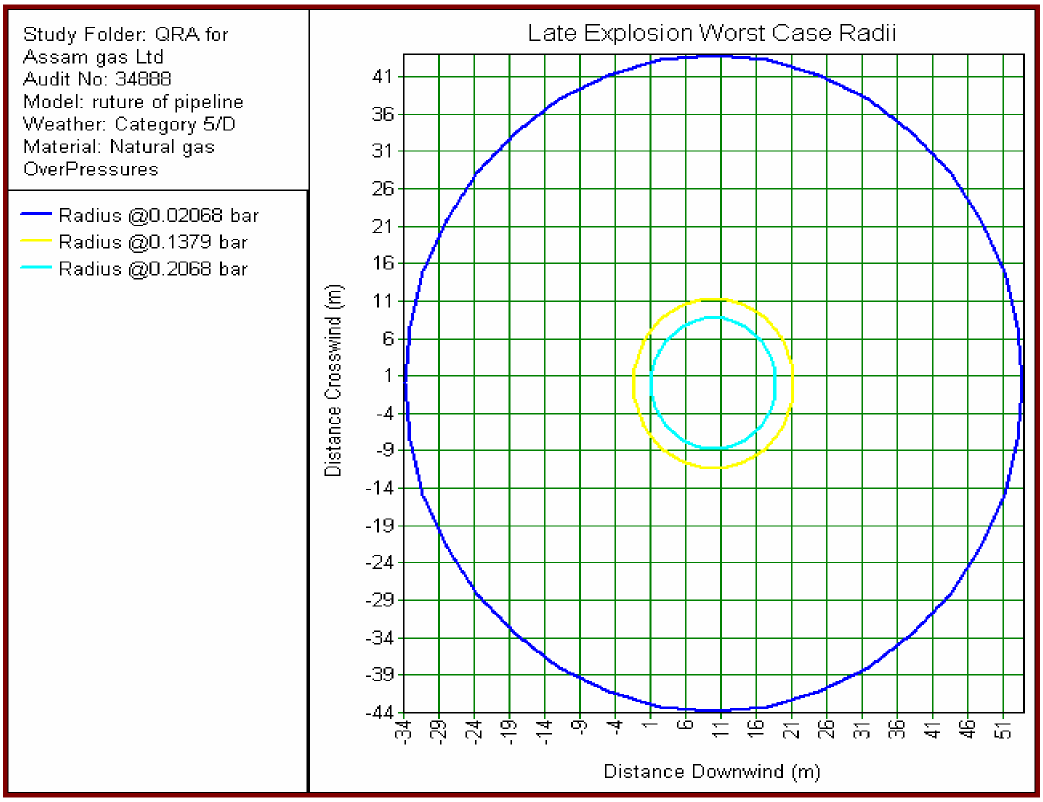
Scenario details	CONCENTRATION AT DISTANCE (M)				
	Concentration in PPM		WEATHER CATEGORY		
			3F	7D	5D
5 mm leakage in buried pipeline	UFL	164806	0.33	0.33	0.34
	LFL	43559.7	1.48	1.34	1.39
	LFL (frac)	21779.9	2.65	2.42	2.60
25 mm leakage in buried pipeline	UFL	164806	1.92	1.88	1.91
	LFL	43559.7	7.03	5.97	6.57
	LFL (frac)	21779.9	14.32	10.58	12.04
100 mm leakage in buried pipeline	UFL	164806	7.02	6.70	6.89
	LFL	43559.7	41.66	37.30	39.06
	LFL (frac)	21779.9	98.98	96.46	93.56

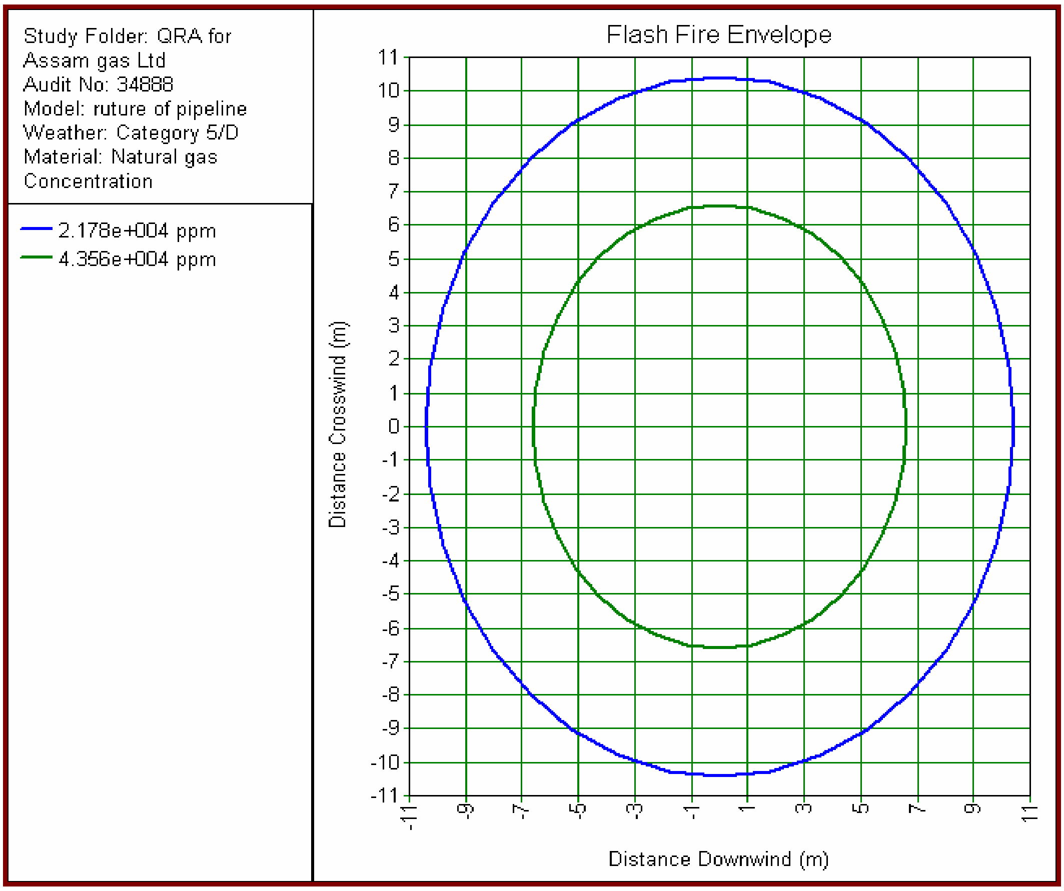
Scenario details	THERMAL DAMAGE DISTANCE BY JET FIRE				MAXIMUM DISTANCE AT OVERPRESSURE LEVEL (M)			
	RADIATION INTENSITY (KW / M2)	WEATHER CATEGORY			OVERPRESSURE (BAR)	WEATHER CATEGORY		
		3F	7D	5D		3F	7D	5D
5 mm leakage in buried pipeline	**4**	NR	NR	NR	**0.02068**	NR	NR	NR
	12.5	NR	NR	NR	**0.1379**	NR	NR	NR
	37.5	NR	NR	NR	**0.2068**	NR	NR	NR
25 mm leakage in buried pipeline	**4**	14.92	14.98	15.02	**0.02068**	24.02	22.09	23.04
	12.5	11.95	12.33	12.17	**0.1379**	13.63	13.13	13.38
	37.5	NR	NR	NR	**0.2068**	12.81	12.42	12.61
100 mm	**4**	63.19	63.54	63.31	**0.02068**	109.01	109.01	109.01

leakage in buried pipeline	**12.5**	49.50	52.35	50.98	**0.1379**	28.22	28.22	28.22
	37.5	39.19	43.32	41.32	**0.2068**	21.84	21.84	21.84




Study Folder: QRA for Assam gas Ltd
Audit No: 34888
Model: ruture of pipeline
Weather: Category 5/D
Material: Natural gas
Ellipse @4 kW/m2
Ellipse @12.5 kW/m2
Intensity Radii for Fireball
Distance Crosswind (m)
Distance Downwind (m)
49
44
39
34
29
24
19
14
9
4
-1
-6
-11
-16
-21
-26
-31
-36
-41
-46
-51


Study Folder: QRA for Assam gas Ltd
Audit No: 34888
Model: ruture of pipeline
Weather: Category 5/D
Material: Natural gas
OverPressures
Radius @0.02068 bar
Radius @0.1379 bar
Radius @0.2068 bar
Late Explosion Worst Case Radii
Distance Crosswind (m)
Distance Downwind (m)
41
36
31
26
21
16
11
6
1
-4
-9
-14
-19
-24
-29
-34
-39
-44


Study Folder: QRA for Assam gas Ltd
Audit No: 34888
Model: ruture of pipeline
Weather: Category 5/D
Material: Natural gas
Concentration
2.178e+004 ppm
4.356e+004 ppm
Flash Fire Envelope
Distance Crosswind (m)
Distance Downwind (m)
11
10
9
8
7
6
5
4
3
2
1
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
-10
-11
-11
-9
-7
-5
-3
-1
1
3
5
7
9
11

CONSEQUENCE RESULTS – TENSUKIA TO DOOMDOOMA

Worst Case Scenario (WCS):-100% Catastrophic Rupture

Scenario details	CONCENTRATION AT DISTANCE (M)				
	Concentration in PPM		WEATHER CATEGORY		
			3F	7D	5D
Rupture in buried pipeline	UFL	164806	2.65	2.83	2.78
	LFL	43559.7	4.81	6.83	5.88
	LFL (frac)	21779.9	6.57	11.85	9.47

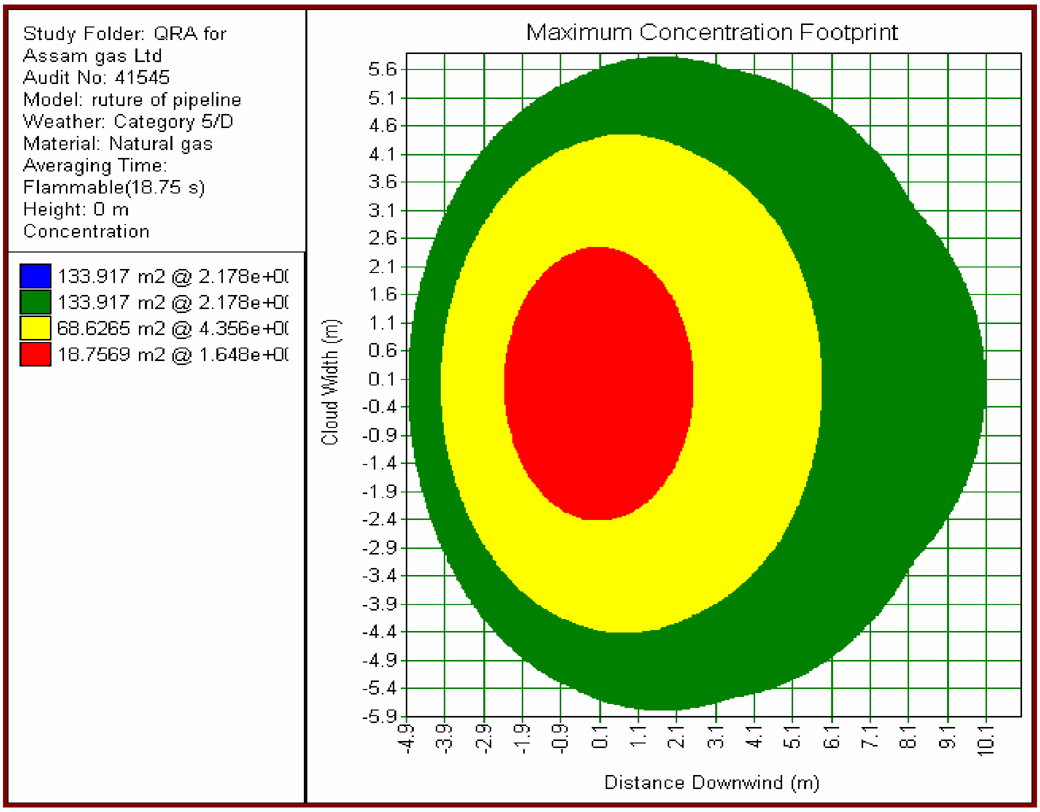
Scenario details	THERMAL DAMAGE DISTANCE BY FIRE BALL				MAXIMUM DISTANCE AT OVERPRESSURE LEVEL (M)			
	RADIATION INTENSITY (KW / M2)	WEATHER CATEGORY			OVERPRESSURE (BAR)	WEATHER CATEGORY		
		3F	7D	5D		3F	7D	5D
Rupture in buried pipeline	**4**	46.32	45.05	45.05	**0.02068**	98.39	98.3878	98.39
	12.5	22.57	21.81	21.81	**0.1379**	25.48	25.48	25.48
	37.5	NR	NR	NR	**0.2068**	19.71	19.71	19.71

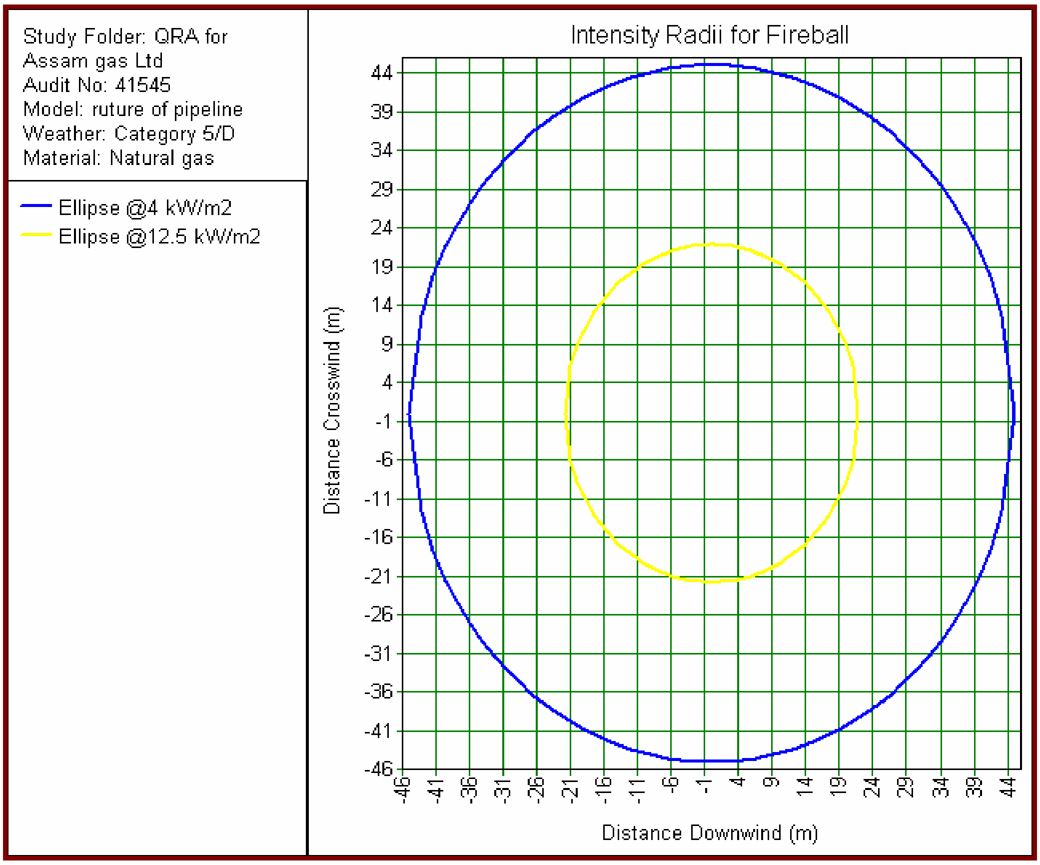
Maximum credible loss Scenario (MCLS): Leakage due to Flange failure or Hose Failure

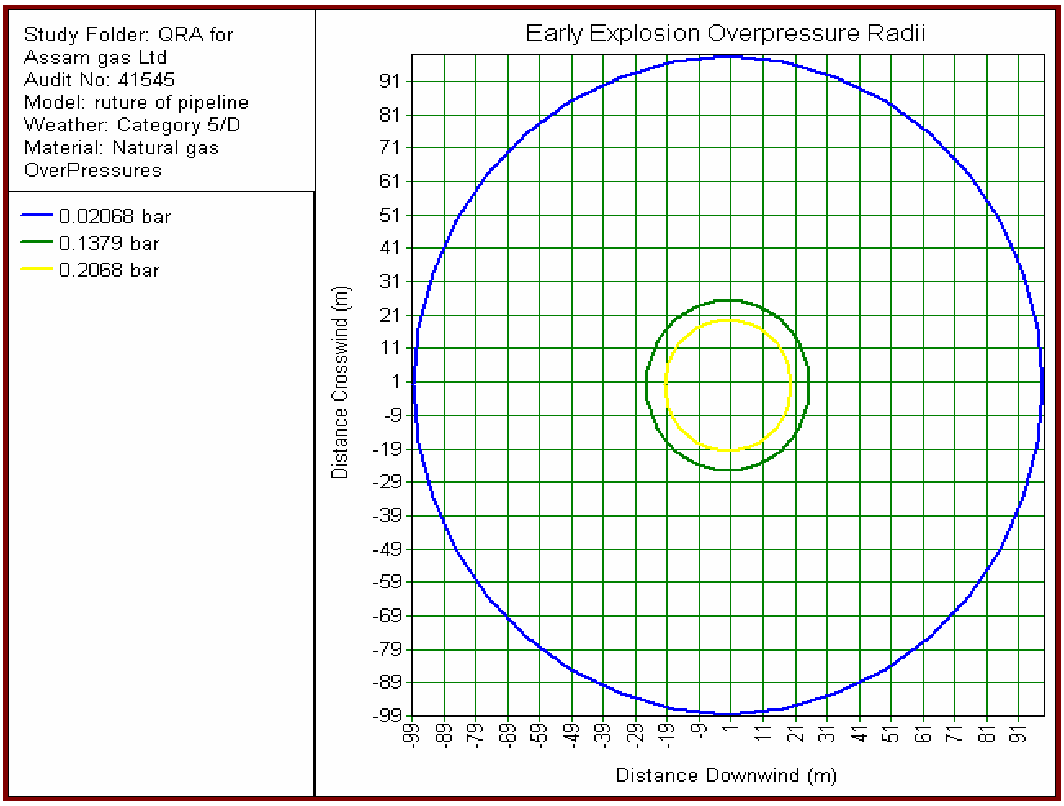
Scenario details	CONCENTRATION AT DISTANCE (M)				
	Concentration in PPM		WEATHER CATEGORY		
			3F	7D	5D
5 mm leakage in buried pipeline	UFL	164806	0.33	0.33	0.34
	LFL	43559.7	1.48	1.34	1.39
	LFL (frac)	21779.9	2.65	2.42	2.60
25 mm leakage in buried pipeline	UFL	164806	1.92	1.88	1.91
	LFL	43559.7	7.03	5.97	6.57
	LFL (frac)	21779.9	14.32	10.58	12.04
100 mm leakage in buried pipeline	UFL	164806	7.02	6.70	6.89
	LFL	43559.7	41.66	37.30	39.06
	LFL (frac)	21779.9	90.82	96.46	93.56

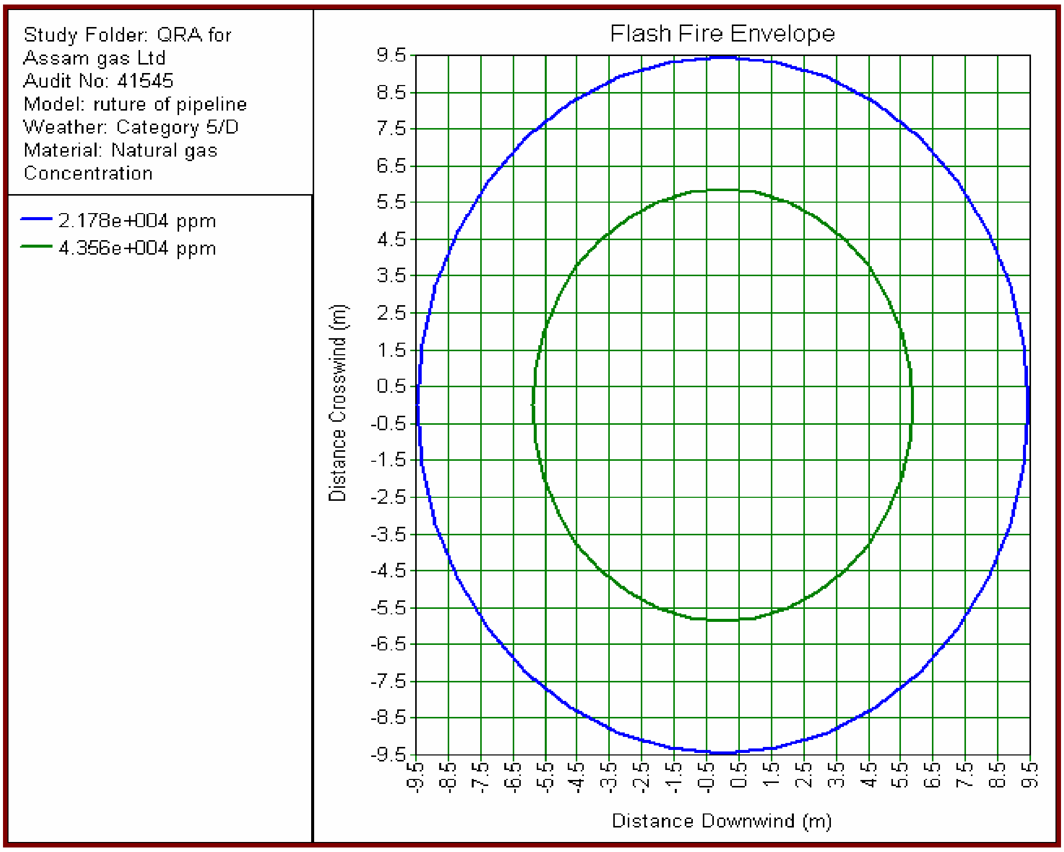
Scenario details	THERMAL DAMAGE DISTANCE BY JET FIRE				MAXIMUM DISTANCE AT OVERPRESSURE LEVEL (M)			
	RADIATION INTENSITY (KW / M2)	WEATHER CATEGORY			OVERPRESSURE (BAR)	WEATHER CATEGORY		
		3F	7D	5D		3F	7D	5D
5 mm leakage in buried pipeline	**4**	NR	NR	NR	**0.02068**	NR	NR	NR
	12.5	NR	NR	NR	**0.1379**	NR	NR	NR
	37.5	NR	NR	NR	**0.2068**	NR	NR	NR
25 mm leakage in buried pipeline	**4**	14.92	14.98	15.02	**0.02068**	24.02	22.09	23.04
	12.5	11.95	12.33	12.17	**0.1379**	13.63	13.13	13.38
	37.5	NR	NR	NR	**0.2068**	12.81	12.42	12.61
100 mm	**4**	63.19	63.54	63.31	**0.02068**	98.39	98.39	98.39

Scenario details	THERMAL DAMAGE DISTANCE BY JET FIRE				MAXIMUM DISTANCE AT OVERPRESSURE LEVEL (M)			
	RADIATION INTENSITY (KW / M2)	WEATHER CATEGORY			OVERPRESSURE (BAR)	WEATHER CATEGORY		
		3F	7D	5D		3F	7D	5D
leakage in buried pipeline	**12.5**	49.50	52.35	50.98	**0.1379**	25.48	25.48	25.48
	37.5	39.19	43.32	41.32	**0.2068**	19.71	19.71	19.71




Study Folder: QRA for Assam gas Ltd
Audit No: 41545
Model: ruture of pipeline
Weather: Category 5/D
Material: Natural gas
Ellipse @4 kW/m2
Ellipse @12.5 kW/m2
Intensity Radii for Fireball
Distance Crosswind (m)
Distance Downwind (m)


Study Folder: QRA for Assam gas Ltd
Audit No: 41545
Model: ruture of pipeline
Weather: Category 5/D
Material: Natural gas
OverPressures
0.02068 bar
0.1379 bar
0.2068 bar
Early Explosion Overpressure Radii
Distance Crosswind (m)
Distance Downwind (m)


Study Folder: QRA for Assam gas Ltd
Audit No: 41545
Model: ruture of pipeline
Weather: Category 5/D
Material: Natural gas
Concentration
2.178e+004 ppm
4.356e+004 ppm
Flash Fire Envelope
Distance Crosswind (m)
Distance Downwind (m)
9.5
8.5
7.5
6.5
5.5
4.5
3.5
2.5
1.5
0.5
-0.5
-1.5
-2.5
-3.5
-4.5
-5.5
-6.5
-7.5
-8.5
-9.5

CONSEQUENCE RESULTS – URIAMGHAT TO GOLAGHAT

Worst Case Scenario (WCS):-100% Catastrophic Rupture

Scenario details	CONCENTRATION AT DISTANCE (M)				
	Concentration in PPM		WEATHER CATEGORY		
			3F	7D	5D
Rupture in buried pipeline	UFL	164806	2.40	2.65	2.52
	LFL	43559.7	4.32	6.67	5.76
	LFL (frac)	21779.9	6.25	12.87	9.26

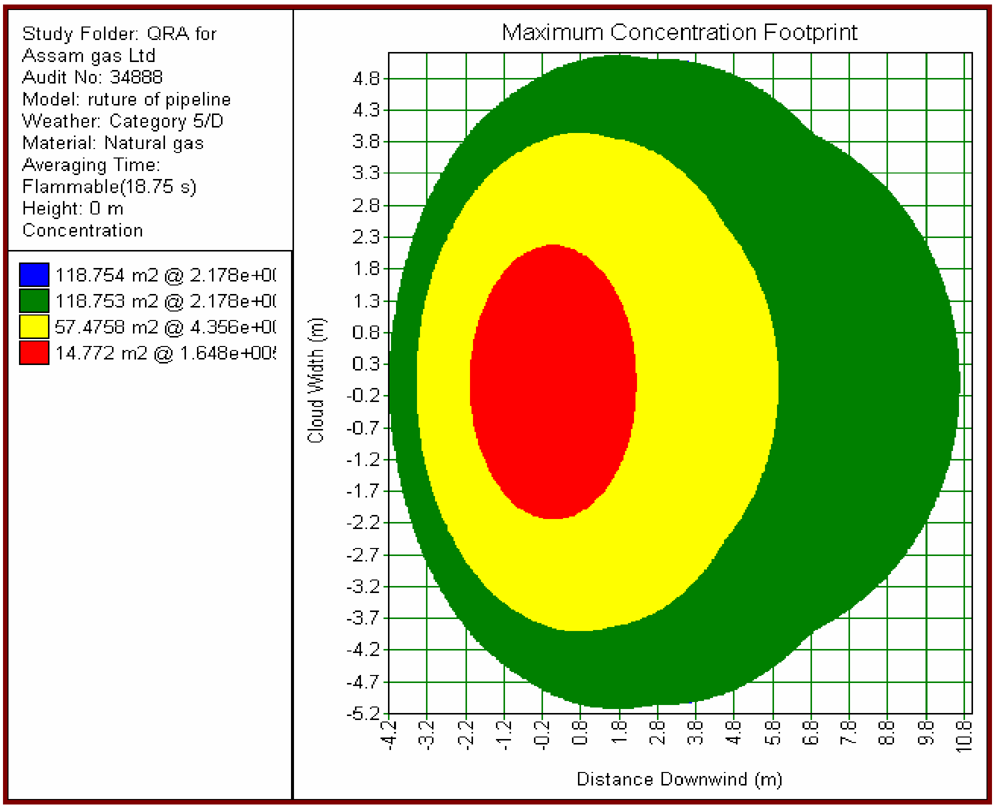
Scenario details	THERMAL DAMAGE DISTANCE BY FIRE BALL				MAXIMUM DISTANCE AT OVERPRESSURE LEVEL (M)			
	RADIATION INTENSITY (KW / M2)	WEATHER CATEGORY			OVERPRESSURE (BAR)	WEATHER CATEGORY		
		3F	7D	5D		3F	7D	5D
Rupture in buried pipeline	**4**	35.79	34.83	34.83	**0.02068**	88.18	88.18	88.18
	12.5	16.02	15.39	15.39	**0.1379**	22.83	22.83	22.83
	37.5	NR	NR	NR	**0.2068**	17.67	17.67	17.67

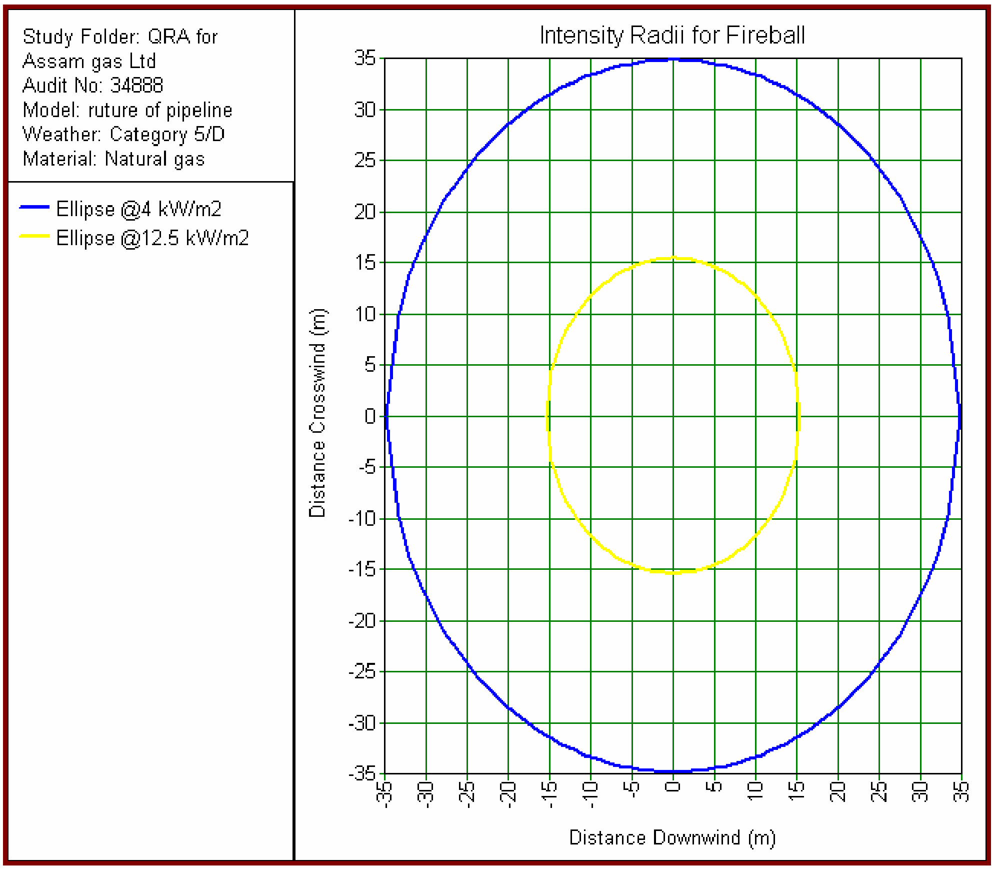
Maximum credible loss Scenario (MCLS): Leakage due to Flange failure or Hose Failure

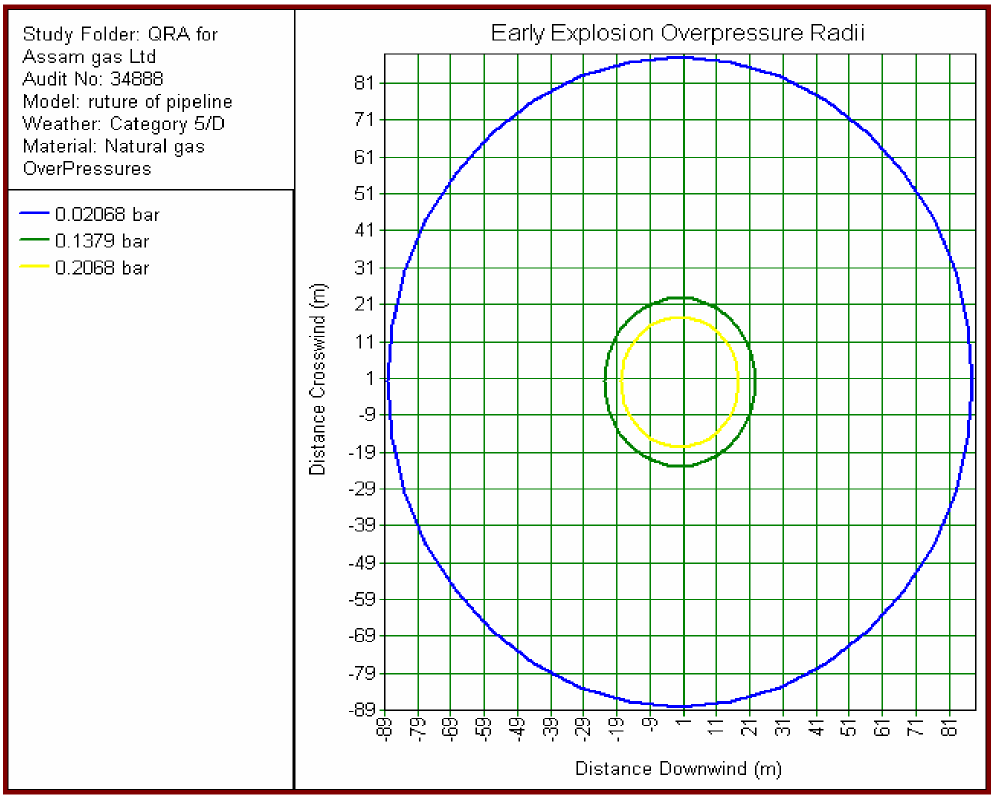
Scenario details	CONCENTRATION AT DISTANCE (M)				
	Concentration in PPM		WEATHER CATEGORY		
			3F	7D	5D
5 mm leakage in buried pipeline	UFL	164806	0.20	0.20	0.20
	LFL	43559.7	1.03	0.96	1.00
	LFL (frac)	21779.9	1.97	1.71	1.85
25 mm leakage in buried pipeline	UFL	164806	1.21	1.20	1.21
	LFL	43559.7	4.84	4.45	4.65
	LFL (frac)	21779.9	8.30	6.59	7.25
100 mm leakage in buried pipeline	UFL	164806	4.77	4.63	4.72
	LFL	43559.7	22.91	20.17	21.40
	LFL (frac)	21779.9	57.79	55.97	56.38

Scenario details	THERMAL DAMAGE DISTANCE BY JET FIRE				MAXIMUM DISTANCE AT OVERPRESSURE LEVEL (M)			
	RADIATION INTENSITY (KW / M2)	WEATHER CATEGORY			OVERPRESSURE (BAR)	WEATHER CATEGORY		
		3F	7D	5D		3F	7D	5D
5 mm leakage in buried pipeline	**4**	NR	NR	NR	**0.02068**	NR	NR	NR
	12.5	NR	NR	NR	**0.1379**	NR	NR	NR
	37.5	NR	NR	NR	**0.2068**	NR	NR	NR
25 mm leakage in buried pipeline	**4**	9.4336	9.2945	9.4225	**0.02068**	NR	NR	NR
	12.5	7.3295	7.3295	7.3152	**0.1379**	NR	NR	NR
	37.5	NR	NR	NR	**0.2068**	NR	NR	NR

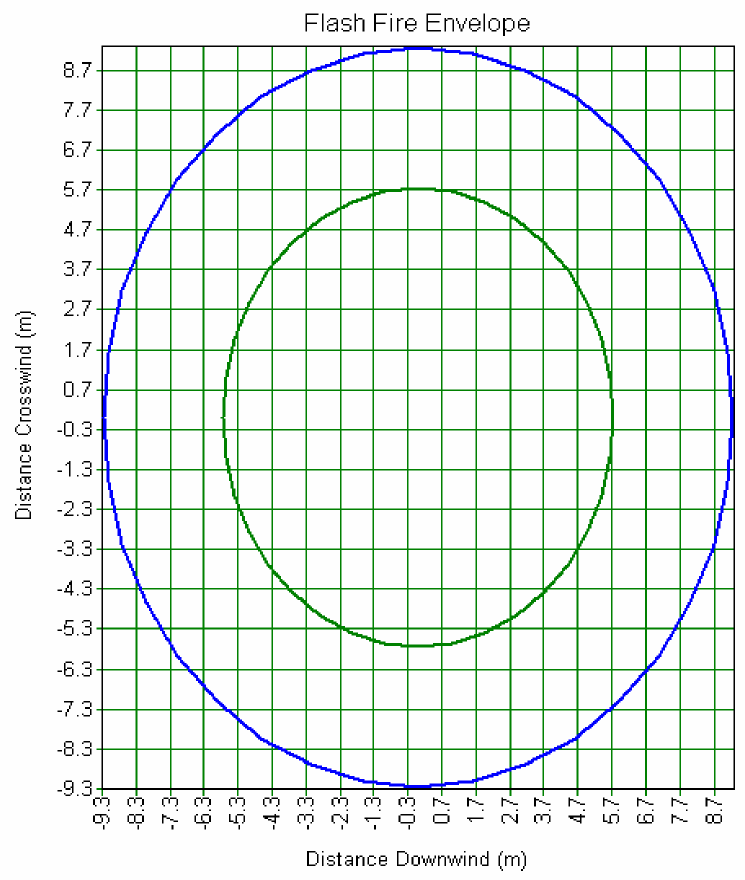
Scenario details	THERMAL DAMAGE DISTANCE BY JET FIRE				MAXIMUM DISTANCE AT OVERPRESSURE LEVEL (M)			
	RADIATION INTENSITY (KW / M2)	WEATHER CATEGORY			OVERPRESSURE (BAR)	WEATHER CATEGORY		
		3F	7D	5D		3F	7D	5D
100 mm leakage in buried pipeline	**4**	42.094	42.521	42.354	**0.02068**	88.18	88.18	88.18
	12.5	33.54	35.488	34.603	**0.1379**	22.83	22.83	22.83
	37.5	26.967	29.746	28.459	**0.2068**	17.67	17.67	17.67




Study Folder: QRA for Assam gas Ltd
Audit No: 34888
Model: ruture of pipeline
Weather: Category 5/D
Material: Natural gas
Ellipse @4 kW/m2
Ellipse @12.5 kW/m2
Intensity Radii for Fireball
Distance Crosswind (m)
Distance Downwind (m)
35
30
25
20
15
10
5
0
-5
-10
-15
-20
-25
-30
-35


Study Folder: QRA for Assam gas Ltd
Audit No: 34888
Model: ruture of pipeline
Weather: Category 5/D
Material: Natural gas
OverPressures
0.02068 bar
0.1379 bar
0.2068 bar
Early Explosion Overpressure Radii
Distance Crosswind (m)
Distance Downwind (m)
81
71
61
51
41
31
21
11
1
-9
-19
-29
-39
-49
-59
-69
-79
-89

Study Folder: QRA for Assam gas Ltd
Audit No: 34888
Model: ruture of pipeline
Weather: Category 5/D
Material: Natural gas
Concentration



CONCLUSION

Consequence analysis is carried out with the help of PHAST software. Following charts gives the brief idea about the results given by the

Assam gas has HSE Design Criteria which presents the safeguards that are identified to mitigate the risks. These safeguards comprise of appropriate layout considerations, emergency shutdown system, , fire & gas detection, and active & passive fire protection requirements based on International codes and standards. These existing safeguards are given appropriate credit within the QRA to determine the residual risk on failure of these safeguards.

The conclusions of the consequence study are as follows:

Catastrophic rupture and leak will generate heat radiation as well as overpressure effect. The heat radiation with 37.5 kW/m2 intensity will travel upto the distance of 60 m and 200 m respectively during Leak and catastrophic rupture.

However overpressure effect in case of catastrophic rupture and leakage at 0.2068 bars will travel upto the distance of 300 m and 160 m respectively.

Following chart summarized the results of heat radiation and overpressure effect

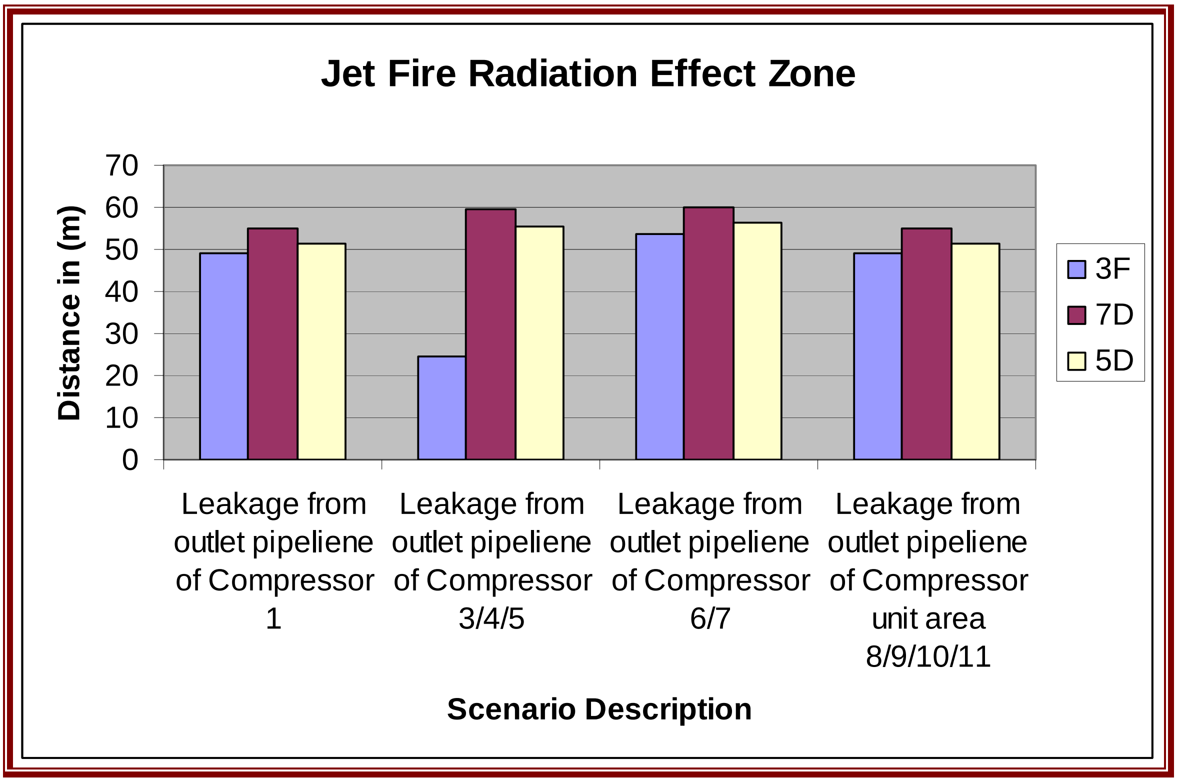


Figure 8 Jet fire radiation Effect from Compressor unit in case of leakage

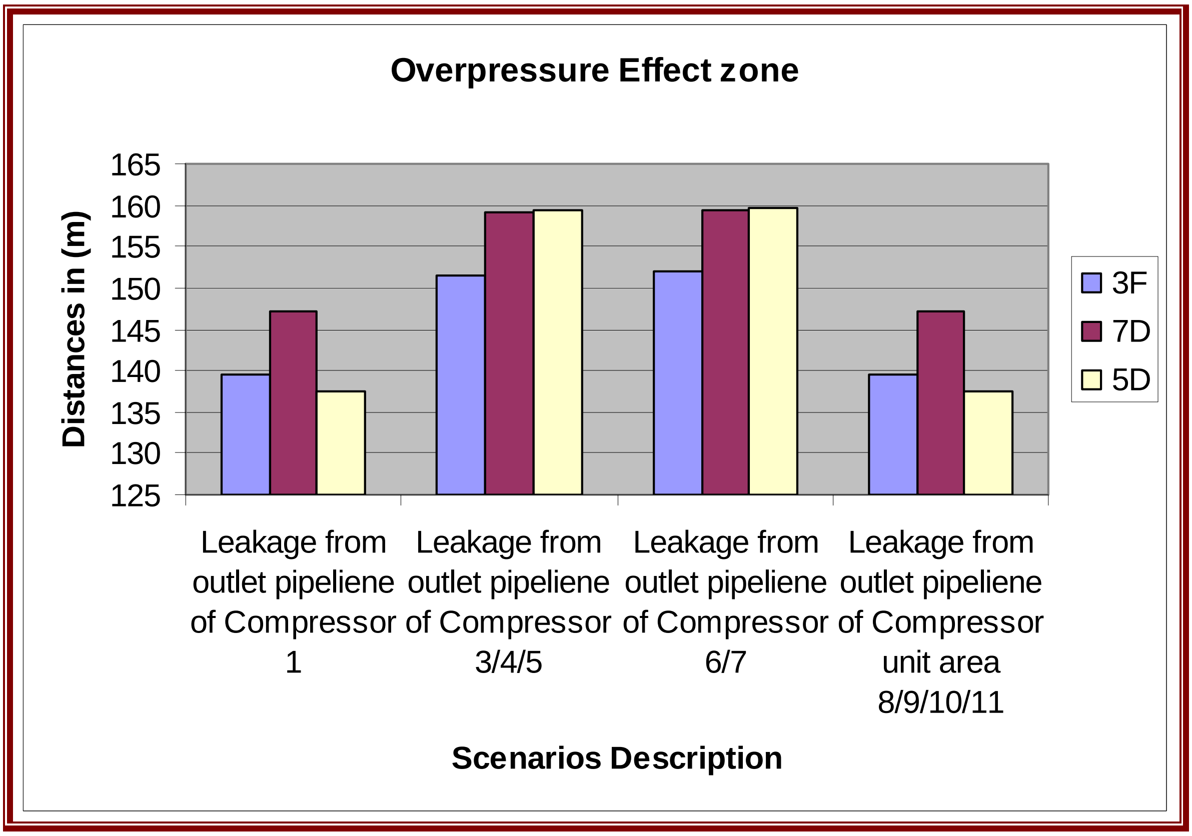


Figure 9 Overpressure damage distances in case of leakage

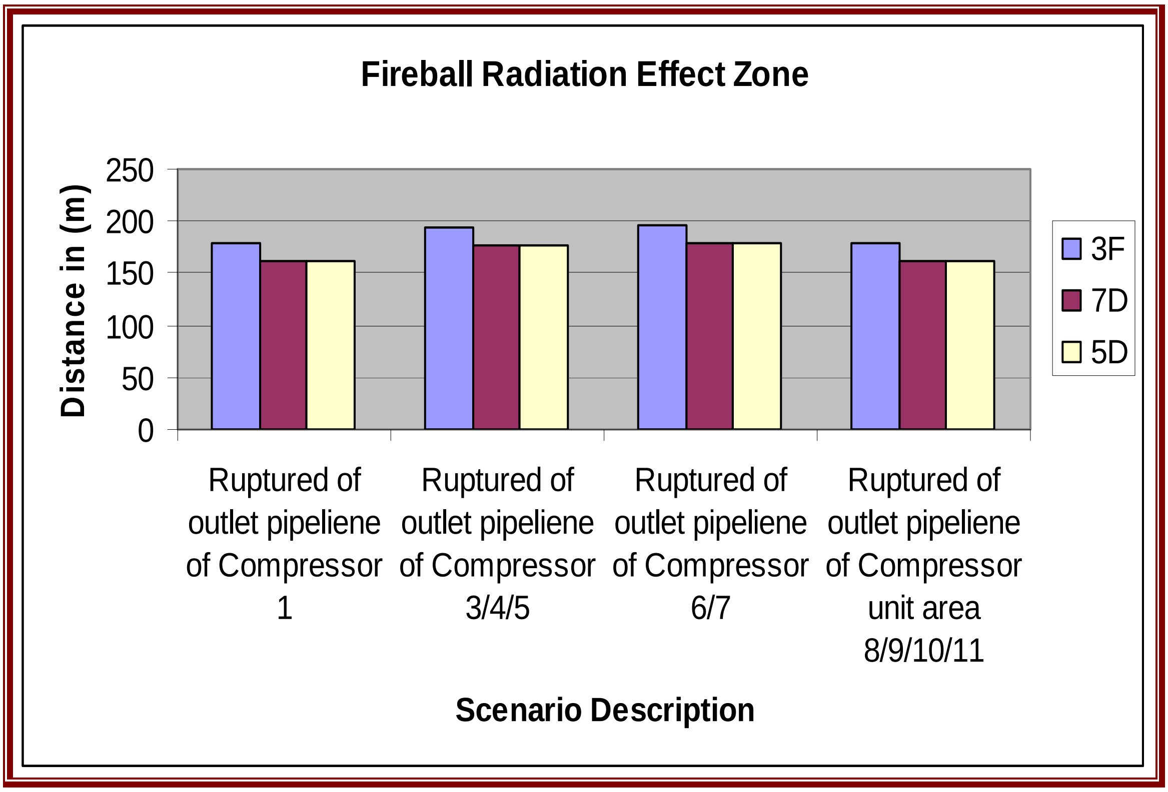


Figure 10 **Fireball radiation effect in case of catastrophic rupture**

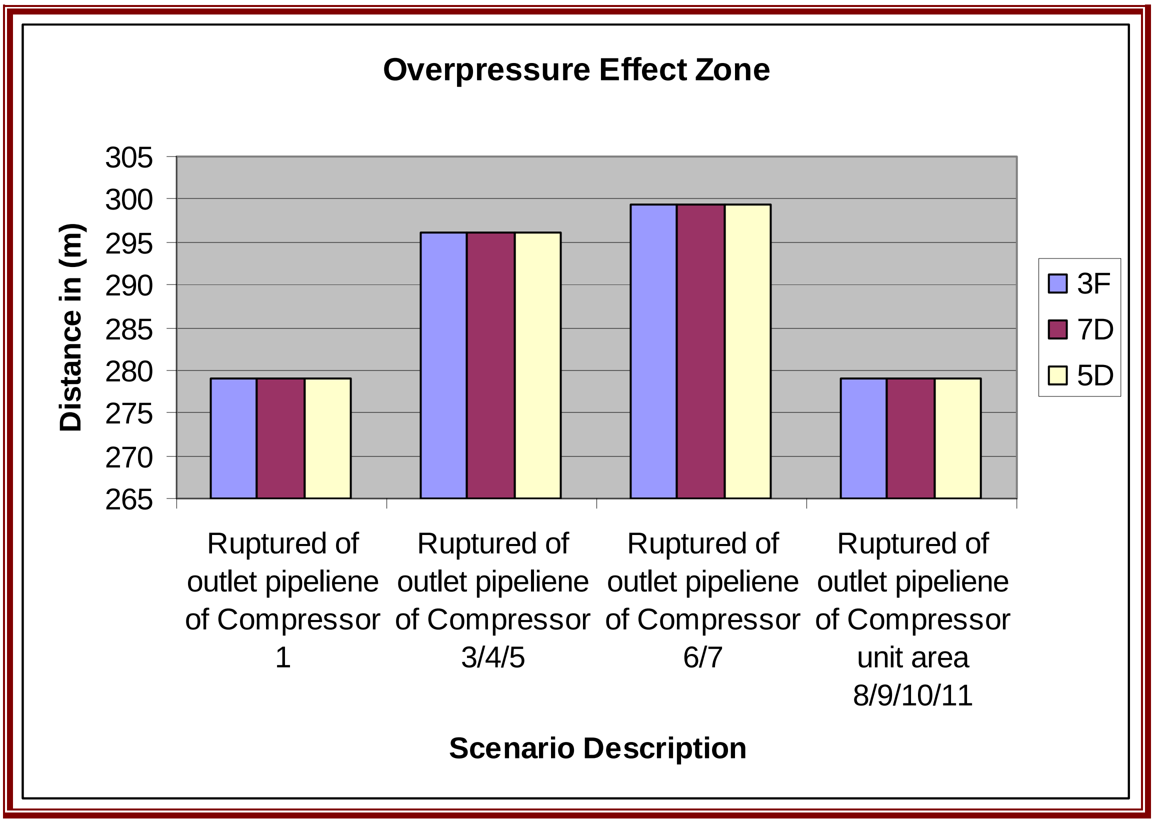


Figure 11 **Overpressure damage distance in case of catastrophic rupture**

All pipelines are underground. The only way of finding exposed pipeline at booster station only. At the time of leakage or catastrophic rupture heat radiation traveled a very few distance from the leakage point. As per the consequence results it is found that heat radiation effect as well as overpressure effect seems very low

GENRAL INFORMATION

Basics of natural gas

Natural gas is an excellent source of energy for your home or business. It is economical, reliable and safe for the environment, but like all sources of energy, it should be used wisely. Always remember safety first when operating natural gas appliances of any kind.

Natural gas is a nontoxic, colorless, and odorless fuel that is lighter than air. This lighter-than-air quality is an important safety factor. If a leak occurs, natural gas will mix readily with air and rise into the atmosphere. As a safety measure the natural gas that is piped to your home or business has a harmless odor similar to rotten eggs so that you can easily detect even the smallest amount of gas that might escape.

From design and construction to operations and maintenance, natural gas utilities like ours set high standards to keep natural gas pipelines incident-free.

Detection of natural gas

Natural gas is one of the safest, most reliable and environmentally friendly fuels in use today, but leaks can occur. There are three key ways to recognize a natural gas leak.

Look. Blowing dirt, bubbling creeks or ponds, dry spots in moist areas or dead plants surrounded by green, live plants also may indicate a natural gas leak.

Listen. An unusual hissing sound near gas lines or appliances may indicate a natural gas leak.

Smell. In it's raw state, natural gas is colorless and odorless. Natural gas utility companies, like Clearwater Gas, add a substance called mercaptan to create the familiar, rotten-egg-like odor usually associated with natural gas. You should take action even if you detect only a faint odor of natural gas in the air.

NATURAL GAS SAFETY TIPS

Here are some key words to help you remember what to do if a natural gas leak is suspected:

Leave. Leave the area immediately. Do not try to find or stop the leak.

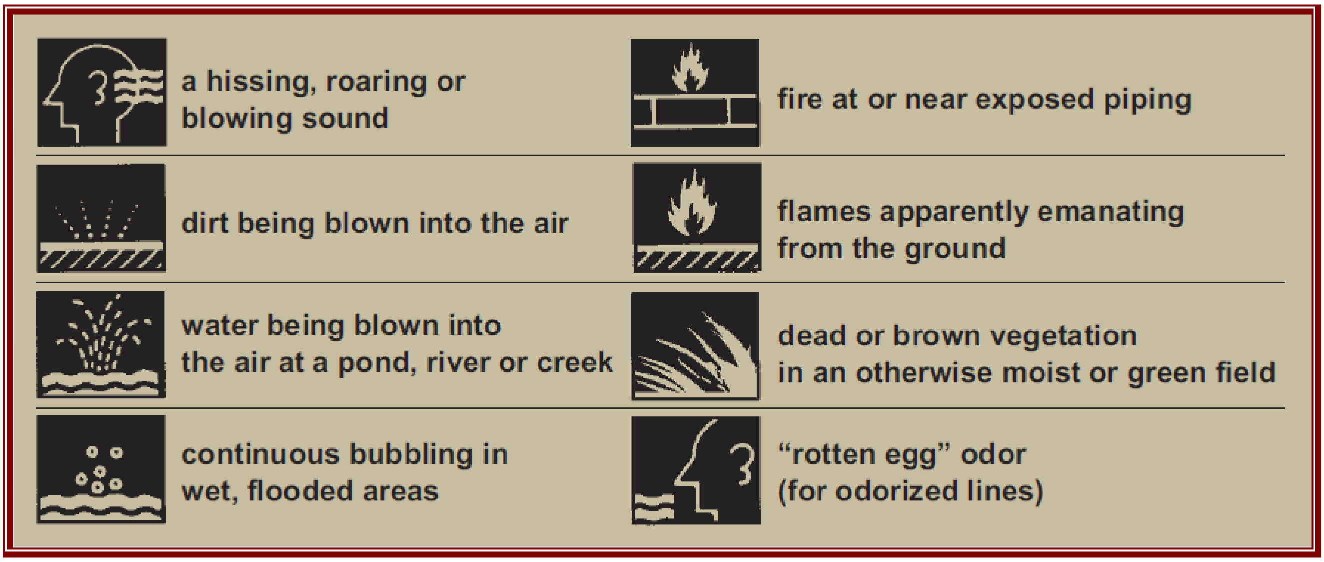
Don't touch. Do not smoke, use a cell phone, flashlight, turn on or off any lights or appliances or operate any kind of vehicle or equipment that could create a spark.

Dial.

If a leak is suspected near a natural gas transmission pipeline, call the number on the pipeline marker. If the smell of gas is particularly strong, or no number is available, hen immediately inform to nearest help center, because pipelines are underground, line markers are used to indicate the approximate location of the pipelines. However, these markers do not indicate how deep the pipeline is buried. The pipeline route can also take twists and turns between markers. Never assume the pipeline lies in a straight line. Always dial before dig

How to identify a leak or failure

One or more of the following signs may indicate a natural gas pipeline leak or failure:



Meeting Safety Standards and More

The design and construction of transmission in Canada are guided by strict regulations made by the National Energy Board (NEB) These standards regulate pipe wall thickness, protective pipe coatings, depth of burial, operating pressures, public safety and system integrity management. These standards are considered the highest in the world.

Brunswick Pipeline prides itself on implementing safety measures that meet or exceed these federal regulations, We took many precautions in the design and construction of the Brunswick Pipeline – because no business objective is more important than the safety of people living and working around the pipeline. Our pipeline includes a broad array of safety features:

- High quality steel and testing at manufacture.
- Application of fusion bond epoxy coating to protect the pipeline against corrosion.
- Cathodic protection (impressed current on the pipeline) to protect against corrosion.
- Specialized welding techniques.
- X-ray or ultrasonic testing of each weld.
- Pre-operation hydrostatic tests to verify structure integrity under extreme pressure.

Safety in Operations

In addition to the features built into the pipeline are safety practices followed in operations to protect the installed pipeline:

- 24 hr/day, 7 days/week monitoring of gas flow pressures
- Plan for rapid pressure loss on the pipeline through a series of valves along the route
- Pipeline marker signs to identify the area where the pipeline is buried .
- Public awareness program to remind people to call before they dig near the pipeline
- Regular mobile patrols to guard against unauthorized activity
- Leakage surveys
- Periodic in-line inspections using sophisticated electronic equipment will check for changes in the steel pipe wall
- Security management plan, including random patrols of cell above ground facilities and the use of other modern security protocols
- Emergency Response Plan, developed with input from local and provincial emergency responders
- Ensure first responders have the training needed to deal with pipeline emergencies
- Always follow “Dial before dig”

Observations during the study

- Online odourization system is not installed in any grid. Process has started for implementation of the same as conformed by them
- No portable/ online gas detector is available at any of the PRS. No gas detector used by them to detect leakages for natural gas. However they have agreed to procure immediately portable gas detectors for CGD. AGCL have gas detector for Compressor station.
- Radiography test record available for some of the welding joints of steel pipelines. However now in new projects they are following T4S norms as confirmed by AGCL
- Safety precaution taken during testing and commissioning are not available.
-
- Radiography test record available for some of the welding joints of steel pipelines. However now in new projects they are following T4S norms as confirmed by AGCL.
- No as built pipe layout drawing is available for old network. However they have prepared layout drawing for reference as confirmed by AGCL. For new projects they are implementing PNGRB regulation (T4S) as per AGCL.
- Detail inspection report for trenching, lowering, backfilling, mechanical clearance etc. are not available for any of the STPL pipeline ranging from 2" NB to 4" NB.
- Piping simulation software for verification of gas velocity is not available.
- GIS presently not available. However AGCL has confirmed that process has started for implementation of GIS system.
- PE pipes and fittings used for underground piping system conform to ISO 4437 & ISO 8085 as per PNGRB regulation and verified from order copy and MTC provided by AGCL. For extension /new upcoming pipeline MDPE pipes are used and Electro fusion welding process has started. However for old network HDPE pipe along with butt welding process were used earlier.
- Display board indicating the PRS are not available in most of the installation.
- Contact no. during any emergency is not displayed in any PRS. However these are displayed in different grid offices.
- Vent lines are either not available or installed at lesser heights than recommended (3 meters above working level) as per PNGRB norm.
- Approach to the PRS and its housekeeping needs to be improved.

- Safety precaution taken during testing and commissioning are not available.
- Pipeline markers are available for Steel and PE pipe network at few locations. However this need to be further improved as per T4S requirements.
- Color coding has been maintained for pipe line network including GI Piping inside the premises of domestic and commercial consumers. However at few locations this needs to be improved further to meet T4S requirements.
- Safety rules and Dos & Don't's are not displayed in most of the PRS and consumers establishments. Need to be improved further to meet T4S requirements.
- Customer owned IPRS installations & downstream piping shall be certified by third party agency and recertification has to be insured by AGCL as to complied T4S regulation. Initial Certification is available with AGCL and checked from records in few of the cases however AGCL has confirmed that they are compiling this but recertification process has to be taken up to meet the regulation.
- As per evidence provided, valves in PE and steel network are vary widely spaced having distances between successive valves are more than 1 Km and 3 Km in PE and Steel network respectively. However on road/river/rail etc. crossing valves upstream and downstream have been provided but needs to be improved further to meet T4S requirements.
- AGCL confirmed that PE network Contains Cast Iron valves at few locations which would replaced at the earliest with steel valves.
- Test certificate are not available for fasteners as per PNGRB norms they should conform to ASTM A153- for hot dip galvanizing. But AGCL confirmed that for further procurement they will compile with T4s regulation.
- Latest edition codes and standards for construction like API 1104, API 5L etc. to be procure however old edition are available.
- HSE management plan is not in force at present. However order place on organization for implementation of the same as per document provided by AGCL.
- No fire protection system available at any of the PRS.

- Following manuals/standards are not available with the entity
    i. EPA 1986 and rules
    ii. Weights and measure rules Act
    iii. Operating manual including start up shut down and emergency Response and disaster management plan.
    iv. Safety manual.

REFERENCES

1. Quantitative Risk Assessment-M.J Borysiewiez, M.A. Borysiewiez, L.Garanty, A. Kozubal
2. Guide to Manufacture, Storage and Import of Hazardous Chemicals Rules (MSIHC), 1989 issued by the ministry of environment and forests, (MoEF) Govt.of India as amended up to date.
3. World Bank Technical papers relating to "Techniques for assessing Industrial Hazards".
4. Major Hazard Control by ILO.
5. Risk Management Program guidelines by EPA (US)
6. World Bank Technical Paper no. 55 – Technica ltd. For assessing hazards – A Manual.
7. PHAST v 6.53-Software
8. Overall plot plan
9. MSDS for Methane, Ethane, Propane, Butane ,Pentane, Hexane, Carbon dioxide, nitrogen

APPENDIX A: ASSUMPTIONS AND RULE SETS

TOPIC:	**Process Material Characterization**
APPLICABILITY:	Consequence Analysis

DATA / RULE SET:	ASSUMPTIONS:
The flow, densities, temperatures and pressured of the streams are taken directly from Heat & Mass Balances supplied for the Project.	
Multi-component process streams have been simplified for release consequences purposes. This is achieved by modeling them as a single stream based on review of molar fraction stream compositions and taking the most representative stream.	It is assumed that the simplification of multi-component process streams will not affect the results. The most representative stream is considered based on the stream that has a potential to cause maximum harm, the effect is likely to be more conservative.

LIKELY EFFECT ON RESULT:

The simplification of multi-component process streams is likely to affect the consequence analysis results such as dispersion, radiation and explosion. The results are likely to be more conservative thus exaggerating the risk slightly.

REFERENCE:

Heat and Material Balance

TOPIC:	**Leak Sizes**	
APPLICABILITY:	Consequence Analysis	
DATA / RULE SET:		**ASSUMPTIONS:**
Leak sizes are defined in terms of diameters of nominally circular holes.		Although real holes in process equipment are unlikely to be circular, the release rate depends on the hole area and is largely independent of the hole shape.
Leak sizes considered for the study are 0-5 mm leak is represented as 5mm 5-25 mm leak is represented as 25mm 25-100mm leak is represented as 100mm >150mm is represented as Rupture		
LIKELY EFFECT ON RESULT:		
The hole sizes will affect the release rate, dispersion, jet fire, pool fire and other consequence analysis results		
REFERENCE:		
CMPT – DNV Technica		

TOPIC:	Release, Isolation and Blowdown
APPLICABILITY:	Consequence Analysis

DATA / RULE SET:	ASSUMPTIONS:
For releases, the quantities available for release are taken as the total isolatable inventory within each section of plant. This assumes that a release occurs at the lowest point of each section.	This approach is conservative for low pressure systems because loss of containment events may occur at elevations above the lowest point hence limiting the quantity of liquid available for release. Considering the lowest point of release also covers release of gas. Operating inventory is considered to be 10% below the Level Safety High (LSH) level of the equipment
For cases where isolation fails, adjacent section inventories are added to the release. This will therefore increase the quantity of material released and duration of release.	Isolation is assumed to be provided by ESD valves of any other valves connected to ESD system. ESD operates as Safety Level 4
Pool fires are restricted by bunds and kerbs wherever applicable. Drainage may have a positive benefit in the reduction of the size of running pool fires. However, this scenario is not considered. Liquid releases are assumed to form circular pools.	The extent of pool spread will be limited by factors such as bunding, kerbing, general layout arrangements and ground elevation and type.
Isolation is assumed to automatically take place after confirmed fire detection (by fire detectors / manual).	The total isolation time is assumed to be a function of detection time, response time and shutdown time (isolation time = detection time + response time + shutdown time). The isolation time is assumed to be 5

TOPIC:	Release, Isolation and Blowdown
APPLICABILITY:	Consequence Analysis

DATA / RULE SET:	ASSUMPTIONS:
	min, considering the time required for ignition (delayed ignition time considered for conservative results), response time (automatic / manual whichever is greater) and ESD valve shutdown time. Fire detection loop is with coverage criteria of 15m per detector.
Draining is not offered any credit in risk reduction	Drain valves are assumed to be manual. Manual draining valves are assumed to be impaired under fire conditions.
De-pressurization is achieved through blowdown system	The blowdown system is assumed to depressurize the isolated inventory to lower pressure or 50% of the initial system pressure (whichever is less) within 15 minutes (maximum), as per API 521. De-pressurization is assumed to take place for 15 min
Consequence time steps are considered in consequence analysis	Upto 5 minutes, the release is assumed to be determined by full inventory at operating pressure From 5 to 20 min, the release is assumed to be the hold-up inventory in the section released at operating pressure After 20 min, the release is assumed to be the remaining hold-up inventory in the section released at 50% operating pressure Time steps continue until exhaustion

TOPIC:	**Release, Isolation and Blowdown**
APPLICABILITY:	Consequence Analysis
DATA / RULE SET:	**ASSUMPTIONS:**
	of inventory
LIKELY EFFECT ON RESULT:	
The above assumptions are likely to affect the release rate, dispersion, jet fire, pool fire and other consequence analysis results	
REFERENCE:	
CMPT – DNV Technica API 521	

TOPIC:	Data Sources
APPLICABILITY:	Frequency / Probability Analysis

DATA / RULE SET:	ASSUMPTIONS:
Part counts are performed from P&IDs and plot plans to determine the numbers of components in each isolatable section.	--
Application of generic failure data, such as TNO Purple Book or E&P Forum to the part count will provide a schedule of release frequencies for each section for loss of containment representative	--
Material reactivity index is used for determining the ignition probability purple book	--

LIKELY EFFECT ON RESULT:

The frequency / probability analysis data sources will affect the frequency analysis conducted for the QRA

REFERENCE:

E&P Forum QRA Directory by SINTEF

Guidelines for Quantitative Risk Assessment, "Purple Book", CPR 18E, Committee for the Prevention of Disaster, 1999

TOPIC:	Vulnerability of Personnel
APPLICABILITY:	Vulnerability Assessment
DATA / RULE SET:	**ASSUMPTIONS:**
Flash Fire Within LFL indoor fatality probability 1.0 outdoor fatality probability	General Industry / Regulator assumption
Explosion 20 mbar 0 indoor fatality probability 0.01 outdoor fatality probability 140 mbar 0 indoor fatality probability 0.3 outdoor fatality probability 210 mbar 0.56 indoor fatality probability 0.3 outdoor fatality probability	Use of explosion probit = 1.47 + 1.35 ln (P), where P is the pressure in psi Indoor fatality probability based on CIA fatality vulnerability curve for hardened structure building
Fireball 500 tdu 0 indoor fatality probability 0 outdoor fatality probability 1000 tdu 0 indoor fatality probability 0.02 outdoor fatality probability 1800 tdu 0.24 indoor fatality probability 0.24 outdoor fatality probability	Based on probit = -38.48 + 2.56 ln $[(W/m^2)^{4/3}T]$ tdu where tdu is the thermal dose unit in $kW/m^2)^{4/3}sec$ and exposure time T is the fire ball duration in seconds
Jet Fire 5 KW/m^2 0 indoor fatality probability <0.01 outdoor fatality probability 12.5 KW/m^2	Based on probit = -38.48 + 2.56 ln $[(W/m^2)^{4/3}T]$ where exposure time T is in seconds and maximum exposure time is 20 sec A fixed 20 sec exposure time is

TOPIC:	Vulnerability of Personnel
APPLICABILITY:	Vulnerability Assessment
DATA / RULE SET:	**ASSUMPTIONS:**
0 indoor fatality probability <0.01 outdoor fatality probability 37.5 KW/m^2 0.56 indoor fatality probability 0.56 outdoor fatality probability	assumed for jet fires 100% fatality for any person found inside the jet fire
Indoor vulnerability for fireballs, pool fires, jet fires.	If out door thermal radiation (in KW/m^2) > 12.5 outdoor, people would attempt to escape outdoors giving indoor fatality probability = outdoor fatality probability If out door thermal radiation (in KW/m^2) < 12.5 outdoor, building is assumed to provide complete protection (unless impingement) and indoor fatality probability = 0
LIKELY EFFECT ON RESULT:	
The vulnerability will affect the risks determined for the worker groups	
REFERENCE:	
Methods of the determination of possible damage, “Green Book”, CPR 16E, TNO 1992	

TOPIC:	**Critical Steel Temperatures and Times to Failure of Vessels, Pipeworks and Structural Steelwork.**
APPLICABILITY:	Vulnerability Assessment

DATA / RULE SET:	**ASSUMPTIONS:**
When a steel vessel, pipe or structure is exposed to fire and/or thermal radiation, the steel temperatures increases. The mechanical properties of the steel are highly dependent on temperature and it is necessary to prevent steel from reaching a critical temperature to prevent failure. This depends on the stresses to which it is subjected and to a certain degree of steel type. The critical steel temperature will normally be in the range 400-550 deg. C. However in some situations where the steel is subject to high levels of stress the critical steel temperature may be lower than this range. In other situations, lower levels of stress may lead to higher critical steel temperatures.	Time to unprotected process equipment failure is based upon 5 min jet fire impingement Pipe rack supports, equipment supports are assumed to be passive fire protected for at least 15 min Buildings in the process area are assumed to be protected against 30 min against direct flame impingement

LIKELY EFFECT ON RESULT:	
The vulnerability will affect the escalation risks	
REFERENCE:	

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AMENDMENT SHEET (To Issue 01)

Sl. No.	Section No.	Page No.	Amendment Particulars	Effective Date	Signature (Amendment incorporated)

This Document is

Approved By	**B. Borpatragohain, Managing Director**
Signature	
Controlled By	**S. Tamuli, Sr. Manager – TS**
Signature	