7.1 RISK ASSESSMENT

7.2.1 INTRODUCTION

The increasing diversity of products manufactured by chemical process industries and their transportation to various terminals has made it more and more common for these industries to use hazardous substances at elevated temperatures and/or pressures. The scale of possible fire and explosion has grown and so the area, which might be affected by such events, especially along the pipeline route. Increasing concern has, therefore, prompted the Ministry of Environment and Forests (MoEF), Government of India, to make risk assessment a mandatory requirement for chemical industry.

Accidental risk involves the occurrence or potential occurrence of some accident consisting of an event or sequence of events resulting into fire, explosion or toxic hazards to human health and environment. Risk Assessment (RA) provides a numerical measure of the risk that a particular facility poses to the public. It begins with the identification of probable potential hazardous events and categorization as per the predetermined criteria. The consequences of major credible events are calculated for different combinations of weather conditions to simulate worst possible scenario. These consequence predictions are combined to provide numerical measures of the risk for the entire facility.

MCA stands for **Maximum Credible Accident** or in other words, an accident with maximum damage distance, which is believed to be probable. MCA analysis for a proposed project does not include quantification of the probability of occurrence of an accident. In practice the selection of accident scenarios for MCA analysis is carried out on the basis of past accident analysis at similar projects, engineering judgement and expertise in the field of risk analysis especially in accident analysis.

For proposed Gujarat State Petronet Limited (GSPL) natural gas pipeline, “Emergency Response Disaster Management Plan” has been prepared and approved by Petroleum Natural Gas Regulatory Board (PNGRB)

M/s. Gujarat State Petronet Limited (GSPL) proposes to lay a network of gas pipeline for the supply of natural gas to various consumers. GSPL is developing a gas pipeline transmission network “Gas Grid” across the State of Gujarat. GSPL proposed to lay a pipeline from Anjar to Chotila in Gujarat State.

The report covers risk assessment study for above mentioned pipeline. International guidelines and software have been used to carry out the study. Mitigation measures have been recommended based on the consequence analysis. Disaster Management Plan (DMP) has been delineated to tackle onsite and offsite emergencies.

7.2.2 OBJECTIVES

The objectives of the study are as follows:

- Study of past accidents information to identify worst accident scenarios
- Identification of hazards through computation of indices
- Generation of credible and worst case scenarios for accidental release of natural gas during transportation

- Computation of damage distances through maximum Credible Accident (MCA) Analysis at various heat loads, wind velocities and atmospheric stability classes for fire and explosion scenarios
- Assessment of the magnitude and severity of the impact in terms of damage to property and injury to personnel
- Recommendation of risk mitigation measures to improve overall safety, prevent fire and explosion and implement emergency response plan.
- Delineation of approach to Emergency Response Disaster Management Plan (ERDMP) to tackle on-site and off-site emergency situations.

7.2.3 APPROACH

The steps involved in Risk assessment (RA) study are detailed below:

7.2.3.1 Identification of Hazards

This shall involve a detailed study of all areas and operations for natural gas evacuation proposes with a view to identify potential physical hazards which could trigger loss causing events such as fire, explosion, toxic release etc. The identification of hazards comprises the following activities.

- Collection of relevant information of the facility
- Computation of Fire and Explosion Indices to categories the hazards according to their general level of risk

7.2.3.2 Hazard Assessment and Evaluation

Hazardous operations would be critically examined with recourse to Maximum Credible Accident (MCA) analysis in order to arrive at risk posed to the surrounding population using software tools like "**Effect**". The maximum damage distances due to accidental release of Natural Gas will be computed for fire and explosion scenarios. The extent of damage will be assessed at various wind velocities, atmospheric stability classes for different heat loads and overpressure waves.

7.2.3.3 Risk Mitigation Measures

Risk mitigation measures towards minimization of onsite and offsite risk identified in the study will be detailed. Risk reduction measures will be recommended based on consequence analysis. The measures will be suggested to bring down risk to As Low as Reasonably Practicable (ALARP).

7.2.3.4 Approach to Disaster Management Plan

An Emergency Preparedness/Management Plan lists out the accidents and the management of such emergencies, if ever they occur due to handling or processing activities related to hazardous materials of GSPL Pipeline. The management plan will be in accordance with national and international regulations like OISD, OSHA, API etc. The DMP will be delineated for on-site and off-site scenarios. Roles and responsibilities of key personnel will be outlined.

7.3 PROJECT DESCRIPTION

GSPL is developing a Gas Pipeline Transmission Network "Gas Grid" across the State of Gujarat, connecting all major supply sources. GSPL proposes to lay a pipeline from Anjar to Chotila in Gujarat covering a length of 196.14 km.

7.3.1 Need of Project

India has been witnessing rapid urban and industrial growth in the past two decades, and with the country's current liberalization policy this growth is expected to accelerate and need additional energy for development. As a consequence of the rapid rate of industrialization in India, fuel needs are increasing at an equally rapid rate and the supply-demand gap is widening and steps must be taken to address this issue. Overland transport of fuels by trucks is uneconomical, unsafe, and is a contributor to environmental degradation in terms of the fuel consumed and pollutants released by vehicles in transit and by accidents and spillages (common on Indian roads). Pipelines are internationally recognized as the preferred alternative for transport of fuels from the point of view of safety, economy and relative environmentally friendliness. The qualities of underground pipelines that make them desirable from these angles are that they are buried underground (at a minimum depth of 1-1.2 m), are controlled by SCADA systems which allow continuous monitoring and rapid closure of valves, etc., and that they are routed to avoid human settlements and ecologically sensitive areas.

Currently, developing countries, like India, which are signatories to various international treaties, do not have any commitment to reduce emission of greenhouse gases. However, in the near future, when India among other developing countries may have to show reduced greenhouse gas emissions intensity per unit of GDP than in the past, any environment-friendly project would be encouraged. At any rate, even without global pressures, local environmental considerations would favour a move towards projects that would contribute to reducing environment pollution. This pipeline and associated facilities project is a step forward in achieving this objective.

The pipeline will result in decongestion of roads, eventually minimizing road accidents and environmental pollution that are generated by other means of transport. This includes both air as well as noise pollution. The pipeline, being underground, will also provide lesser direct contact with the populace thereby reducing its impact as well as provide better overall security.

The road and rail transportation systems, at present, have to share the load of transporting raw materials and finished products from the supply centres to the demand / consumer centres. Rail transport is utilized for carrying bulk of the petroleum products throughout the country and the balance quantity is transported by road. This is stretching the transport sector capacity and hindering the movement of other essential raw materials and products.

Transportation of gas by pipeline is comparatively less expensive than the other modes of transport both in the capital and operating costs. If a good network of pipelines is implemented throughout the country, this will ensure that the pipeline transported products will be available to the consumers at a lower cost than alternate modes of transport.

7.4 MAXIMUM CREDIBLE ACCIDENT (MCA) ANALYSIS

Risk Evaluation

Accidental risk involves the occurrence or potential occurrence of some accident consisting of an event or sequence of events resulting into fire, explosion or toxic hazards to human health and environment.

Risk Assessment (RA) provides a numerical measure of the risk that a particular facility poses to the public. It begins with the identification of probable potential hazard events at an industry and categorization as per the predetermined criteria. The consequences of major credible events are calculated for different combinations of weather conditions to simulate worst possible scenario. These consequence predictions are combined to provide numerical measures of the risk for the entire facility.

MCA stands for Maximum Credible Accident or in other words, an accident with maximum damage distance, which is believed to be probable. MCA analysis does not include quantification of the probability of occurrence of an accident. In practice the selection of accident scenarios for MCA analysis is carried out on the basis of engineering judgement and expertise in the field of risk analysis especially in accident analysis.

Detailed study helps in plotting the damage contours on the detailed plot plan in order to assess the magnitude of a particular event. A disastrous situation is the outcome of fire, explosion or toxic hazards in addition to other natural causes that eventually lead to loss of life, property and ecological imbalances.

7.4.1 Methodology of MCA Analysis

The MCA analysis involves ordering and ranking of various sections in terms of potential vulnerability. The data requirements for MCA analysis are:

- Operating manual
- Flow diagram and P&I diagrams
- Detailed design parameters
- Physical and chemical properties of all the chemicals
- Detailed plant layout
- Detailed area layout
- Past accident data

Following steps are involved in the MCA analysis:

- Identification of potential hazardous sections and representative failure cases
- Visualization of release scenarios considering type and the quantity of the hazardous material

- Damage distance computations for the released cases at different wind velocities and atmospheric stability classes for heat radiations and pressure waves
- Drawing of damage contours on plot plan to show the effect due to the accidental release of chemicals

7.4.2 Past Accident Data Analysis

Analysis of events arising out of the unsafe conditions is one of the basic requirements for ensuring safety in any facility. The data required for such an analysis has either to be generated by monitoring and/or collected from the records of the past occurrences. This data, when analysed, helps in formulation of the steps towards mitigation of hazards faced commonly. Trends in safety of various activities can be evaluated and actions can be planned accordingly, to improve the safety.

Data analysis helps in correlating the causal factors and the corrective steps to be taken for controlling the accidents. It is, therefore, of vital importance to collect the data methodically, based on potential incidents, sections involved, causes of failure and the preventive measures taken. This helps to face future eventualities with more preparedness.

- **27th April 1985 failure of pipeline due reduction in pipe wall thickness by atmospheric corrosion**

This report describes the rupture of a 30 inch natural gas pipeline in a rural area near to Beaumont, Kentucky, USA at 09:10 on 27th April 1985. The failure was caused by a reduction in pipe wall thickness due to atmospheric corrosion. The resulting fire burned an area about 213m long and 152m wide.

- **February 21St 1986 Lancaster, Kentucky**

This report describes the rupture of a 30 inch natural gas pipeline at Lancaster, Kentucky, USA at 02:05 on February 21st 1986. The failure was caused by a reduction in pipe wall thickness due to corrosion following insufficient protection. The resulting fire burned an irregular area of about 6 hectares.

- **February 15th, 1994 Burstall (Maple Creek), Saskatchewan, Canada**

This report describes the rupture of 42-inch natural gas pipeline near Maple Creek, Saskatchewan, Canada which occurred at approximately 19:40 mountain standard time (MST), on 15 February 1994. The rupture was caused by ductile fracture of a de-lamination in the mid-wall of the pipe as a result of diffusion of atomic hydrogen at inclusions in the pipe steel during normal pipeline operations.

- **April 15th 1996 La Salle, River Crossing, Manitoba, Canada**

This report describes the rupture of a 864-millimetre pipeline under a river in Canada which occurred at 18:15 eastern standard time (EST), on 15 April 1996. It was followed by an explosion and fire at 18:29 EST these igniting a house 178.1 m south of the rupture site. Trees and other vegetation on both sides of the river were damaged or destroyed, 97,800 m^3 of natural gas was lost.

- **May 2010, Trans Alaska Pipeline System, USA**

During a routine maintenance check, power went out, causing a valve to open and channel oil into a storage tank, which overflowed. Oil streamed into a bermed secondary containment area. That containment area is lined with an impermeable liner and state and company officials say no oil escaped from the area about 5,000 barrels, making it the third-largest spill ever from the 800-mile pipeline.

7.4.3 Hazard Identification

Identification of hazards is an important step in Risk Assessment as it leads to the generation of accidental scenarios. The merits of including the hazard for further investigation are subsequently determined by its significance, normally using a cut-off or threshold quantity.

Once a hazard has been identified, it is necessary to evaluate it in terms of the risk it presents to the employees and the neighboring community. In principle, both probability and consequences should be considered, but there are occasions where it either the probability or the consequence can be shown to sufficiently low or sufficiently high, decisions can be made on just one factor.

During the hazard identification component, the following considerations are taken into account.

- Properties of natural gas
- Location of process unit facilities for hazardous materials.
- The types and design of underground and above ground pipeline systems
- The quantity of material that could be involved in an airborne release
- The nature of the hazard (e.g. airborne toxic vapours or mists, fire, explosion, large quantities stored or processed handling conditions) most likely to accompany hazardous materials spills or releases

7.4.3.1 Fire and Explosion Index (FEI) [1]

Fire and Explosion Index (FEI) is useful in identification of areas in which the potential risk reaches a certain level. It estimates the global risk associated with a process unit and classifies the units according to their general level of risk. FEI covers aspects related to the intrinsic hazard of materials, the quantities handled and operating conditions. This factor gives index value for the area which could be affected by an accident, the damage to property within the area and the working days lost due to accidents. The method for evaluation of FEI involves following stages.

- Selection of pertinent pipeline system which can have serious impact on pipeline safety
- Determination of Material Factor (MF): This factor for a given substance in the process unit gives intrinsic potential to release energy in case of fire or an explosion. Material Factor can be directly obtained from Dow's Fire and Explosion Index Hazard classification Guide of American Institute of Chemical Engineers, New York. The factor can also be evaluated from NFPA indices of danger, health, flammability and reactivity.
- Determination of Unit Hazard Factor: The Unit Hazard Factor is obtained by multiplication of General Process Hazard (GPH) factor and Special Process Hazard (SPH) factor. GPH factor is computed according to presence of exothermic reactions and loading and unloading operations. The penalties due to each of these reactions / operations are summed up to compute GPH factor. Similarly, SPH factor can be evaluated for the operations close to

flammable range or pressures different from atmospheric. Penalties of these operations for both factors can be obtained from Dow's FEI index form.

Fire and explosion index is then calculated as the product of Material Factor (MF) and Unit Hazard Factor. Degree of hazards based on FEI is given in the following **Table 7.1**.

Preventive and protective control measures are recommended based on degree of hazard. Therefore, FEI indicates the efforts to be taken to reduce risks for a particular unit. FEI computed for various pipeline are given in **Table 7.2**.

7.4.4 MCA Analysis

MCA analysis encompasses defined techniques to identify the hazards and compute the consequent effects in terms of damage distances due to heat radiation, toxic releases, vapour cloud explosion etc. A list of probable or potential accidents of the major units in the complex arising due to use, storage and handling of the pipeline natural gas is examined to establish their credibility. Depending upon the effective hazardous attributes and their impact on the event, the maximum effect on the surrounding environment and the respective damage caused can be assessed. Flow chart of accidental release of pipeline natural gas is presented in **Figure 7.1**.

Hazardous substance, on release can cause damage on a large scale. The extent of the damage is dependent upon the nature of the release and the physical state of the material. In the present report the consequences for flammable hazards are considered and the damages caused due to such releases are assessed with recourse to MCA analysis.

Flammable substances on release may cause Jet fire and less likely unconfined vapour cloud explosion causing possible damage to the surrounding area. The extent of damage depends upon the nature of the release. The release of flammable materials and subsequent ignition result in heat radiation wave or vapour cloud depending upon the flammability and its physical state. Damage distances due to release of pipeline natural gas depend on atmospheric stability and wind speed. It is important to visualize the consequence of the release of such substances and the damage caused to the surrounding areas. Computation of damage distances are carried out at various atmospheric stability conditions for various wind velocities and the result is tabulated. Pasquill-Giffard atmospheric stability classes with corresponding weather conditions are listed in **Table 7.3**.

7.4.4.1 Fire and Explosion Scenarios

Combustible materials within their flammable limits may ignite and burn if exposed to an ignition source of sufficient energy. On process plants, this normally occurs as a result of a leakage or spillage. Depending on the physical properties of the material and the operating parameters, the combustion of material in a plant may take on a number of forms like jet fire and flash fire.

- **Jet Fire**

Jet fire occurs when flammable material of a high exit velocity ignites. In process industries this may be due to design (flares) or an accidental. Ejection of flammable material from a vessel, pipe or pipe flange may give rise to a jet fire and in some instances the jet flame could have substantial "reach". Depending on wind speed, the flame may tilt and impinge on pipeline, equipment or structures. The thermal radiation from these fires may cause injury to people or damage equipment some distance from the source of the flames.

- **Flash Fire**

A flash fire is the non-explosive combustion of a vapour cloud resulting from a release of flammable material into the open air, which after mixing with air, ignites. A flash fire results from the ignition of a released flammable cloud in which there is essentially no increase in combustion rate. The ignition source could be electric spark, a hot surface, and friction between moving parts of a machine or an open fire.

Flash fire may occur due to its less vapour temperature than ambient temperature. Hence, as a result of a spill, they are dispersed initially by the negative buoyancy of cold vapours and subsequently by the atmospheric turbulence. After the release and dispersion of the flammable fuel the resulting vapour cloud is ignited and when the fuel vapour is not mixed with sufficient air prior to ignition, it results in diffusion fire burning. Therefore the rate at which the fuel vapour and air are mixed together during combustion determines the rate of burning in the flash fire.

The main dangers of flash fire are radiation and direct flame contact. The size of the flammable cloud determines the area of possible direct flame contact effects. Radiation effects on a target depend on several factors including its distance from the flames, flame height, flame emissive power, local atmospheric transitivity and cloud size. Most of the time, flash combustion lasts for no more than a few seconds.

- **Vapour Cloud Explosion**

The Vapour Cloud Explosion (VCE) begins with a release of a large quantity of flammable vaporizing liquid or gas from a storage tank, transport vessel or pipeline producing a dangerous overpressure. These explosions follow a well-determined pattern. There are basically four features, which must be present for an effective vapour cloud explosion to occur with an effective blast. These are:

  - The release of natural gas must be flammable and at a suitable condition of temperature and pressure which depends on the properties natural gas. The materials which come under this category, range from liquefied gases under pressure (e.g. butane, propane); ordinary flammable liquids (e.g. cyclohexane, naphtha) to non-liquefied flammable gases (e.g. ethylene, acetylene)
  - Before the ignition, a cloud of sufficient size must have been formed. Normally ignition delays of few minutes are considered the most probable for generating the vapour cloud explosions
  - A sufficient amount of the cloud must be within the flammable range of the material to cause extensive overpressure
  - The flame speed determines the blast effects of the vapour cloud explosions, which can vary greatly

The flammable content of a gas cloud is calculated by three-dimensional integration of the concentration profiles, which fall within the flammable limits. If the gas cloud ignites, two situations can occur, namely non-explosive combustion (flash fire) and explosive combustion (flash fire + explosion).

- **Lower and Upper Flammability Limit**

In case of any spillage and leakages of hydrocarbons / flammable material, probability of getting ignited is depending on whether the air borne mixture is in the flammable region. The Lower flammability limit corresponds to minimum proportion of combustible vapour in air for combustion. The Upper flammability limit Correspond to maximum proportion of combustible vapour in air for combustion and the concentration range lying between the lower and the upper limit is called as flammable range. For natural gas, Lower Explosive Limit (LEL) is 5 % at (NTP, 1992) whereas Upper Explosive Limit (UEL) is 15 % at (NTP, 1992).

7.4.4.2 Models for the Calculation of Heat load and Shock Waves[2]

If a flammable gas or liquid is released, damage resulting from heat radiation or explosion may occur on ignition. Models used in this study for the effects in the event of immediate ignition and the ignition of a gas cloud will be discussed in succession. These models calculate the heat radiation or peak overpressure as a function of the distance from the torch, the ignited pool or gas cloud. The physical significance of the various heat loads is depicted in **Table 7.4**.

7.4.4.3 Model for Pressure Wave

A pressure wave can be caused by gas cloud explosion. The following damage criteria are assumed as a result of the peak overpressure of a pressure wave:

- 0.03 bar over pressure wave is taken as the limit for the occurrence of wounds as a result of flying fragments of glass
- Following assumptions are used to translate an explosion in terms of damage to the surrounding area:
  - Within the contour area of the exploding gas cloud, Casualties are due to burns or asphyxiation. Houses and buildings in this zone will be severely damaged.
  - In houses with serious damage, it is assumed that one out of eight persons present will be killed as a result of the building collapse. Within the zone of a peak over pressure of 0.3 bar the risk of death in houses is 0.3 x 1/8 = 0.0375, and in the zone with a peak over pressure of 0.1 bar the probability of death is 0.1 x 1/8 = 0.0125, i.e. one out of eighty people will be killed.

The significance of the peak over pressure 0.3 bar, 0.1 bar, 0.03 bar and 0.01 bar are depicted in **Table 7.5**.

7.4.5 Computation of Damage Distances

Damage distances for the accidental release of hazardous materials have been computed at different weather conditions. In these conditions 1, 2 and 4 are wind velocities in m/s and F and D are atmospheric stability classes. These weather conditions have been selected to accommodate worst case scenarios to get maximum effective distances. DNV based software **PHAST Micro 6.51** has been used to carry out consequence analysis. Damage distances computed for different pipeline sections are described below:

7.4.6 Results of maximum credible Accident (MCA) Analysis

Identified Maximum Credible Accident scenarios (MCA's) or Maximum credible loss scenario's (MCLS) for GSPL pipeline are BLEVE, VCE and jet /Back fire. Among these three scenarios BLEVE may lead to damage the property of SV station.

However, chances of occurrence of BLEVE and VCE are rarest of rare. In subsequent headings, results of these scenarios are tabulated.

Continuous release of Natural gas through 10 MM, 25 MM, 50 MM bore from 36" Pipeline

The most probable case could be that of a continuous release. Any leakage in the system would result in to a continuous release and the plume may travel down wind. Analyzing downwind concentration, it has been found that NG quantity in air is well within Upper & Lower Explosion Limits (UEL & LEL) up to a considerable distance. Ignition of this plume may results into VCE. The results are tabulated in **Table 7.6.** Damage distance due to VCE after continuous release of NG through 10 mm bore from 36" NG pipeline (462 KG) is presented in **table 7.7**. Similarly continuous release of NG through 25 mm bore from 36" pipeline the results are shown in **table 7.8** and damage distance in **Table 7.9**. The continuous release of NG through 50 mm bore is shown in **table 7.10** and the damage distance in **Table 7.11**.

Catastrophic failure of 36" natural gas pipeline entering into the SV station

Pipeline Sections carrying Natural Gas:

Due to catastrophic failure for any reason or due to major leakage through pipeline joints, valves, etc. results in release of Natural gas in atmosphere in sufficient quantity to form ignition mixture with air. This may lead to vapour cloud explosion due to delayed ignition. Hence, Pipeline sections are also studies for VCE. As same above, 100% of pipeline quantity is considered here for study of VCE.

Following are the sections of pipelines considered for VCE as well for BLEVE:

In compliance to MHISC rules 2000, it is necessary to consider 1000 m pipeline (500 m before and 500 m after) inventory of pipeline which is equal to 33.93 MT. Results of VCE for pipeline section failure are tabulate in **Tables 7.12-7.13**.

Conclusion: Results of VCE scenarios shows that, the damage distances for catastrophic failure of NG pipeline are more as compared to others and all are falling beyond the SV station. It is required to install gas detectors at strategic locations and maintenance of them. Immediate attention to any small leakage can avoid major hazard. However a chance of occurrence is far far remote as mentioned in documentation.

Boiling Liquid Expansion Vapour Explosion (BLEVE) Scenario

A combination of fire and explosion, sometimes referred as fireball, a BLEVE occurs with an intense radiant heat emission in a relatively shorts time interval along with generation of heavy pressure waves and flying fragments of the vessel. As implied by the term, the phenomenon can occur within a vessel or tank or pipeline in which a liquefied gas is kept at a temperature above its atmospheric boiling point. If a pressure vessel fails as a result of a weakening of its structure the contents are instantaneously released from the vessel as a turbulent mixture of liquid and vapor, expanding rapidly and dispersing in air as a cloud. When this cloud is ignited, a fireball occurs, causing enormous heat radiation intensity within a few seconds. This heat intensity is sufficient to cause severe skin burns and deaths at several hundred meters from the vessel, depending on the quantity of the gas involved.

A BLEVE can therefore be caused by a physical impact on a vessel, for example from a traffic accident with a road tanker or a derailment of, or it can be caused by fire impinging upon or engulfing a vessel and thus weakening its structure. A BLEVE involving a 50 tons propane tank can cause third-degree injuries at distances of approximately 200 meters and blisters at approximately 400 meters.

The phenomenon of BLEVE results in the sudden rupture of vessel containing liquefied flammable gas under pressure due to fire impingement. The immediate ignition of the expanding fuel air mixture leads to the intense combustion creating a fireball.

BLEVE is studied for Pipeline sections of 1000 meter entering into the SV station. 100% of total quantity of Natural gas is within the pipeline considered for study of BLEVE scenario. Quantified results for BLEVE scenario is presented in **table 7.14**.

7.5 EVALUATION OF RISK

Risk is quantified in terms of probability of occurrence of hazardous event and magnitude of its consequences as discussed in the earlier part of the report. The probability of occurrence of hazardous event (e.g. failure of a pipeline) has been taken from International standards. The consequence modelling was carried out in order to assess the extent of damage by visualizing accidental release scenarios for pipeline. The risk to the human due to accidental release scenarios is represented in two ways viz. individual risk and societal risk which are described in following sections.

7.5.1 Individual Risk

The individual risk (IR) level is more specifically defined as the Individual Risk Per Annum (IRPA), which is the calculated annual risk loading to a specific individual or group of individuals. Clearly this depends on the amount of time in a year that the individual spends in different risk areas. The individual risk calculation takes account of the fact that people move from one place to another.

When calculating individual risk from major accident scenarios, it is normal to take account of protection by buildings. Individual risk is typically depicted as contour plots on overall plot plan of a facility, the risk level falling off rapidly as one move away from the source of the leak / epicenter of potential explosions.

7.5.2 Societal Risk

Societal risk is used in quantified risk assessment (QRA) studies and is depicted on a cumulative graph called an F/N curve. The horizontal axis is the number of potential fatalities, N. The vertical axis is the frequency per year that N or more potential fatalities could occur, F. This risk indicator is used by authorities as a measure for the social disruption in case of large accidents.

For pipelines there is no single location for an event and the population affected varies along the pipeline route, this curve is not normally generated unless a large group of people can be affected over a reasonable distance.

7.5.3 Risk Acceptance Criteria

The level of risk in QRA study is quantified with an express purpose of comparing against typical acceptable risks. The acceptable risk levels can change with time and place. In context of current exercise, attention is drawn to **Figure 7.2** that show the commonly acceptable individual risks in different designated land zones, viz. plant areas, buildings in plant areas, residential or office complexes, and very large institutional buildings.

7.5.3.1 Tolerability of Risk (IR values)

Although there are differences between the legislation adopted in the various countries, there appears to be broad consensus on the tolerability of risk. The majority of the countries would accept risk levels for the public around 10^{-5}/yr whilst the more stringent countries would set the tolerability level at 10^{-6}/yr. detailed guidelines available from various countries have been presented below.

7.5.3.2 API RP 752

Very similar information is conveyed in API 752 that specially addresses the normally acceptable risk levels for plant buildings and pipeline.

Total Individual Risk*	Action Indicated
> 1.0×10^{-3}	Risk mitigation or further risk assessment is required
1.0×10^{-3} to 1.0×10^{-5}	Risk reduction should be considered
<1.0×10^{-5}	Further risk or assessment reduction need not be considered

*Total maximum individual risk for the maximum exposed individual in the building

7.5.3.3 Acceptable Societal Risks

Acceptable societal risk, in terms of number of people likely to die of a certain contingency and the likelihood thereof, also varies from region to region. Different countries have attempted to set upper bounds for societal risks that may be acceptable. There is a lower bound as well, below which there is no cause for concern. The area between these two curves represents situations wherein judicious reductions / mitigations of risk may be called for. Technically, the zone has been termed as ALARP (as Low As Reasonably Practicable) region, indicating the philosophy behind risk reduction / mitigation.

7.5.3.4 Ignition Probability

Releases of flammable gases vapour or liquids significantly above their normal (NAP) boiling point from onshore underground pipelines running through rural areas is as given below in **Table 7.15** (OGP guidelines).

Releases of flammable gases, vapour or liquids significantly above their normal (Normal Atmospheric Pressure (NAP)) boiling point from onshore cross-country pipelines running through industrial or urban area is as given in **Table 7.16**.

7.5.3.5 Failure Frequencies

The frequency of releases from equipment has been determined by application of generic frequency data available from various sources.

Failure Frequencies for Anjar-Chotila Pipeline have been taken from HSE UK.

The failure frequencies for Natural Gas Pipelines have been presented in **Table 7.17**.

7.5.4 International Risk Criteria

United Kingdom

In the UK the "Control of Major Accident Hazards" (COMAH) regulations are in line with the latest EU "Seveso-2" Directive. The regulations do not formally require a quantitative risk assessment, but the guidance notes make clear that in some circumstances quantification will help or could be asked for by the UK regulator - the Health and Safety Executive (HSE) - and this is often done in practice.

To advise planning authorities on developments around industrial installations, the UK HSE has been developing risk acceptance criteria over the years. A comprehensive treatment of the subject of tolerability of risk was given in a report titled "Reducing Risks Protecting People”. The report repeated the concept and criteria as argued by the Royal Society in 1983. It accepted the concept of tolerable Individual Risk as being the dividing line between what is just tolerable and intolerable and set the upper tolerable limit for workforce fatalities at 10^{-3}/yr (1 in a thousand) for workers and 10^{-4}/yr (1 in 10 thousand) for members of the public. A level at which risks might be broadly acceptable but not altogether negligible was set at 10^{-6}/yr (1 in a million). The region in between would be controlled by the ALARP concept.

ALARP can be demonstrated in a variety of ways, depending on the severity of the worst case scenario. These are expressed in HSE guidance to Inspectors Consultation Draft September 2002. When a QRA is carried out, then the F/N regions are defined as in the **Figure. 7.3**.

Unlike the Netherlands (see below), the potential workforce fatalities are included in the F/N curve.

Canada: Major Industrial Accidents Council of Canada (MIACC)

The MIACC recommend individual risk levels for use in respect to hazardous substances risk from all sources, i.e. there is no need to distinguish between risk from a fixed facility at which hazardous substances may be found, or a pipeline or a transportation corridor. The acceptability levels are equally applicable. With these considerations in mind, the guidelines for acceptable levels of risk are given in **Table 7.18**.

It is important to emphasize that these guidelines do not prohibit all activities or structures within the various risk contours, but rather restrict land use within each zone. As is the case for many other land use questions (e.g. flood plains), the contours are used to define special restrictions on land uses. This aspect of the guidelines is particularly important since, as discussed in a subsequent section, land use controls around industrial sites have important legal and economic implications.

The guidelines are thought to be realistic in terms of existing practices of risk management and levels of risk. They are also compatible with criteria that have been selected and implemented in other industries and other countries. In a practical sense, these criteria can only achieve authority if they represent a consensus view of Canadian society. They must not impose unrealistic requirements on industry and should reflect the contemporary standards of the society to which they are applied.

Malaysia

The criteria used by the Department of Environment (DOE) for existing facilities are outlined below for residential and industrial areas:

- Residential 1 x 10^{-6} fatalities / person / year
- Industrial 1 x 10^{-5} fatalities / person / year

In words, the acceptability criteria are as follows: the risk of death to persons in a residential area must not exceed 1 chance in a million per person per year and the risk of death to persons in a nearby industrial area must not exceed 1 chance in 100,000 per person per year.

If the quantified individual risk compares favourably with the acceptability criteria, then it is deemed acceptable. If not, the components of the overall risk are re-examined to determine where risk mitigation measures can be implemented cost effectively. Risk evaluation must also be conducted taking into account the fact that hazard analysis and consequence assessment only gives an estimation of risks from a facility. In many cases the expertise and the knowledge required to model various failure scenarios do not exist prior to the accident occurring. For instance, although dispersion models are used in the modelling of the release of large masses of dense gases (in the 100s of tonnes), there has never been a large scale experimental release to justify the models used. Only the gross behaviour of the vapour cloud, i.e. density intrusion-gravity spreading and passive dispersion can be modelled. Obstacles and terrain effects cannot be incorporated in present day models; however they can have substantial effects on the dispersion of the cloud. Therefore, as a safety factor, a standard quantitative risk assessment technique is always to error the conservative side in assumption making.

Australia

The Western Australia (WA) Department of Planning has adopted risk criteria for hazardous installations. They are based on risk contours and can be summarized as follows:

- A risk level in residential zones of one in a million per year (1 x 10^{-6}/yr) or less, is so small as to be acceptable to the WA EPA (Environmental Protection Agency);
- A risk level in "sensitive developments", such as hospitals, schools, child care facilities and aged care housing developments, of between one half and one in a million per year (5 x 10^{-7} and 1 x 10^{-6}/yr) is so small as to be acceptable to the WAEPA;
- Risk levels from industrial facilities should not exceed a target of fifty in a million per year (1 in 20,000) at the site boundary for each individual industry, and the cumulative risk level imposed upon an industry should not exceed a target of one hundred in a million per year (1 in 10,000);
- A risk for any non-industrial activity, located in buffer zones between industrial and residential zones, often in a million per year or lower is so small as to be acceptable to the WA EPA;
- A risk level for commercial developments, including offices, retail centers and showrooms located in buffer zones between industrial facilities and residential zones, of five in a million per year or less, is so small as to be acceptable to the WA EPA.

The Netherlands

The policy statement approved by the Dutch Parliament states the following criteria for existing facilities. The risk is unacceptable if the 10^{-6}/yr risk contours affect residential areas or the F/N curve is above 10 fatalities with a frequency of 10^{-5}/yr with a slope of -2. This is illustrated in **Figure 7.4**.

Below the criteria, the ALARP, "As Low as Reasonably Practicable", principle should be used.

AH Dutch installations should meet the criteria for new facilities by the year 2005. For the Societal Risk it should be emphasised that the exposure or "presence" factor of population used for calculating the F/N curve during the day is 0.7 and 1 during night. Also the assumption is made that being indoors gives protection where the fraction of people being indoors is 0.93 during daytime and 0.99 during night time.

Hong Kong Government Criteria

The Hong Kong government has published "Interim Risk Guidelines for Potential Hazardous Installations". The guideline covers new installations and expansion of existing installations and also controls the development of land around installations. It should be pointed out that although these are described as "guidelines" they are very strictly applied in practice. They are seen as necessary because of the special circumstances of Hong Kong, where there is a dense population in close proximity to industrial facilities, and are mainly used for land-use planning decisions. Societal risk guidelines are shown in **Figure 7.5** and set forth two criteria;

- A risk contour of 10^{-5}/yr for fatality as an upper limit of tolerability.
- The maximum F/N curve exceeds the line through the point of 10 fatalities at a frequency of 10^{-4}/yr with a slope of -1. No event at any frequency should take place which causes more than 1000 deaths.

The Hong Kong regulators scrutinise each risk assessment closely and insist on the use of consistent methodology from case to case.

7.5.5 Results and Discussions

Individual risk and societal risk are computed using software SAFETI MICRO 6.51 for different location in main pipeline. The probabilities of failure of the Pipeline is taken from HSE UK and risk estimation has been done for Anjar-Chotila pipeline

Risk Transects and F/N curves have been generated considering different population pockets with corresponding densities and probable ignition sources which are shown in **Figure 7.6** and **Figure 7.7** respectively.

7.6 RISK MITIGATION MEASURES

The scope of the study covers mitigation measures based on Maximum Credible Accident (MCA) Analysis. The Fire and Explosion Indices were computed for the identification and screening of vulnerable sections and consequence analysis was carried out for the accidental release scenarios of MAH (Major Accident Hazard) at various atmospheric conditions. The following are general and specific mitigation measures

7.6.1 General Recommendations

Fire prevention and code enforcement is one of the major areas of responsibility for the fire service. Following are the general recommendations for the proposed facility

- Facility should be equipped with the following active FFS at the terminals
    - Water supply
    - Fire hydrant and monitor nozzle installation
    - Foam system
    - Water fog and sprinkler system
    - Mobile Firefighting equipment
- Firefighting system should be designed as per codes and standards applicable like OISD 226, Industrial design best practices, PNGRB guideline, TAC guideline and others regulatory guidelines etc
- Surrounding population (includes all strata of society) should be made aware of the safety precautions to be taken in the event of any mishap in the surrounding area of Pipelines. This can effectively be done by conducting the safety training programs.
- Buildings possibly subjected to external blast waves should be made of reinforced concrete. The windows should be made of blast resistant glass with strong frame.
- Escape routes & assembly points (Muster Point) should be provided at strategic locations and should be easily accessible from the terminal.
- To minimize domino effects, grating and vent panels should be provided as per section 40 of the factory act 1948
- Critical switches and alarm should be always kept in line
- Fire, Gas Detection Systems to be installed at strategic locations near the units and pipelines handling hydrocarbons at higher temperatures and pressures to assess any leak
- Periodical mock drills should be conducted so as to check the alertness and efficiency of the Disaster Management plan (DMP) and Emergency Rescue Plan (ERP)and records should be maintained
- Signboard including important phone numbers, no smoking signs, No mobile phones and type of siren to be operated during emergency should be installed at various locations for creating safety awareness at field.

7.6.2 Specific Recommendations

The leakage of natural gas could create a vapour cloud that can ignite. Secure the area, and keep the public and fire department personnel out of the vapour cloud at a safe distance. Fire fighting personnel and fir fighting equipment should be at upwind side, out of the path of escaping gas.

If the leaking gas ignites, the resultant radiant heat can threaten surrounding population and facilities. Set up handlines and large-caliber streams to protect exposed structures. Do not attempt to extinguish burning gas outdoors; let it burn.

7.6.2.1 Natural Gas Pipeline

Likelihood of failure factors considered in our plan include

- External corrosion.
- Internal corrosion.
- Third-party damage.
- Pipe design and materials.
- Potential for ground movement.
- System operations.

These failure factors are each examined through analysis of these variables:

- Environment – conditions that exert some influence on a pipeline.
- Design – conditions associated with the pipeline that cannot be easily changed.
- Asset Integrity Management. Failure of O&M practices– non-destructive testing or inspection performance data.
- Rehabilitation – performance testing or the disposition of inspection results.

Individual impact on environment, business and/or the population and the total impact are consequence of failure factors used to help us evaluate the potential impact of a pipeline release. Our consequence of failure analysis considers the sensitivity of the impacted variable as well as the type of product released and the volume.

Using accepted scientific techniques and formulas, the likelihood and consequence of failure variables are used to identify and prioritize pipeline failure risks. This analysis helps us to address the most significant risks first to protect the public and the environment and to systematically plan our maintenance and testing activities.

The risk mitigation component of the integrity management (IM) plan describes programs that we use to reduce the risk of a release by decreasing the likelihood of a pipeline failure or the consequence of a pipeline failure, or both.

Preventive measures begin with the design and construction of our pipelines and facilities. These measures include design specifications, selection of suitable construction materials, development and selection of welding procedures, pipe coatings and catholic protection systems. Other measures help to ensure the proper design, installation, operation and maintenance of internal and external corrosion prevention systems.

Additionally, manufacturing controls are used to promote high-quality installation of the pipeline and facilities and to limit operating stress.

Should have a comprehensive preventive maintenance program to inspect, maintain and test facilities. We check and adjust our cathodic protection system, routinely test valves to verify they are operating correctly and calibrate electronic components

Monitor the pipeline 24 hours a day, 365 days a year from control center and through regular aircraft and/or ground patrols that keep tabs on activity near pipeline. Our gathering pipelines are monitored during operation as some do not operate around the clock.

7.6.2.2 Control Rooms at SV Stations

- The building shall be located upwind of the wind direction
- Adequate number of doors shall be provided in the control room for safe exit
- Halon / Dry chemical fire extinguishers should be used in control rooms and computer rooms
- Smoke detectors system shall be provided for control rooms at suitable locations

7.6.2.3 Gas Detection Systems

The various methodologies that can be adopted for gas dispersion control are:

Gas detection systems play a major role in the prevention or mitigation of a major accident or incident. Prompt detection of a toxic or flammable release allows people to be informed early enough to make their escape, or where the release is explosive, to automatically switch off ignition sources. Other counter measures may include the activation of local and remote alarms, isolation of process fluids by automatically closing valves or initiating additional emergency response services. Gas detection systems do not prevent the initial release. Gas detection systems only respond to a release event. In order to determine the magnitude of any Emergency Response Plan it is necessary to simulate a large scale gas release. This simulation will determine the boundaries or end point where a release of a toxic substance will no longer be harmful to people or where explosive gas/air mixtures will no longer ignite. Knowledge of gas dispersion is fundamental to conduct a simulation.

A gas detection system is not simply a handful of gas detectors spread across an industrial plant. The choice of detection technology, quantity of detectors and routine service and maintenance of the entire gas detection system are all important. However, the real challenge is to identify the possible migration path of any gas release based on a variety of factors wind direction, ambient temperatures, terrain, process pressures etc, which establishes the correct location of gas detectors. It is not practical to saturate an industrial plant with gas detectors, nor is it sensible to install only a single gas detector in a large area. Risk should be reduced as low as reasonably practicable (ALARP). It means that ALARP involves weighing a risk against the trouble, time and money needed to control it.

There are two main types of gas detectors; a point gas detector which monitors the immediate vicinity of the gas detector, or an open path gas detector which monitors a much larger area between two points. Each type of gas detector has its own strengths and weaknesses. It is also important to choose the correct measuring technology as some gas detectors may be poisoned by other chemicals in use, or be susceptible to high humidity or give invalid readings due to cross sensitivities. In all applications it is important to avoid spurious gas alarms.

In case of SV station there must be gas detector as well as gas alarm must be installed in various location

7.6.3 SCADA Systems

SCADA systems provide for safe, reliable, semi-efficient operation of gas transmission systems. Advanced applications and interfaces to business systems provide the keys for highly profitable operation. The SCADA system is equipped with world class standards to take care of corrective and preventive measures with auto monitors and leak detection with advance alarm system and safety measures. Auto trip off system is also inbuilt.

7.6.3.1 Pipelines

The physical connection to the pipeline is through the end devices or instrumentation. This instrumentation is connected to Programmable Logic Controllers (PLCs), Remote Terminal Units (RTUs) and/or flow computers, depending on the type of remote station. Data then flows from these remote devices through the communications network to the SCADA host (also referred to as the SCADA Master or Master Station).

7.6.3.2 SV Stations

For transportation of natural gas through pipeline, there is a need to acquire the permanent land for surface facilities stations i.e Sectionizing Valve Stations/ Intermediate Pigging Stations, Receiving Terminal/Dispatch Terminal (SV/IP/RT/DT) at interval of approx. 20-25 km through pipeline depending upon the class location & availability of land. SV Stations helps to maintain the pressure levels of the flow of gas during shutdown(if any) & in case of any emergency.

7.6.4 Mitigation of Electrical Risk

- Emergency lighting shall be available at all critical locations including the operator’s room to carry out safe shut down of the plant, ready identification of firefighting facilities such as fire water pumps and fire alarm stations.
- All electrical equipments shall be free from carbon dust, oil deposits, and grease
- Use of approved insulated tools, rubber mats, shockproof gloves and boots, tester, fuse tongs, discharge rod, safety belt, hand lamp, wooden or insulated ladder and not wearing metal ring and chain.
- Flame and shock detectors and central fire annunciation system for fire safety should be provided.
- Temperature sensitive alarm and protective relays to make alert and disconnect equipment before overheating
- Prevent higher humidity and temperature near electric insulations.
- Danger from excess current due to overload or short circuit should be prevented by providing fuses, circuit breakers (ELCB or RCB), thermal protection
- Carbon dioxide, halon or dry chemical powder type fire extinguishers are to be used for electrical fires.

7.6.5 Fire Protection System

The typical firefighting system in case of emergency for the various facilities described under this project is outlined in this section. The exact details of the firefighting systems and capabilities to be installed and developed will be finalized after the completion of detailed engineering in consultation with the concerned process and equipment vendors and fire. It is also to be understood that not all facilities described below will be applicable for every installation. The outline of the fire system proposed is described below:

Fire protection system shall be designed in accordance with the requirements of OISD 117,141 guidelines, Tariff Advisory Committee (TAC) of India, NFPA standards, PNGRB guidelines and others standards as per design requirements and safe best engineering practices. It shows that will have full capability for early detection and fire suppression systems. The system will primarily consist of:

- Hydrant system
- Foam protection system
- DV (Deluge operated) operated sprinkler system
- Fire detection and alarm system
- All types Portable Fire Extinguishers

7.6.6 Risks to Personnel

Good safety management, strict adherence to safety management procedures and competency assurance will reduce the risk. Safety practices are needed to carry out jobs safely and without causing any injury to self, colleagues and system.

For total safety of any operation, each team member must religiously follow the safety practices / procedures pertaining to respective operational area. If every team member starts working with this attitude, zero accident rate is not a distant dream.

Any operation is a team effort and its success depends upon the sincerity, efficiency and motivation of all team members. Safety in such operations is not a duty of a single person, but it is everyone's job. Use of protective fireproof clothing and escape respirators will reduce the risk of being seriously burnt. In addition, adequate firefighting facilities and first aid facilities should be provided, in case of any emergency.

7.6.7 Risks to Environment

In general, the frequency of leaks is low. Ensuring proper safety can still lower this frequency. Risk reducing measures include proper training for personnel, presence of well-trained engineers and strict adherence to safety management procedures to be incorporated in the plan.

7.6.8 Training

On job training to the engineers on various facts of risk analysis would go a long way in improving their horizon which in turn is expected to reflect in the operation of plant, especially from the safety stand point. In order to combat with emergency situations arising out of accident release of piped natural gas (Low / High pressure system), it is necessary for industries to prepare an exhaustive offsite and onsite emergency preparedness plan.

7.6.9 Personal Protective Equipment (PPE)

Personal Protective Equipment (PPE) provides additional protection to workers exposed to workplace hazards in conjunction with other facility controls and safety systems.

PPE is considered to be a last resort that is above and beyond the other facility controls and provides the worker with an extra level of personal protection. **Table 7.1** presents general examples of occupational hazards and types of PPE available for different purposes. Recommended measures for use of PPE in the workplace include:

- Active use of PPE if alternative technologies, work plans or procedures cannot eliminate, or sufficiently reduce, a hazard or exposure
- Identification and provision of appropriate PPE that offers adequate protection to the worker, co-workers, and occasional visitors, without incurring unnecessary inconvenience to the individual
- Proper maintenance of PPE, including cleaning when dirty and replacement when damaged or worn out. Proper use of PPE should be part of the recurrent training programs for Employees
- Selection of PPE should be based on the hazard and risk ranking described earlier in this section, and selected according to criteria on performance and testing established

7.7. APPROACH TO EMERGENCY RESPONSE & DISASTER MANAGEMENT PLAN (ERDMP)

In spite of various preventive and precautionary measures taken in works, the possibility of a mishap cannot be totally ruled out. Hence the need to prepare emergency plan for dealing with the incidences which may still occur and are likely to affect life and property in the residential areas and other places are identified in this plan. Such an emergency could be the result of malfunction or non-observance of operating instructions. It could, at times, be the consequences of acts outside the control of residents / employees like severe storm, flooding, or deliberate acts of arson or sabotage.

7.7.1 Objectives

The objective of any facility is to ensure safe and trouble free operation which can be achieved by taking precautions in designing the pipeline as per the standard codes, selecting proper material of construction and instruments. Safety should also be ensured by operating the facility by trained manpower. In spite of all precautions, accidents may happen due to human error or system malfunction. Any accident involving release of hazardous material may cause loss of human lives and property and damage to the environment. Industrial installations are vulnerable to various natural as well as manmade disasters. Examples of natural disasters are flood, cyclone, earthquake, lightening whereas manmade disasters are fire, explosion, accidental leakage of toxic and poisonous gases and liquids, civil war, nuclear attacks, terrorist activities etc.

The purpose of ERDMP is to give an approach to detail organizational responsibilities, actions, reporting requirements and support resources available to ensure effective and timely management of emergencies associated to production and operations in the site. The overall objectives of DMP are:

- Ensure

- safety of people, protect the environment and safeguard commercial considerations
- Immediate response to emergency scene with effective communication network and organized procedures.
- Obtain early warning of emergency conditions so as to prevent impact on personnel, assets and environment;
- Safeguard personnel to prevent injuries or loss of life by protecting personnel from the hazard and evacuating personnel from an installation when necessary
- Minimize the impact of the event on the installation and the environment, by:
  - Minimizing the hazard as far as possible
  - Minimizing the potential for escalation
  - Containing any release.
- To provide guidance to help stack holders take appropriate action to prevent accidents involving hazardous substances and to mitigate adverse effects of accidents that do nevertheless occur. **Figure 7.8** shows effect of loss of containment from the process

7.7.2 Disaster Scenarios

Various scenarios that are anticipated to cause major emergencies are fire, explosion and natural calamities like cyclone, flood and earthquake. All emergencies relevant to oil evacuation pipeline are presented in brief in the following text

- High Pressure of operating Natural Gas pipeline.
- Leakage of Natural Gas from flange joints.
- High noise during release of Natural Gas at high pressure.
- Flash fire
- Jet fire
- Explosion due to NG release in confined place.

Causes of Disasters

The common causes for the above events are tabulated below for the reference

Man made	**Natural Calamities**	**Extraneous**
• Heavy Leakage	• Flood	• Riots/Civil Disorder/ Mob Attack
• Fire	• Earth Quake	• Terrorism
• Explosion	• Cyclone	• Sabotage
• Failure of Critical Control system	• Outbreak of Disease	• Bomb Threat
• Design deficiency	• Excessive Rains	• War / Hit by missiles
• Unsafe acts	• Tsunami	• Abduction
• Inadequate		• Food Poisoning/

- maintenance
- Water Poisoning

7.7.3 Different Levels of Emergencies

Emergencies can be categorized into three broad levels on the basis of seriousness and response requirements, namely,

Level 1: This is an emergency or an incident which;

- can be effectively and safely managed, and contained within the site, location or installation by the available resources;
- has no impact outside the site, location or installation

Level 2: This is an emergency or an incident which;

- cannot be effectively and safely managed or contained at the location or installation by available resource and additional support is alerted or required;
- is having or has the potential to have an effect beyond the site, location or installation and where external support of mutual aid partner may be involved;
- is likely to be danger to life, the environment or to industrial assets or reputation

Level 3: This is an emergency or an incident with off-site impact which;

- Could be catastrophic and is likely to affect the population, property and environment inside and outside the installation, and management and control is done by district administration. Although the Level-III emergency falls under the purview of District Authority but till they step in, it should be responsibility of the unit to manage the emergency

7.7.4 Key Elements

Following are the key elements of Disaster Management Plan:

- Basis of the plan
- Accident prevention procedures/measures
- Accident/emergency response planning procedures
- On-site Disaster Management Plan
- Off-site Disaster Management Plan

7.7.4.1 Basis of the Plan

Identification and assessment of hazards is crucial for on-site emergency planning and it is therefore necessary to identify what emergencies could arise in storage of various products. Hazard analysis or consequence analysis gives the following results.

- Hazards from spread of fire or release of flammable and toxic chemicals from storage and production units.

- Hazards due to formation of pressure waves due to vapour cloud explosion of flammable gases and oil spill hazards.

7.7.4.2 Accident/Emergency Planning and Response Procedures

Emergency rarely occurs; therefore activities during emergencies require coordination of higher order than for planned activities carried out according to fixed time schedule or on a routine day-to-day basis. To effectively coordinate emergency response activities, an organizational approach to planning is required. The important areas of emergency planning are Organization and Responsibilities, Procedures, Communication, Transport, Resource requirements and Control Centre. Offsite emergency requires additional planning over and above those considered under onsite plans, which should be properly integrated to ensure better co-ordination.

The emergency planning includes anticipatory action for emergency, maintenance and streamlining of emergency preparedness and ability for sudden mobilization of all forces to meet any calamity.

7.7.4.3 On-site Emergency Response and Disaster Management Plan (ERDMP)

Onsite Emergency/disaster is an unpleasant event of such magnitude which may cause extensive damage to life and property due to the emergencies resulting from deficiencies in Operation, Maintenance, Design and Human error, Natural Calamities like Flood and Earthquake; and deliberate and other acts of man like Sabotage, Riot and War etc. An Onsite Disaster may occur all of a sudden or proceeded by a Major Fire. The GSPL purpose for making on-site disaster management plan should be

- To protect persons and property of pipeline associated equipments in case of all kinds of accidents, emergencies and disasters
- To inform people and surroundings about emergency if it is likely to adversely affect them
- To inform authorities including helping agencies (doctors, hospitals, fire, police transport etc.) in advance, and also at the time of actual happening
- To identify, assess, foresee and work out various kinds of possible hazards, their places, potential and damaging capacity and area in case of above happenings. Review, revise, redesign, replace or reconstruct the process, plant, vessels and control measures if so assessed.

During an emergency in order to handle disaster / emergency situations, an organizational chart entrusting responsibility to various personnel showing their specific roles during emergency should be available.

Before Crisis

- Prepare a plan for the SV stations premises and surroundings showing therein the areas of various hazards like fire, explosion, location of assembly points, fire station or equipments room, telephone room, emergency control rooms and nearby hospitals along the pipeline route
- The fire protection equipment shall be kept in good operating condition at all the time and firefighting system should be periodically tested for people functioning logged for record and corrective action.
- The firefighting training shall be provided to all officers and operators

- There should be regular mock fire drills and record of such drills shall be maintained
- Assign key personnel and alternate responsible for the pipeline safety
- Describe risk associated with each operation conducted.

During Crisis

- Evacuate the space near to pipeline and SV stations
- Perform no other duties that may interfere with their primary responsibilities
- Notify the operator if they experience any warning signs or symptoms of exposures or detect a dangerous condition
- Reporting Procedure

In the event of fire from accidental release of flammable gas or liquid, a person seeing the incident will follow the laid down procedure and report as follows:

- Will dial the nearest telephone
- Will state his name and exact location of emergency
- Will contact affected officers on duty
- People reporting the accident will remain near the location to guide emergency crew arriving at the scene

In case fire emergency person should activate the nearest available push button type instrument which will automatically sound an alarm in fire control room indicating the location of fire.

After Crisis

- Report injuries or blood or body fluid exposures to the appropriate supervisor immediately.
- Assembly points: Assembly points shall be set up farthest from the location of likely hazardous events, where pre-designed persons from the works, contractors and visitors would assemble in case of emergency. Up-to-date list of pre-designed employees shift wise must be available at these points so that roll call could be taken. Pre-designated persons would take charge of these points and mark presence as the people come into it
- Wash wounds and skin sites that have been affected with soap & water
- Workers should be seen as soon as possible by a health professional
- Provide information to the relevant public authority and community including other closely located facilities regarding the nature of hazard and emergency procedure in event of major accident
- Record and discuss the lessons learned and the analysis of major accidents and misses with employees and employee representative

Emergency Organization and Responsibilities

The Emergency Response Disaster management Plan (ERDMP) shall identify the safe transition from normal operation to emergency operations and systematic shut down, if any, and the delegation of authority from operations personnel to emergency response personnel. For this purpose, the plan shall identify an emergency response organization with appropriate lines of authority with succession planning and actuating the response management. Responsibilities for decision making shall be clearly shown in an emergency organization chart. The plan shall identify each responder's position, mission, duties and reporting relationship.

Overall objectives of an emergency control organization shall be:

- To promptly control problems as they develop at the scene.
- To prevent or limit the impact on other areas and offsite.
- To provide emergency personnel, selecting them for duties compatible with their normal work functions wherever feasible. The duties and functions assigned to various people shall include making full use of existing organizations and service groups such as fire, safety, occupational health, medical, transportation, personnel, maintenance, and security.
- Employees must assume additional responsibilities as per laid down procedure of ERDMP whenever an emergency alarm sounds.
- In setting up the organization, the need for round the clock coverage shall be essential. Shift personnel must be prepared to take charge of the emergency control functions or emergency shutdown of system, if need be, until responsible personnel arrive at the site of emergency. The organization should have an alternate arrangement for each function.

Roles and Responsibilities

Chief Incident Controller (CIC)

The Chief Incident Controller (CIC) shall have overall responsibility to protect personnel, site facilities, and the public before, during, and after an emergency or disaster. The CIC shall be present at the main emergency control centre for counsel and overall guidance. Responsibilities of the Chief Incident Controller shall include the following:

- Assessment of situation and declaration of emergency
- Mobilisation of main coordinators and key personnel
- Activation Emergency Control Centre
- Taking decision on seeking assistance from mutual aid members and external agencies like Police, Fire Brigade, Hospitals etc
- Continuous review of situation and decide on appropriate response strategy
- Taking stock of casualties and ensure timely medical attention
- Ensuring correct accounting and position of personnel after the emergency
- Ordering evacuation of personnel as and when necessary
- Taking decision in consultation with District Authorities when an Offsite emergency to be declared

Site Incident Controller (SIC)

The Site Incident Controller shall be identified by the Chief Incident Controller and will report directly to him. SIC should be nominated by the entity in each shift 24 hrs. Responsibilities of the Chief Incident Controller shall include the following:

- The SIC shall maintain a workable emergency control plan, establish emergency control centres, organize and equip the organization with ERDMP and train the personnel;
- The SIC shall be capable of making quick decisions and taking full charge;
- The SIC shall communicate to the Emergency Control Centre where it can coordinate activities among groups;
- The SIC shall be responsible for ensuring that appropriate local and national government authorities are notified, preparation of media statements, obtaining approval from the CIC and releasing such statements once approval received;
- The SIC shall also ensure the response to the incidents or the emergencies, as the case may be, is in line with entity procedures, coordinating business continuity or recovery plan from the incident. He must ensure next of kin are notified in a timely manner;
- The SIC shall also coordinate if any specialist support is required for the above purpose; and
- The SIC shall decide on seeking assistance of mutual aid members and external agencies like police, fire brigade, hospital etc.

Administration and Communication Coordinator

Responsibilities of the administration and communication controller shall include the following:

- To coordinate with mutual aid members and other external agencies
- To direct them on arrival of external agencies to respective coordinators at desired locations
- To activate the medical center and render first aid to the injured. arrange ambulance and coordination with hospitals for prompt medical attention to casualties
- To ensure head counts at assembly points
- To arrange procurement of spares for firefighting and additional medicines and drugs
- To mobilize transport to various teams for facilitating the response measures
- To monitor entry and exit of personnel into and out of premises
- To ensure only authorized personnel enter into the premises
- To regulate the flow of traffic into and out of premises and control the mob outside, if any, with the assistance of the police
- To provide administrative and logistics assistance to various teams
- To arrange evacuation as directed by the chief incident controller, and in coordination with the civil authorities like police, panchayat/municipal authorities etc.

Fire Safety Coordinator and Fire Team

Responsibilities of the Fire and Safety Coordinator shall include the following:

- To activate emergency sirens as per the practiced codes
- To take charge of all firefighting and rescue operations and safety matters
- To ensure that key personnel are called in and to release crew of firefighting operations as per emergency procedure
- Assess functioning of his team and communicate with the CIC and or administrative controller for any replenishment or, replacement of manpower or firefighting equipment
- Direct the fire brigade personnel and mutual aid members to their desired roles as also proper positioning of the manpower and equipment
- To decide the requirement of mutual aid and instruct fire station, who, in turn will contact mutual aid members
- To coordinate with outside fire brigades for properly coordinated firefighting operation
- To ensure that casualties are promptly sent to first aid center / hospital
- To arrange requirement of additional firefighting resources including help from mutual aid partners
- Ensure empty and loaded trucks are removed to safer area to the extent possible so as not to affect emergency handling operations
- Continually liaise with the SIC and or CIC and implement the emergency combat strategies as communicated by him; and
- Ensure adequate hydrant pressure in the mains and monitor water level in the reservoir.

Support and Auxiliary Services for Major Installations

The following additional coordinators may be nominated and delegated the specific responsibilities falling under the basic functions of SIC and or CIC:

- Human Resources and Welfare Services Coordinator
- Transport and Logistics Services Coordinator
- Media and Public Relations Coordinator
- Operations and Technical Coordinator
- Security Coordinator.

The Security Coordinator reports to the Chief / Site Incident Controller and is responsible for security of the installation during any incident or emergency situation and for implementing the actions below:

- Obtaining an approved visitor list from the security department or reception for ensuring that personnel on the list are escorted to reception by security staff
- Maintaining security of the office in the event of an office evacuation
- Providing office security and assisting authorities in the event of civil unrest or when required organizing additional security at the emergency scene

- Obtaining initial briefing from Chief / Site Incident Controller and providing security information and or status reports to Site Incident Controller during the emergency
- Assuming responsibility for any task delegated by Chief Incident Controller
- Assessing the emergency, identify security specific problems and recommend solutions to Chief Incident Controller

Maintenance of ERDMP Records

There shall be maintenance of ERDMP records for all kind of emergencies covering near miss, Level I, Level II and Level III. Organization shall maintain an Incident Record Register for the above purpose and post–disaster documentation like resources deployed, relief, rehabilitation measures and lesson learned to avoid reoccurrence of any such emergency. Head of HSE or any other designated personnel by the CIC/SIC shall be responsible for maintenance of such records.

- A good public relations program is extremely important in an emergency situation. Inquiries will normally be received from the media, government agencies, local organizations and the general public
- This section of the Response Plan shall include a public relations or media plan. It should identify an Information Officer that is well equipped and trained in media relations
- Initial releases shall be restricted to statements of facts such as the name of the installation involved, type and quantity of spill, time of spill, and countermeasure actions being taken. All facts must be stated clearly and consistently to everyone

Recorder

The Recorder responsibility is to maintain an accurate time record of key information received from the incident or emergency location and to record the actions initiated by the site incident controller and for implementing the emergency response actions below:

- to record key incident events/actions on incident status board/display manually or electronically
- to maintain essential equipment checklist status
- to ensure all status and information is up to date and correctly displayed
- to take all necessary recorded material to the alternate ECC room in the event of emergency in main ECC room
- to maintain a log book

Communications Services

- The Communications Coordinator shall ensure the following actions below
- Ensuring the Emergency Control Centre (ECC) equipment and systems are maintained to a high standard and remain functional throughout the emergency
- Ensuring a backup communication system is available in the event of the ECC Room is not available

- Providing quality and diverse communication systems for use in routine and emergency situations

Flow of Information

- Control Centre shall receive the information form field either in person or from the various systems available in the installation.
- On receipt of information, the control room shift In-charge will actuate the ERDMP and notify the emergency to site incident controller.
- Control room shift in-charge will act as site incident controller till arrival of designated person.
- SIC or CIC depending upon the level of emergency will actuate the ERDMP and inform the concerned authorities as depicted above in the chart.

Emergency control centres (ECC)

- Each installation shall have the provision of ECC preferably with a backup arrangement.
  - The ECC shall be away from potential hazards and provide maximum safety to personnel and equipment.
  - Preference should be given to a non-combustible building of either steel frame or reinforced concrete construction.
  - The ECC should have at least two exits and adequate ventilation
- Following certain basic supplies and dedicated equipment shall be made available at the ECC.
  - A copy of the ERDMP.
  - Maps and diagrams showing buildings, roads, underground fire mains, important hazardous material and process lines, drainage trenches, and utilities such as steam, water, natural gas and electricity are required.
  - Aerial photographs, if possible, and maps showing the site, adjacent industries, the surrounding community, high-ways, rivers, etc., help determine how the disaster may affect the community so that the proper people can be notified, adequate roadblocks established, and the civil authorities advised.
  - Names, addresses, and telephone numbers of employees.
  - Names, addresses, and telephone numbers of off-site groups and organizations that might have to be contacted should be available.
  - All telephone lists should be reviewed for accuracy on a scheduled basis and updated, as necessary.
  - Dedicated and reliable communication equipment should be provided at the ECC. Enough telephones and one fax line to serve the organization for calls both on-and off-the-site. Two-way radio equipment shall be provided to maintain continuity of communications when other means fail and also provides an excellent way of keeping in contact with field activities.

- All ECC should have emergency lights so that operations can continue in the event of power failure.
- Facilities for recording the sequence of events should be provided to assist in investigating causes, evaluating performance, and preparing reports. This can range from a pan board, logbook to a tape recorder with a person assigned to record pertinent information.
- ECC should also have dedicated computer with LAN/ internet facility to access the installation data and also it should have the latest and updated soft copies of all standard operating practices (SOP) etc.

Assembly Points

- There should be pre-designated areas in safe zone as per quantitative risk assessment, where the personnel like workers, staff, contractor workers etc. not involved in emergency operations (as per ERDMP) shall assemble in case of an emergency.
- Depending on the location of the emergency, the assembly point can vary. For each potential hazardous zone, a specific assembly point shall be identified and clearly marked on the zones or maps.
- The assembly point should be clearly marked with directional display board along the route. Route should be well lighted with florescent marking.
- During an emergency, pre-designated persons would take charge of this point and take the roll call of the people reporting. Provisions should be made for assembly points, communication and headcount facilities at assembly points, and personnel to control the movement of assembled employees.

Resources for controlling Emergency

- To meet all possible emergencies, installation has to provide a number of systems and resources based on the risk level as identified above in addition to requirements under the Factories Act, 1948 and other statutory regulations applicable to the installation
- The available emergency control systems and facilities within the installation shall be as under.
    - Fire and gas detection system
    - Fire protection system (Active and Passive)
    - Fire fighting systems
    - Ambulance facility in house, if not available then should be available on urgent call basis
    - Rescue facilities and personal protective equipments (PPEs)

  - First aid and medical facilities round the clock with availability of minimum one nurse (24X7) and doctor in the first aid room.
  - Communication facilities
  - Escape route and evacuation zones
  - Emergency shutdown Pipeline system
- Required resources shall be suitably incorporated into the plan. Number and type shall be as per the relevant code, standards and best practices in the industry. This section shall also identify sources of local assistance including telephone numbers and names of contacts for:
  - fire departments
  - police
  - municipal and provincial agencies
  - hospitals
  - doctors
  - other relevant company facilities
  - mutual aid organizations
  - cooperatives
  - helicopter and air transport services
  - surface transport services
  - safety and monitoring equipment suppliers
  - spill response and/or cleanup services
- Installations shall also determine type of resources such as equipment, personnel, technology, expertise, etc. provided by the respective governments under different conditions.

Demographic Information

ERDMP shall be prepared based on the following information:

- Neighbouring population in a 5km radius
- Housing colonies near pipeline system
- Sensitive institutions such as schools, hospitals, religious establishments and old aged homes, etc.
- Cattle and livestock
- Flora and fauna

Medical Facilities

Details of medical facilities to be provided in the ERDMP as per the following:

- facilities available at first aid center

- details of trained persons in first aid in the plant
- facilities available at identified hospitals
- facilities available at other local hospitals
- antidotes and emergency medicines
- details of specialist doctors in the town
- details of hospital in nearby cities

Evacuation

- Planning and training on evacuation techniques are important in preventing injuries. Evacuation of local communities or people near the site may be prudent depending on the situation and downwind dispersion information etc. Although this action will normally be initiated and handled by district authorities, the affected installation shall help to implement such evacuation.
- This evacuation plan shall also consider:
    - basis for recommending onsite or offsite actions
    - authorize person for area or site evacuation
    - mode of communication
    - training in locating exits from buildings, areas and the site
    - location of escape equipment
    - provisions for flashlights or other supplemental lighting
    - which areas can function as safe area
    - Moving crosswind from gas or fume releases, etc.
    - Provision of food and drinking water at assembly point and transfer point.
- If evacuation takes place after initial head counts are reported, means for recounting may be necessary. Where it is safe to do so, areas being evacuated should be thoroughly searched to ensure everyone has departed safely. Portable mobile vehicle for announcement should be available in the emergency.

Information to Public

- The safety measures to be taken in the event of an emergency shall be made known to the general public who are likely to be affected
- For the purpose, use of Dos' and Don'ts' shall be prepared and furnished to the Crisis management Group. Display boards carrying do's and don'ts should be located outside the pipeline system

ERDMP for pipelines carrying petroleum products and retail outlets

- ERDMP for pipelines carrying petroleum products should follow modern methods of surveillance of Pipeline and take guidance from all the aspects of Disaster Management Plan mentioned in the ERDMP. **Schedule–VII** should be referred, which is in line with Chemical Disaster by National Disaster Management Authority.
- ERDMP for retail outlets should take care of all aspects mentioned in ERDMP and shall also refer to OISD STD– 225.

Schedule –VII

ERDMP for Pipelines carrying petroleum products

Pipelines are assuming importance as a means of transport of hazardous substances. Crude oil, its derivatives and natural gas are among the main substances transported by pipelines. The Guidelines, therefore, comprise:

- Creation and maintaining an administrative framework to facilitate the development of a safe and environmentally sound transportation infrastructure, including pipelines for hazardous substances.
- The pipeline operator has the primary responsibility for the safety of the systems and for taking measures to prevent incident s and to limit their consequences for human health and the environment.
- Pipelines for the transport of hazardous substances will be designed and operated so as to prevent any uncontrolled release into the environment.
- Risk assessment methods should be used in evaluating pipeline integrity and impact on human health and the environment. Land-use planning considerations will be taken into account both in the routing of new pipelines (e.g. to limit proximity to populated areas and water catchment areas to the extent possible), and in decisions concerning proposals for new developments/building in the vicinity of existing pipelines.
- Pipeline operators and the authorities responsible for pipelines shall review and, if necessary, develop and implement systems to reduce third-party interference, which is a cause of incident including their effects.
- National legislation shall be clear, enforceable and consistent to facilitate safe transport and international cooperation.
- Competent authorities should ensure that pipeline operators:
    - Draw up emergency plans.
    - Provide the authorities designated for that purpose with the necessary information to enable them to draw up Off-Site emergency plans.
    - Emergency plans shall be coordinated between pipeline operators and competent authorities, as well as with fire brigades and other disaster control units.
- Pipelines shall be designed, constructed and operated in accordance with recognized national and international codes, standards and guidelines, notified by the Board.

- Consideration will be given to the impact on the safety of a pipeline such as design and stress factors, quality of material, wall thickness, and depth of burial, external impact protection, markings, route selection and monitoring.
- The safety of the pipelines shall be demonstrated through a suitable risk assessment procedure including the worst case scenario and including breakdowns and external additional loads.
- The pipeline operator shall draw up a Pipeline Management System (PMS) to ensure that it is properly implemented. The PMS shall be designed to guarantee a high level of protection of human health and the environment. The following issues shall be addressed by the safety management system.
    - The pipeline will be inspected and maintained regularly. Only reliable trained staff or qualified contractors may carry our maintenance work on a pipeline. Third party confirmatory assessment bodies should inspect the pipeline at regular intervals as far as required by the Board. These inspections are to cover in particular the proper condition of the pipeline and the functioning of the equipment ensuring pipeline safety.
    - Organization ability, roles and responsibilities, identification and evaluation of hazards, operational control, and management of change, planning for emergencies, monitoring performance, audit and review shall be duly addressed in the Pipeline Management System.

7.7.5 Off-site Disaster Management Plan

Off Site Emergency means an emergency that takes place in an installation and the effects of emergency extends beyond the premises or the emergency created due to an incident, catastrophic incidents, natural calamities, etc. It no longer remains the concern of the installation management alone but also becomes a concern for the general public living outside and to deal with such eventualities shall be the responsibilities of district administration;

Off-site emergency plan means a response plan to control and mitigate the effects of catastrophic incidents in above ground installation (AGI) or underground installations (UGI) or road transportation. This plan should be prepared by the district administration based on the data provided by the installation(s), to make the most effective use of combined resources, i.e. internal as well as external to minimize loss of life, property, and environment to restore facilities at the earliest

Emergency is a sudden unexpected event, which can cause serious damage to personnel life, property and environment along the oil evacuation pipeline, which necessitate evolving Off-site Emergency Plan to combat any such eventuality. In Offsite disaster management plan, many agencies like Revenue, Public Health, Fire Services, Police, Civil Defence, Home Guards, Medical Services and other Voluntary organization are involved. Thus, handling of such emergencies requires an organized multidisciplinary approach.

Evacuation of people required, if leak from the pipeline and SV station, can be done in orderly way. The different agencies involved in evacuation of people are Civil Administration (both state and central), non Govt. organizations and Police authorities.

Before Crisis

This will include the safety procedure to be followed during an emergency through posters, talks and mass media in different languages including local language. Leaflets containing dos/ don'ts before and during emergency should be circulated to educate the people in vicinity

- People in vicinity of hazardous installation, and others who are potentially affected in the event of an accident, should be aware of the risks of accidents, know where to obtain information concerning the installation, and understand what to do in the event of an accident
- Non-governmental Organizations (NGO's) (Such as environmental, humanitarian and consumer group) should motivate their constituents and others, to be involved in risk reduction and accident prevention efforts. They should help to identify specific concerns and priorities regarding risk reduction and prevention, preparedness and response activities
- NGO's should facilitate efforts to inform the public and should provide technical assistance to help the public analyze and understand information that is made available
- Public authorities (at all levels) and management of hazardous installation should established emergency planning activities/ program's for accidents involving the hazardous substance
- All parties who will be involved in emergency planning process. In this respect public health authorities, including experts from information centres should be involved in relevant aspects of offsite emergency planning
- Emergency warning alert system should be in place to warn the potentially affected public, or there is an imminent threat of an accident
- The system chosen should be effective and provide timely warning. Suitable warning system could include or a combination of for e.g.: sirens, automatic telephone message, and mobile public address system

During Crisis

- Central Control Committee: As the off-site plan is to be prepared by the government a central control committee shall be formed under the chairmanship of area head. Other officers from police, fire, factory, medical, engineering, social welfare, publicity, railway, transport and requisite departments shall be incorporated as members. Some experts will also be included for guidance. The functions of committee should be:
    - To work as main co-coordinating body constituted of necessary district heads and other authorities with overall command, coordination, guidance, supervision, policy and doing all necessary things to control disaster in shortest times
    - To prepare, review, alter or cancel this plan and to keep it a complete document with all details
    - To take advice and assistance from experts in fields to make plan more successful
    - To set in motion all machineries to this plan in event of disaster causing or likely to cause severe damage to public, property or environment
    - The incident control committee, traffic control committee and press publicity committee will first be informed, as they are needed first

- Medical Help, Ambulance and Hospital Committee: This committee consisted of doctors for medical help to the injured persons because of disaster. Injuries may be of many types. As such doctors are rarely available we have to mobilize and utilize all available doctors in the area. Functions and duties of the committee include:
    - To give medical help to all injured as early as possible
    - Civil surgeon is the secretary who will organize his team
    - On receiving information to rush to spot he will immediately inform his team and will proceed with all necessary equipments
    - First aid and possible treatment shall be provided at the spot or at some convenient place and patients may be requested to shift to hospitals for further treatment
    - All efforts shall be made on war basis to save maximum lives and to treat maximum injuries
    - Continuity of the treatment shall be maintained till the disaster is controlled
- Traffic Control, Law and Order: The committee is headed by District Superintendent of Police. Functions and duties of this committee should be:
    - To control traffic towards and near disaster , to maintain law and order
    - To evacuate the places badly affected or likely to be affected
    - To shift the evacuated people to safe assembly points
    - To rehabilitate them after disaster is over.
    - Necessary vehicles, wireless sets and instruments for quick communications shall be maintained and used as per need

After Crisis

- At the time of disaster, many people may badly be affected. Injured people shall be treated by medical help, ambulance and hospital committee, but those not injured but displaced kept at assembly points, whose relative or property is lost, houses collapsed and in need of any kind of help shall be treated by this welfare and restoration committee. Functions and duties of this committee are:
    - To find out persons in need of human help owing to disastrous effect. They may give first aid if medical team is not available
    - They will serve the evacuated people kept at assembly points. They will arrange for their food, water, shelter, clothing, sanitation, and guidelines to reach any needful places
    - They will look for removal and disposal of dead bodies, for help of sick, weak, children and needy persons for their essential requirements
    - The team will also work for restoration of detached people, lost articles, essential commodities etc.
    - The team will also look after the restoration of government articles

  - The team will also ensure that the original activities, services and systems are resumed again as they were functioning before the disaster
- Police Department
  - The police should assist in controlling of the accident site, organizing evacuation and removing of any seriously injured people to hospitals.
  - Co-ordination with the transport authorities, civil defence and home guards
  - Co-ordination with army, navy, air force and state fire services
  - Arrange for post mortem of dead bodies
  - Establish communication centre
- Fire Brigade
  - The fire brigade shall organize to put out fires and provide assistance as required.
- Hospitals and Doctors
  - Hospitals and doctors should be ready to treat any injuries.
  - Co-ordinate the activities of Primary Health Centres and Municipal Dispensaries to ensure required quantities of drugs and equipments
  - Securing assistance of medical and paramedical personnel from nearby hospitals/institutions
  - Temporary mortuary and identification of dead bodies
- Media
  - The media should have ready and continuous access to designated officials with relevant information, as well as to other sources in order to provide essential and accurate information to public throughout the emergency and to help avoid confusion
  - Efforts should be made to check the clarity and reliability of information as it becomes available, and before it is communicated to public
  - Public health authorities should be consulted when issuing statements to the media concerning health aspects of chemical accidents
  - Members of the media should facilitate response efforts by providing means for informing the public with credible information about accidents involving hazardous substances
- Non-governmental organizations (NGO)
  - NGO's could provide a valuable source of expertise and information to support emergency response efforts. Members of NGOs could assist response personnel by performing specified tasks, as planned during the emergency planning process. Such tasks could include providing humanitarian, psychological & social assistance to members of community and response personnel.
- Duties of NGO are listed below:
  - Evacuation of personnel from the affected area

- Arrangements at rallying posts and parking yards
- Rehabilitation of evacuated persons
- Co-ordination with other agencies such as police, medical, animal husbandry, agriculture, electricity board, fire services, home guards and civil defense.
- Establishing shelters for rescue, medical, firefighting personnel

- District Administration

On receipt of information, District Administration may take the following actions as per Schedule-V derived from the National Disaster Management Guidelines Chemical Disasters (Industrial), April, 2007. However, on receipt of information, following actions should be taken care

- to keep watch on the overall situation
- rush ambulance to the incident site if casualties are reported
- direct cranes or any other such equipment to carry out rescue operations
- Issue warning messages to people through public address system, if any evacuation is required.
- arrange emergency vehicles for evacuation purposes
- give direction to hospitals having burns injury ward for readiness to receive patient in case of incident involving fire
- provide basic amenities, e.g., water, electricity, food and shelter to the affected people as required

In addition to the above, the Schedule-V shall be followed

Schedule – V

The important Roles and Responsibilities of Various Stakeholders

- The district authority is responsible for the Off-Site emergency plan and it shall be equipped with up-to-date Major Accident Hazard units, website, control room etc., with provisions for monitoring the level of preparedness at all times. Regular meetings of various stakeholders of Chemical Disaster Management will be conducted by district administration/District Disaster Management Authority to review the preparedness of Chemical Disaster Management.
- The police will be an important component of all disaster management plans as they will be associated with investigation of incident s/disasters. Police take overall charge of the Off-Site situation until the arrival of the district collector or its representative at the scene.
- The fire services are one of the first responders and shall be adequately trained and equipped to handle chemical emergencies. Fire services are to acquire a thorough knowledge of likely hazards at the incident site and the emergency control measures required to contain it.
- In a chemical emergency, the revenue department shall coordinate with other agencies for evacuation, establishment of shelters and provision of food, etc.
- When required for evacuation purposes in a chemical emergency, the

- Department of transport should made transport promptly available.
- The role of civil society and private sector in the Off-Site plan shall be defined.
- The health department needs to assure that all victims get immediate medical attention on the site as well as at the hospitals/health-care facility where they are shifted. In addition, the department needs to network all the health-care facilities available in the vicinity for effective management and also take effective measures to prevent the occurrence of any epidemic.
- Pollution control boards need to ascertain the developing severity of the emergency in accordance with responsive measures by constant monitoring of the environment. If and when an area is fit for entry will depend upon the results of the monitoring. A decontamination operation would be required to be carried out with the help of other agencies and industries.

7.7.6 Emergency Preparedness Plan and Response

- Industry should continue to share its experience with respect to the use of safety management systems for pipelines, and improve the efficiency of individual elements / techniques of these systems
- General principles applicable to emergency planning for hazardous installations also apply to pipelines, it may be necessary to make further efforts
- Emergency planning for pipelines may be complicated because of some of their characteristics including the fact that pipelines are normally unmanned; the length and location of pipelines; the need to be able to shut off or depressurized the flow of material, and the need to ensure access by emergency response personnel
- Pipeline location will be clearly marked at fence lines and road crossings to minimize risk of third party damage
- Industry responsible for pipelines should review and necessary, develop and implement systems to reduce third party interference as this is a major cause of accident
    - This should be done in co-operation with public authorities in all regions
    - Systems for reducing third party interference involve ensuring that proper information is circulated among interested parties concerning the location of pipeline in a given area. In, addition it is important to facilitate communication between the pipeline operator and third parties
    - In order to facilitate learning from experience, industry responsible for pipelines (as well as public authorities and other stakeholders) should improve sharing of information on improving safety of pipelines and on accidents / near-miss case histories
    - This should include concerning pipelines that reach the end of their intended useful or design life. Options for dealing with pipeline that are no longer in use include removal, outright abandonment, or abandonment with additional actions. Care should be taken to properly assess the associated risks to each option, on a case-by-case basis recognizing that the best solution in a given situation may be a combination of methods

- Information should also be pooled and shared on the extent of the pipeline systems, on the amount of materials they convey, and on statistical analysis of the use of pipelines to transport hazardous substances
- Information should be collected and made available concerning the relationship between failure and the characteristic of the pipeline, in order to better understand the nature and causes of accidents (e.g., relating to age, size, location, and construction of the pipeline)

- Public education is often an integral part of damage prevention program. Pipeline route maps could be supplied and informal training given to groups to alert them. The quality of the public education program can assessed by evaluating components
- An appropriate level of public education is to be mail outs, advertisements, and speaking engagements for urban areas, and mail outs with annual landowner / tenant visits for rural areas. The program generates these standards by simply identifying the population density value and assigning points accordingly.

7.7.7 Training

On job training to the engineers on various facets of risk analysis would go a long way in improving their horizon which in turn is expected to reflect in the operation of plant, especially from the safety stand point. In order to combat with emergency situations arising out of accident release of hazardous chemicals, it is necessary for industries to prepare an exhaustive offsite and onsite emergency preparedness plan. The fire crew belonging to the firefighting department shall be given intensive training for the use of all equipment and in various firefighting methods for handling different types of fires.

References

1) Dow fire and explosion index hazard classification guide, seventh edition 1994 Published by AIChE
2) Techniques for assessing industrial hazards by World Bank
3) Marshall, V.C. (1977)' How lethal are explosives and toxic escapes'
4) OGP Risk Assessment Data Directory, Report No. 434 – 1 March 2010
5) Failure Rate and Event Data for use within Risk Assessments (28/06/2012) by HSE UK, from RAS/06/05 by Keeley
6) Petroleum and Natural Gas Regulatory Board, ERDMP Guidelines 2010

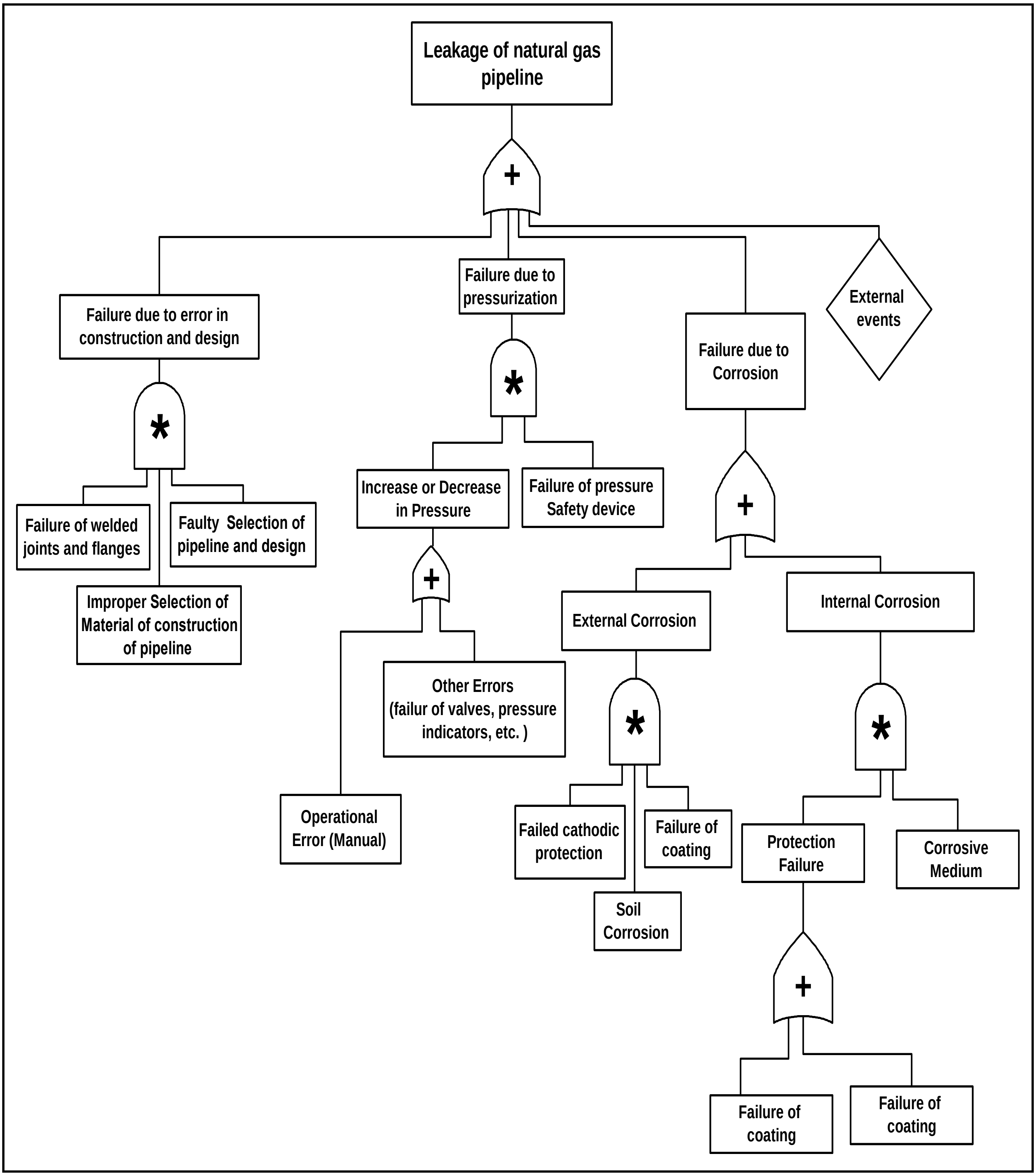

FIGURE 7.1: GENERAL STRUCTURE OF FAULT TREE ANALYSIS FOR PIPELINE SYSTEM

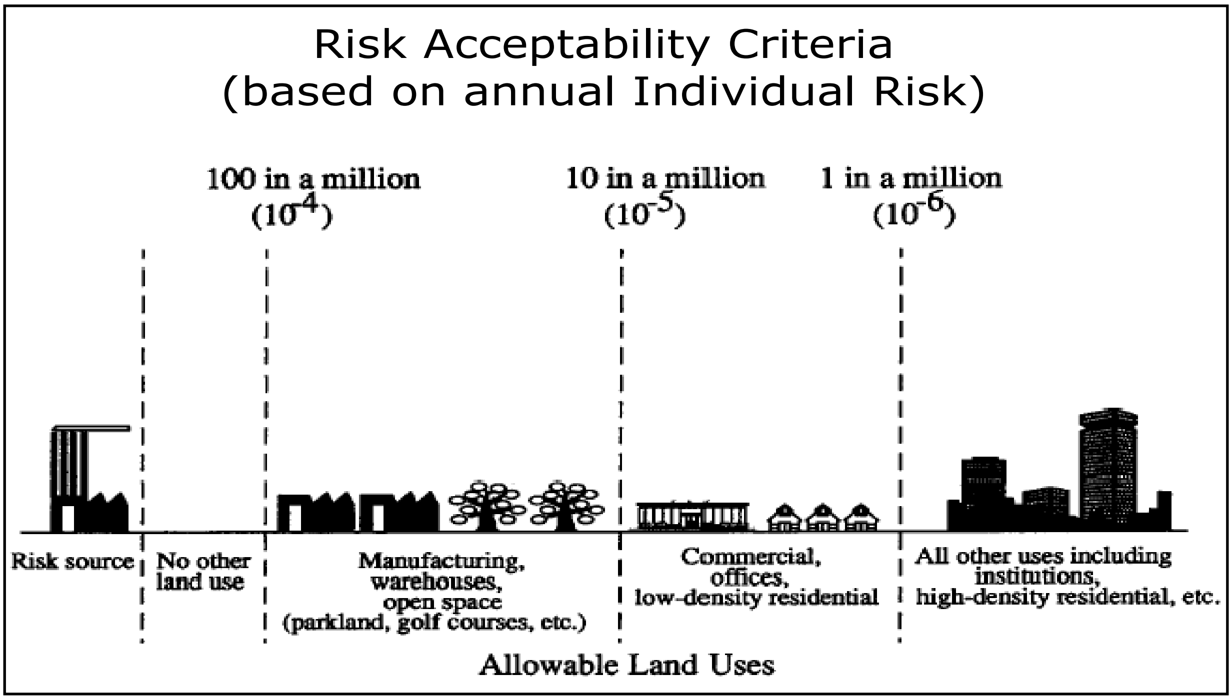

FIGURE 7.2: COMMONLY ACCEPTABLE INDIVIDUAL RISKS IN DIFFERENT DESIGNATED LAND ZONES

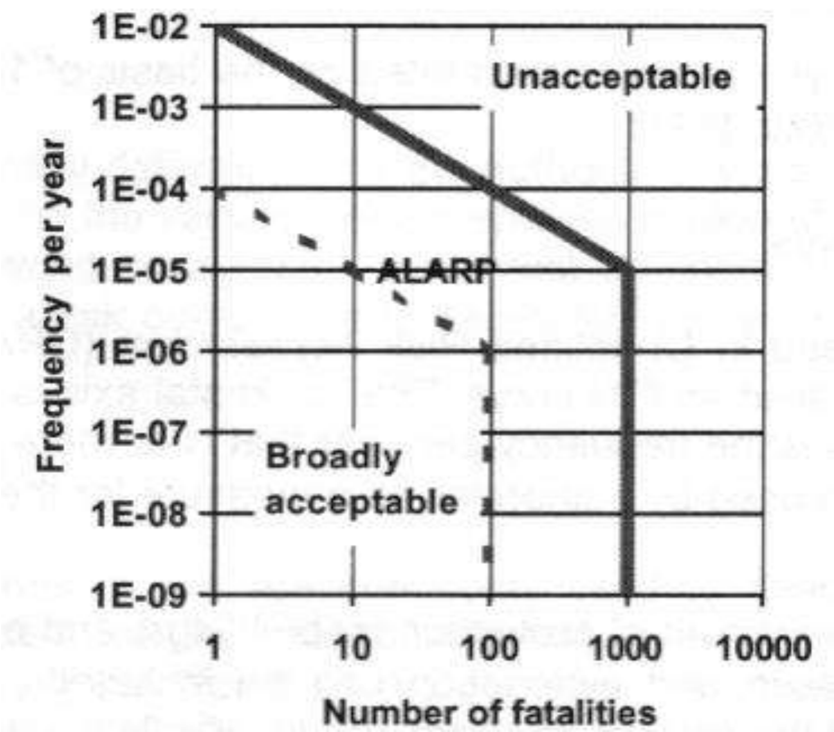

FIGURE 7.3: UNITED KINGDOM SOCIETAL RISK GUIDELINES (RISK TO WORKFORCE & PUBLIC)

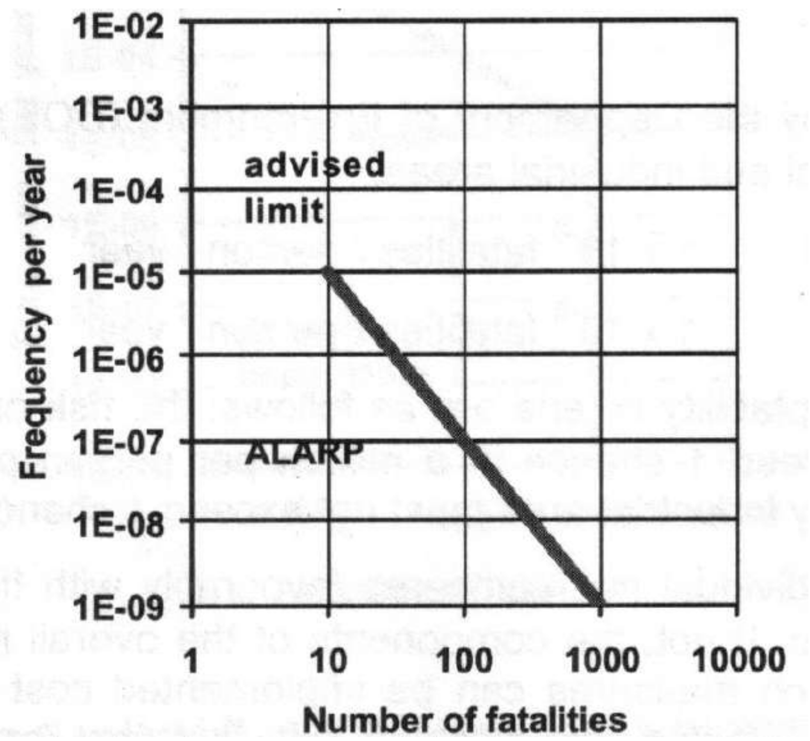

FIGURE 7.4: NETHERLANDS SOCIETAL RISK GUIDELINES (RISK TO PUBLIC ONLY)

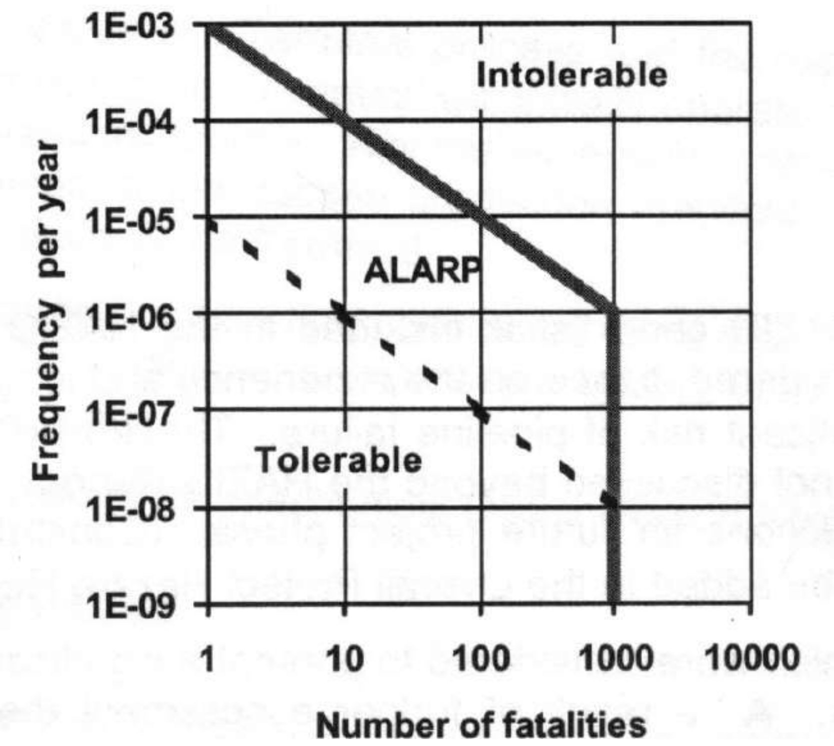

FIGURE 7.5: HONG KONG SOCIETAL RISK GUIDELINES (RISK TO PUBLIC ONLY)

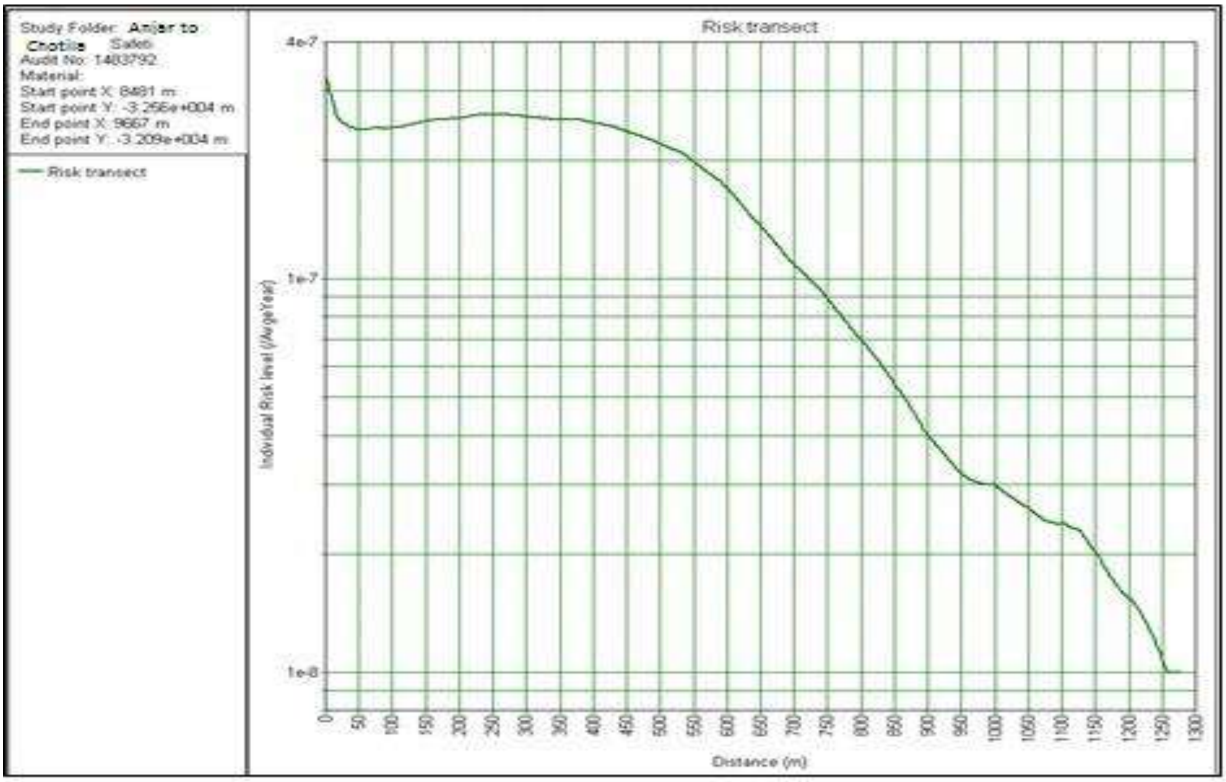

FIGURE 7.6: RISK TRANSECT FOR ANJAR - CHOTILA PIPELINE

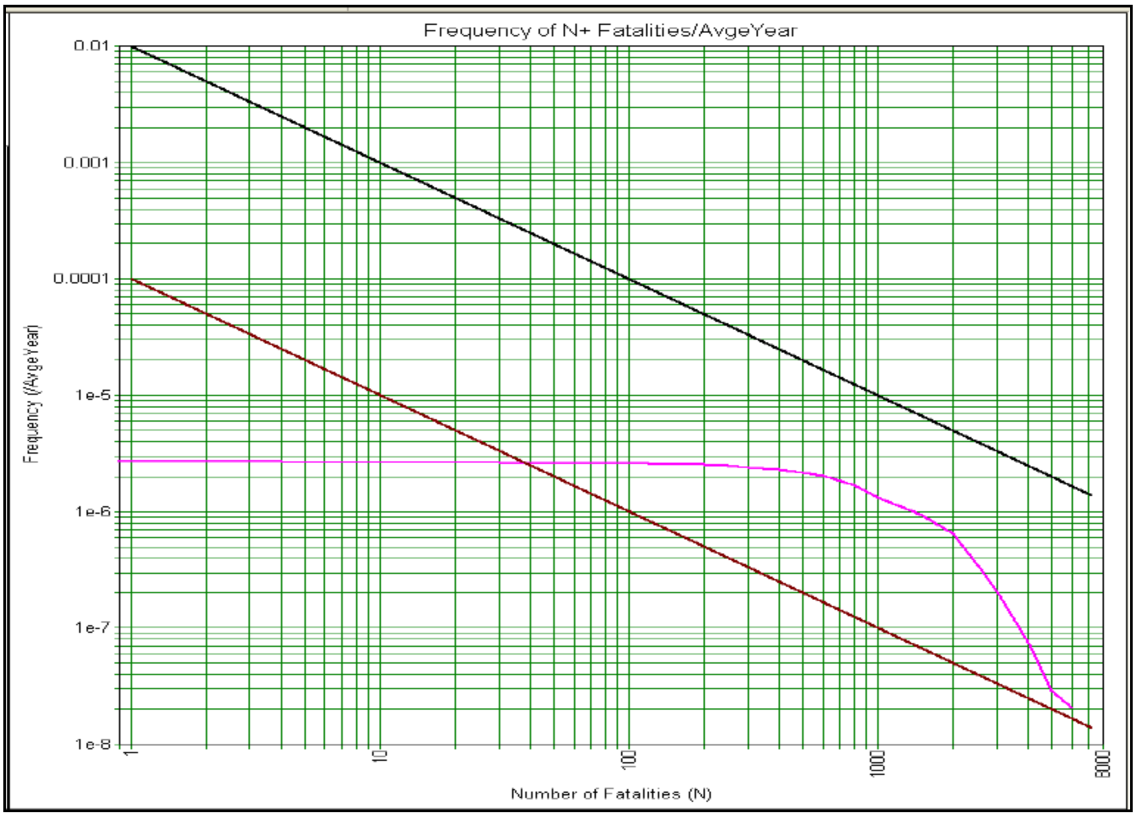

FIGURE 7.7: F/N CURVE FOR ANJAR - CHOTILA PIPELINE

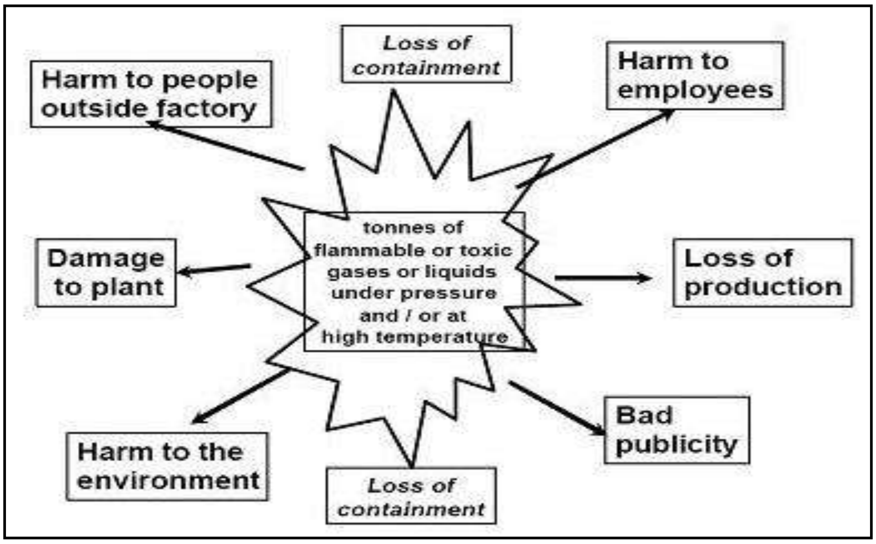

FIGURE 7.8: FOCUS ON LOSS OF CONTAINMENT FROM THE PROCESS

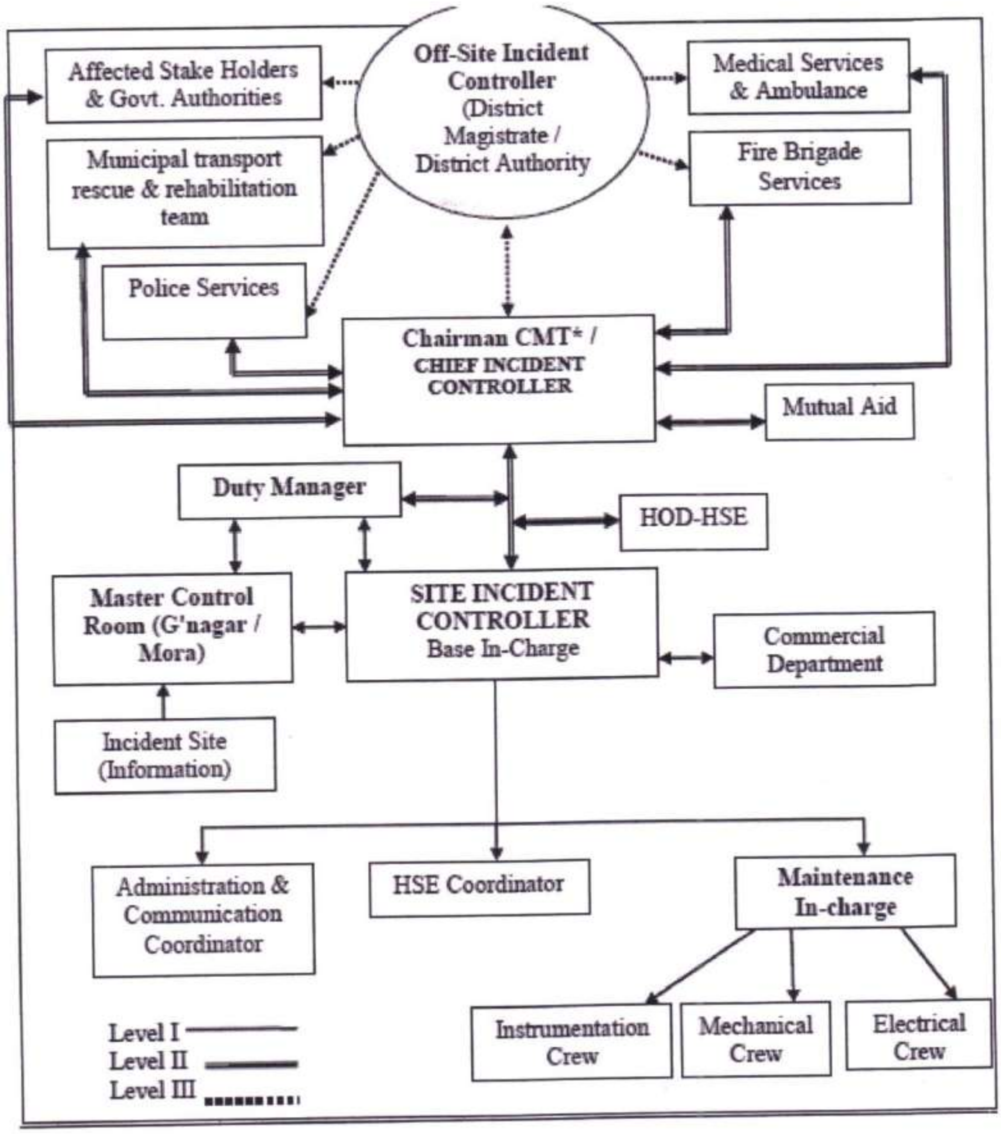

FIGURE 7.9: MANAGEMENT TEAM FOR DISASTER MANAGEMENT PLAN

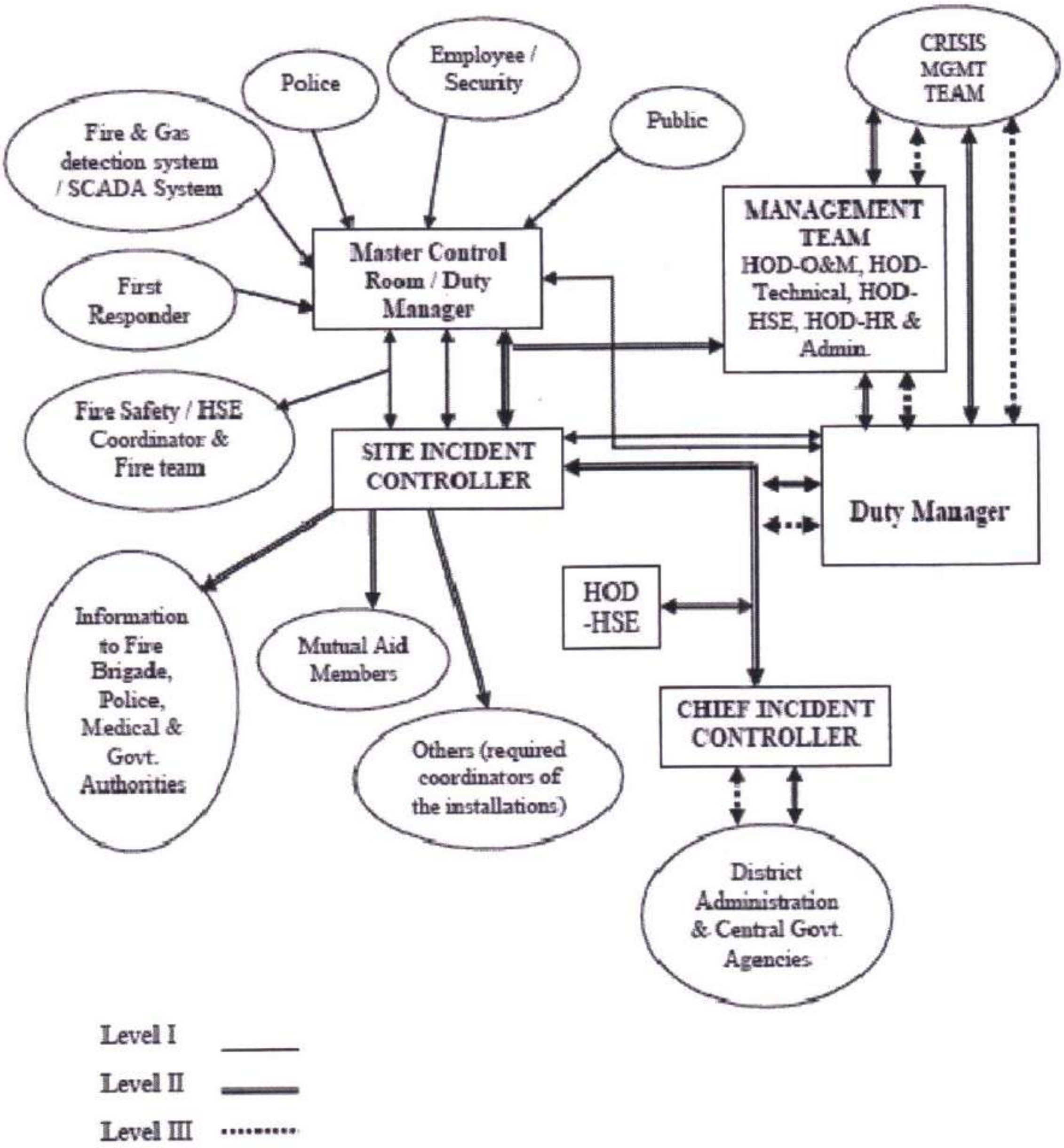

FIGURE 7.10: VARIOUS ORGANIZATIONS INVOLVED DURING EMERGENCIES

TABLE 7.1
DEGREE OF HAZARDS BASED ON FEI

FEI Range	Degree of Hazard
0-60	Light
61-96	Moderate
97-127	Intermediate
128-158	Heavy
159 and Above	Severe

TABLE 7.2
FIRE AND EXPLOSION INDEX FOR PIPELINE NATURAL GAS

Sr. No.	Unit Name	FEI	Category
Anjar - Chotila Pipeline			
1.	Anjar- Chotila Main Pipeline	115.60	Intermediate

TABLE 7.3
PASQUILL – GIFFARD ATMOSPHERIC STABILITY

Sr. No.	Stability Class	Weather Conditions
1.	A	Very unstable – sunny, light wind
2.	A/B	Unstable - as with A only less sunny or more windy
3.	B	Unstable - as with A/B only less sunny or more windy
4.	B/C	Moderately unstable – moderate sunny and moderate wind
5.	C	Moderately unstable – very windy / sunny or overcast / light wind
6.	C/D	Moderate unstable – moderate sun and high wind
7.	D	Neutral – little sun and high wind or overcast / windy night
8.	E	Moderately stable – less overcast and less windy night
9.	F	Stable – night with moderate clouds and light / moderate wind
10.	G	Very stable – possibly fog

TABLE 7.4
LIST OF DAMAGES ENVISAGED AT VARIOUS HEAT LOADS

Sr. No.	Heat loads (kW/m^2)	Type of Damage Intensity	
		Damage to Equipment	**Damage to People**
1	37.5	Damage to process equipment	100% lethality in 1 min. 1% lethality in 10 sec
2	25.0	Minimum energy required to ignite wood	50% Lethality in 1 min. Significant injury in 10 sec
3	19.0	Maximum thermal radiation intensity allowed on thermally unprotected equipment	--
4	12.5	Minimum energy required to melt plastic tubing	1% lethality in 1 min
5	4.0	-	First degree burns, causes pain for exposure longer than 10 sec
6	1.6	--	Causes no discomfort on long exposures
Source: World Bank (1988). Technical Report No. 55: Techniques for Assessing Industrial Hazards. , Washington, D.C: The World Bank.			

TABLE 7.5
DAMAGE CRITERIA FOR PRESSURE WAVES

Human Injury		Structural Damage	
Peak Over Pressure (bar)	**Type of Damage**	**Peak Over Pressure (bar)**	**Type of Damage**
5-8	100% lethality	0.3	Heavy (90% damage)
3.5-5	50% lethality	0.1	Repairable (10% damage)
2-3	Threshold lethality	0.03	Damage of Glass
1.33-2	Severe lung damage	0.01	Crack of windows
1-1.33	50% Eardrum rupture	-	-
Source: Marshall, V.C. (1977)' How lethal Is explosives and toxic escapes'.			

TABLE 7.6
CONTINUOUS RELEASE OF NATURAL GAS THROUGH 10 MM BORE FROM 36 "NG PIPELINE

Bore sizes (mm)	10MM			Outflow Quantity			462 Kg/10 Min		
Wind Conditions*									
Distance from Source	Wind Velocity = 1 m/s			Wind Velocity = 2 m/s			Wind Velocity = 4 m/s		
	Percent %	Quantity (Kg)	Max Conc. $M3/m^3$	Percent %	Quantity (Kg)	Max Conc. $M3/m^3$	Percent %	Quantity (Kg)	Max Conc. $M3/m^3$
75	31.7	146	4.34	47.9	221	1.90	MAXIMUM CONCENTRATION IS BELOW THE LOWER LIMIT		
100	39.8	184	3.00	35.6	164	1.15			
150	48.2	223	1.63	MAXIMUM CONCENTRATION IS BELOW THE LOWER LIMIT					
200	28.8	133	9.94						
250	9.2	43	6.56						
300	MAXIMUM CONCENTRATION IS BELOW THE LOWER LIMIT								

We are considering the outflow of the natural gas through 10 MM bore which is calculated 0.77 Kg/s. We have considered continues release of NG for maximum 10 minutes.

TABLE 7.7
DAMAGE DISTANCES DUE TO VCE WHICH RESULTS AFTER CONTINUOUS RELEASE OF NATURAL GAS THROUGH 10 MM BORE FROM 36 "NG PIPELINE (462 KG)

SN	Unit	PL Section: Incoming Line to SV station
1	Service	NG
2	Max. Outflow quantity (MT)	0.462

SN	Unit	PL Section: Incoming Line to SV station		
3	Accident Scenario	VCE		
4	Quantity within UEL & LEL (KG)	146	221	-
5	Effect of Wind:	I	II	III
	Chosen wind condition			
	Distance Covered by Cloud (gas plume)			
6	Duration of fire ball (s)	3.1	3.5	-
7	Dia. of cloud (m)	32.7		-
8	Max. Intensity of Radiation at center of the cloud (KW/m^2)	179.2	179.2	-
9	Damage Distance (m) for heat radiation (from center of fireball)			
	Severe damage to life & property (100% Lethality)	16.35	18.75	-
	100% Lethality (37.5 KW/m2)	31.44	35.92	-
	50% Lethality (25 KW/m2)	39.53	45.3	-
	1% Lethality (12.5 KW/m2)	52.48	28.08	-
	First degree burns (4.5 KW/m2)	86.35	96.27	-

TABLE 7.8

CONTINUOUS RELEASE OF NATURAL GAS THROUGH 25 MM BORE FROM 36 "NG PIPELINE

Bore sizes (mm)	**25MM**			**Outflow Quantity**			**2592 Kg/10 Min**		
Distance from Source	**Wind Velocity = 1 m/s**			**Wind Velocity = 2 m/s**			**Wind Velocity = 4 m/s**		
	Percent %	**Quantity (Kg)**	**Max Conc. M3/m^3**	**Percent %**	**Quantity (Kg)**	**Max Conc. M3/m^3**	**Percent %**	**Quantity (Kg)**	**Max Conc. M3/m^3**
75	19.7	511	0.84	29.8	771	0.47	39.9	1035	0.12
100	24.1	625	0.64	38.0	984	0.32	14.6	378	0.739
150	33.1	858	0.40	48.4	1255	0.17	MAXIMUM CONCENTRATION IS BELOW THE LOWER LIMIT		
200	41.4	1073	0.27	31.1	805	0.10			
250	47.3	1227	0.20	10.6	275	0.067			
300	46.9	1215	0.15	MAXIMUM CONCENTRATION IS BELOW THE LOWER LIMIT					
350	36.0	933	0.11						
400	25.1	651	0.091						
450	14.7	382	0.074						
500	5.8	150	0.06						

Bore sizes (mm)	**25MM**			**Outflow Quantity**			**2592 Kg/10 Min**		
Distance from Source	**Wind Velocity = 1 m/s**			**Wind Velocity = 2 m/s**			**Wind Velocity = 4 m/s**		
	Percent %	**Quantity (Kg)**	**Max Conc. $M3/m^3$**	**Percent %**	**Quantity (Kg)**	**Max Conc. $M3/m^3$**	**Percent %**	**Quantity (Kg)**	**Max Conc. $M3/m^3$**
550	MAXIMUM CONCENTRATION IS BELOW THE LOWER LIMIT								

We are considering the outflow of the natural gas through 25 MM bore which is calculated 4.92 Kg/s. We have considered continues release of NG for maximum 10 minutes.

TABLE 7.9
DAMAGE DISTANCES DUE TO VCE WHICH RESULTS AFTER CONTINUOUS RELEASE OF NATURAL GAS THROUGH 25 MM BORE FROM 36 "NG PIPELINE (2.592 KG)

SN	**Unit**	**PL Section: Incoming Line to SV station**		
1	Service	NG		
2	Max. Outflow quantity (MT)	2.592		
3	Accident Scenario	VCE		
4	Quantity within UEL & LEL (KG)	511	771	1035
5	Effect of Wind:	I	II	III
	Chosen wind condition			
	Distance Covered by Cloud (gas plume)			
6	Duration of fire ball (s)	4.3	4.8	5.2
7	Dia. of cloud (m)	49.2	56.2	61.9
8	Max. Intensity of Radiation at center of the cloud (KW/m^2)	179.2	179.2	179.2
9	Damage Distance (m) for heat radiation (from center of fireball)			
	Severe damage to life & property (100% Lethality)	24.6	28.1	30.95
	100% Lethality (37.5 KW/m2)	46.74	53.2	58.38
	50% Lethality (25 KW/m2)	58.24	66.12	72.42
	1% Lethality (12.5 KW/m2)	77.02	87.11	95.41
	First degree burns (4.5 KW/m2)	123.0	139.45	153.55

We are considering the outflow of the natural gas through 50 MM bore which is calculated 19.4 Kg/s. We have considered continues release of NG for maximum 10 minutes.

TABLE 7.10

CONTINUOUS RELEASE OF NATURAL GAS THROUGH 50 MM BORE FROM 36 "NG PIPELINE

Bore sizes (mm)	**50MM**			**Outflow Quantity**			**2592 Kg/10 Min**		
Distance from Source	**Wind Velocity = 1 m/s**			**Wind Velocity = 2 m/s**			**Wind Velocity = 4 m/s**		
	Percent %	**Quantity (Kg)**	**Max Conc. M3/m^3**	**Percent %**	**Quantity (Kg)**	**Max Conc. M3/m^3**	**Percent %**	**Quantity (Kg)**	**Max Conc. M3/m^3**
75	14.5	1676	1.24	19.4	2241	0.857	39.5	4548	0.30
100	16.9	1947	1.03	24.0	2767	0.648	47.7	5493	0.19
150	21.8	2516	0.73	33.6	3871	0.40	26.8	3094	0.095
200	26.7	3085	0.43	42.5	4896	0.265	1.5	172	0.053
250	31.6	3654	0.36	48.1	5546	0.186	MAXIMUM CONCENTRATION IS BELOW THE LOWER LIMIT		
300	36.5	4223	0.28	42.8	4933	0.136			
350	41.4	4792	0.25	30.4	3505	0.103			
400	46.3	5361	0.22	18.3	2105	0.079			
450	47.9	5520	0.19	7.4	858	0.063			
500	48.2	5554	0.16	MAXIMUM CONCENTRATION IS BELOW THE LOWER LIMIT					
550	43.6	5028	0.13						
600	37.4	4314	0.12						
650	31.2	3597	0.10						
700	25.1	2889	0.091						
750	19.1	2200	0.081						
800	13.4	1547	0.072						
850	8.2	950	0.064						
900	3.8	439	0.057						
950	MAXIMUM CONCENTRATION IS BELOW THE LOWER LIMIT								

TABLE 7.11

DAMAGE DISTANCES DUE TO VCE WHICH RESULTS AFTER CONTINUOUS RELEASE OF NATURAL GAS THROUGH 50 MM BORE FROM 36 "NG PIPELINE (11.526 KG)

SN	**Unit**	**PL Section: Incoming Line to SV station**
1	Service	NG
2	Max. Outflow quantity (MT)	11.526

SN	Unit	PL Section: Incoming Line to SV station		
3	Accident Scenario	VCE		
4	Quantity within UEL & LEL (KG)	1676	2241	4548
5	Effect of Wind:	I	II	III
	Chosen wind condition			
	Distance Covered by Cloud (gas plume)			
6	Duration of fire ball (s)	5.9	6.3	7.6
7	Dia. of cloud (m)	72.4	79.5	100.1
8	Max. Intensity of Radiation at center of the cloud (KW/m^2)	179.2	179.2	179.2
9	Damage Distance (m) for heat radiation (from center of fireball)			
	Severe damage to life & property (100% Lethality)	36.2	39.75	50.05
	100% Lethality (37.5 KW/m2)	67.97	74.37	92.95
	50% Lethality (25 KW/m2)	84.03	91.79	114.18
	1% Lethality (12.5 KW/m2)	110.37	120.66	150.1
	First degree burns (4.5 KW/m2)	178.00	195.73	244.43

TABLE 7.12
VCE SCENARIO - CLOUD DRIFTING, DILUTION & QUANTITY OF NG WITHIN UEL & LEL FOR INSTANTANEOUS RELEASE OF NG FROM CATASTROPHIC FAILURE OF THE 36 "PIPELINE ENTERING INTO THE SV STATION (1000 METERS)

Distance from Source	Wind Velocity = 1 m/s			Wind Velocity = 2 m/s			Wind Velocity = 4 m/s		
	Percent %	Quantity (Kg)	Max Conc. M3/m3	Percent %	Quantity (Kg)	Max Conc. M3/m3	Percent %	Quantity (Kg)	Max Conc. M3/m3
75	12.4	**4197**	1.51	15.3	**5186**	1.17	28.4	**9643**	0.512
100	13.9	4714	1.31	18.1	6139	0.941	36.9	12306	0.353
150	17.1	5789	1.01	24.2	8198	0.643	47.9	16262	0.190
200	20.3	6864	0.74	30.3	10257	0.345	35.6	12074	0.115
250	23.5	7939	0.612	36.9	12537	0.343	15.5	5244	0.752
300	26.7	9014	0.523	42.7	14491	0.263	Maximum Concentration is below the lower limit		
350	29.9	10089	0.421	47.0	15952	0.206			
400	33.1	11164	0.420	48.3	16397	0.165			
450	36.3	12239	0.394	42.3	14358	0.134			
500	39.5	13314	0.380	34.0	11541	0.111			
550	42.7	14389	0.375	25.7	8726	0.09312			
600	45.9	15464	0.360	17.7	5998	0.0788			
650	49.1	16539	0.340	10.2	3476	0.0673			
700	53..2	17614	0.320	4.0	1346	0.0580			

Distance from Source	Wind Velocity = 1 m/s			Wind Velocity = 2 m/s			Wind Velocity = 4 m/s		
	Percent %	Quantity (Kg)	Max Conc. M3/m3	Percent %	Quantity (Kg)	Max Conc. M3/m3	Percent %	Quantity (Kg)	Max Conc. M3/m3
750	57.3	18689	0.260	Maximum Concentration is below the lower limit					
800	61.4	19764	0.240						
850	65.5	20839	0.165						
900	37.2	12610	0.119						
950	33.0	11209	0.109						
1000	28.9	9814	0.0996						
1050	24.9	8435	0.0914						
1100	20.9	7083	0.0842						
1150	17.0	5770	0.0777						
1200	13.3	4512	0.0719						
1250	9.8	3326	0.0667						
1300	6.6	2238	0.0620						
1350	3.8	1278	0.0577						
1400	1.5	499	0.0539						
1425	Maximum Concentration is below the lower limit								

TABLE 7.13
DAMAGE DISTANCES DUE TO VCE WHICH RESULTS AFTER CATASTROPHIC FAILURE OF THE 36 "PIPELINE ENTERING INTO THE SV STATION (1000 METERS)

SN	Unit	PL Section: Incoming Line to SV station		
1	Service	NG		
2	Max. Outflow quantity (MT)	33.93		
3	Accident Scenario	VCE		
4	Quantity within UEL & LEL (KG)	4197	5186	9643
5	Effect of Wind:	I	II	III
	Chosen wind condition			
	Distance Covered by Cloud (gas plume)			
6	Duration of fire ball (s)	7.5	7.9	9.3
7	Dia. of cloud (m)	97.54	104.4	127.8
8	Max. Intensity of Radiation at center of the cloud (KW/m2)	179.2	179.2	179.2
9	Damage Distance (m) for heat radiation (from center of fireball)			
	Severe damage to life & property (100% Lethality)	39.75	52.2	63.9

SN	Unit	PL Section: Incoming Line to SV station		
	100% Lethality (37.5 KW/m2)	90.58	96.81	117.6
	50% Lethality (25 KW/m2)	111.24	118.82	143.58
	1% Lethality (12.5 KW/m2)	146.3	156.39	190.57
	First degree burns (4.5 KW/m2)	298.16	254.83	309.5

TABLE 7.14
DAMAGE DISTANCES DUE TO BLIEVE IN 1000 METER NG PIPELINE DUE TO EXTERNAL HEATING SOURCE

SN	Unit	1000 M Pipeline
1	Service	NG
2	Max. Outflow quantity (MT)	33.93
3	Accident Scenario	BLEVE
4	Duration of fire ball (s)	12.8
5	Dia. of cloud (m)	192.3
6	Max. Intensity of Radiation at center of the cloud (KW/m2)	179.2
7	Damage Distance (m) for heat radiation (from center of fireball)	
	* Severe damage to life & property (100% Lethality) Damage of glass	89.6
	* 100% Lethality (37.5 KW/m2)	174.47
	* 50% Lethality (25 KW/m2)	211.07
	* 1% Lethality (12.5 KW/m2)	284.39
	* First degree burns (4.5 KW/m2)	460.75

TABLE 7.15
IGNITION PROBABILITY OF PIPELINES RUNNING THROUGH RURAL AREAS (OGP)

Release Rate (Kg/s)	Ignition Probability
0.1	0.0010
0.2	0.0011
0.5	0.0013
1	0.0014
2	0.0016
5	0.0018
10	0.0020
20	0.0035
50	0.0073
100	0.0126

200	0.0220
500	0.0459
1000	0.0800

TABLE 7.16
IGNITION PROBABILITY OF PIPELINES RUNNING THROUGH INDUSTRIAL OR URBAN AREA (OGP)

Release Rate (Kg/s)	Ignition Probability
0.1	0.0010
0.2	0.0017
0.5	0.0033
1	0.0056
2	0.0095
5	0.0188
10	0.0316
20	0.0532
50	0.1057
100	0.1778
200	0.2991
500	0.5946
1000	1.0000

TABLE 7.17
FAILURE FREQUENCIES FOR NATURAL GAS PIPELINE

Type of release	Failure Frequency (per year)
Catastrophic Rupture	2.6×10^{-7}
Low Hole Leak	3.7×10^{-5}

TABLE 7.18
LAND USE AND INDUSTRIAL RISK ACCORDING TO MIACC

Location (based on risk level)	Possible land uses
From risk source to 1 in 10,000 (10^{-4}) risk contour:	No other land uses except the source facility, pipeline or corridor
1 in 10,000 to 1 in 100,000 (10^{-4} to 10^{-5}) risk contours:	uses involving continuous access and the presence of limited numbers of people bút easy evacuation, e.g. open space (parks, golf courses, conservation areas, trails, excluding recreation facilities such ás arenas), warehouses, manufacturing plants
1 in100,000 to 1 in 1,000,000 (10^{-5} to 10^{-6}) risk contours	Uses involving continuous access but easy evacuation, e.g., commercial uses, low-densily residential areas, offices
Beyond the 1 in 1,000,000 (10^{-6}) risk contour	All other land uses without restriction including institutional uses, high-density residential areas, etc.

TABLE 7.19
SUMMARY OF RECOMMENDED PERSONAL PROTECTIVE EQUIPMENT ACCORDING TO HAZARD

Objective	Workplace Hazards	Suggested PPE
Eye and face protection	Flying particles, molten metal, liquid chemicals, gases or vapours, light radiation	Safety glasses with side-shields, protective shades, etc.
Head protection	Falling objects, inadequate height clearance, and overhead power cords	Plastic helmets with top and side impact protection
Hearing protection	Noise, ultra-sound	Hearing protectors (ear plugs or ear muffs)
Foot protection	Failing or rolling objects, points objects. Corrosive or hot liquids	Safety shoes and boots for protection against moving and failing objects, liquids and chemicals
Hand protection	Hazardous materials, cuts or lacerations, vibrations, extreme temperatures	Gloves made of rubber or synthetic material (Neoprene), leather, steel, insulation materials, etc.
Respiratory protection	Dust, fogs, fumes, mists, gases, smokes, vapors	Facemasks with appropriate filters for dust removal and air purification (chemical, mists, vapors and gases). Single or multi-gas personal monitors, if available
	Oxygen deficiency	Portable or supplied air (fixed lines). Onsite rescue equipment
Body / leg protection	Extreme temperatures, hazardous materials, biological agents, cutting and laceration	Insulating clothing, body suits, aprons etc. of appropriate materials

TABLE 7.20
LIST OF DAMAGES ENVISAGED AT VARIOUS HEAT LOADS

Sr. No.	Heat loads (kW/m²)	Type of Damage Intensity	
		Damage to Equipment	Damage to People
1.	37.5	Damage to process equipment	100% lethality in 1 min. 1% lethality in 10 sec
2.	25.0	Minimum energy required to ignite wood	50% Lethality in 1 min. Significant injury in 10 sec
3.	19.0	Maximum thermal radiation intensity allowed on thermally unprotected equipment	--
4.	12.5	Minimum energy required to melt plastic tubing	1% lethality in 1 min
5.	4.0	-	First degree burns, causes pain for exposure longer than 10 sec
6.	1.6	--	Causes no discomfort on long exposures
Source: World Bank (1988). Technical Report No. 55: Techniques for Assessing Industrial Hazards. , Washington, D.C: The World Bank.			