CHAPTER 6

RISK ASSESSMENT AND CONSEQUENCE ANALYSIS

6.1 INTRODUCTION

Hydrocarbons operations are generally hazardous in nature by virtue of intrinsic chemical properties of hydrocarbons or their temperature or pressure of operation or a combination of these. Fire, explosion, hazardous release or a combination of these are the hazards associated with hydrocarbons operations. These have resulted in the development of more comprehensive, systematic and sophisticated methods of **Safety Engineering,** such as, **Hazard Analysis** and **Risk Assessment** to improve upon the integrity, reliability and safety of hydrocarbons operations.

The primary emphasis in safety engineering is to reduce risk to human life and environment. The broad tools attempt to minimize the chances of accidents occurring. Yet, there always exists, no matter how remote, that small probability of a major accident occurring. If the accident involves hydrocarbons in sufficient large quantities, the consequences may be serious to the project, to surrounding area and the population therein.

Risk assessment for underground pipeline transport operations of crude oil and natural gas is discussed briefly in this chapter because the same will be carried out by the proposed 3 pipeline projects.

6.2 IDENTIFICATION OF HAZARDS IN PIPELINE, TRANSPORT OPERATIONS OF CRUDE OIL AND NATURAL GAS

Various hazards associated with pipeline transport operations of crude oil and natural gas are briefly described in following sub-sections.

Crude oil and natural gas are flammable and explosive in nature. On release of crude oil and natural gas, jet fire, flash fire and vapour cloud explosion may occur. Starting point of the following 3 pipelines will be near location TP (in Baghjan OCS) and the end point of the 3 pipelines will be as under:

- Secondary Tank Farm (STF) for Baghjan-STF 200 mm NB Crude Oil Pipeline
- CGGS & OTP near W/50 for Baghjan-CGGS & OTP 400 mm NB Gas Pipeline
- Makum OCS for Baghjan-Makum OCS 100 NB Crude Oil Pipeline

Each pipeline will be provided with Scraper Pig Launcher and Pig Receiver traps suitable for intelligent pigging. Each crude oil pipeline will also have three numbers of indirect heaters installed at suitable intermittent places along the ROW of pipeline to heat the crude oil of the pipeline to save it from congealing. The pipelines will be pre- coated with three layers of polyethylene for external protection and will have Cathodic Protection System for

protection from corrosion. These pipelines will be buried 1.2 m below ground in the same ROW.

Failure mode can be from a small leak (say 25 mm diameter) to a catastrophic rupture of pipeline and possible outcomes can be jet fire or flash fire or vapour cloud explosion after the escape of crude oil or natural gas through 1.2 m thick soil layer above buried pipeline to ground surface.

6.2.1 Immediate Ignition: Jet Fire

Released crude oil or natural gas on immediate ignition will result in jet fire. The extent of injury to people will depend on heat flux and heat exposure duration. Table 6.1 gives tolerable intensities and damages to various objects.

6.2.2 Delayed Ignition: Flash Fire

If released quantity of crude oil and natural gas is not ignited immediately, vapour cloud of volatile fraction of crude oil (up to C_5 fractions) and natural gas will spread in surrounding area depending upon wind velocity and direction. When a portion of vapour cloud concentration is in between lower and upper flammability limits, presence of an ignition source in entire length of vapour cloud movement path may result in a flash fire. Flash fire will cause essentially no over pressure effect. Lower and upper flammability (LFL and UFL) for some gaseous hydrocarbons are as under:

Compound	**LFL (% in air)**	**UFL (% in air)**
Methane	5.0	15.0
Ethane	3.0	12.5
Propane	2.1	9.5
Butane	1.6	7.9

6.2.3 Delayed Ignition: Vapour Cloud Explosion

If released quantity of crude oil or natural gas is not ignited immediately, vapour cloud of volatile fraction of crude oil (up to C_5 fractions) and natural gas will spread in the surrounding area. When a portion of vapour cloud concentration lies in between lower and upper flammability limit and has some degree of confinement, presence of an ignition source may set fire in hydrocarbon vapour cloud generating an over pressure effect. Since ROW of buried pipelines is in open plain field, the presence of some degree confinement over ground surface for hydrocarbon vapour cloud explosion to occur and generate pressure wave is unlikely unless hydrocarbon vapour cloud enters into an above ground structure near ROW and explosion takes place within the confinement of the structure to generate overpressure wave on ignition.

Extent of damage due to the peak overpressure resulting from blast wave is given below:

Peak Overpressure	Extent of Damage
0.830 bar	Total Destruction
0.350 bar	Heavy Damage
0.170 bar	Moderate Damage
0.100 bar	Minor Damage
0.005 bar	Start of Window Shattering

6.3 CONSEQUENCE ANALYSIS

Detailed Quantitative Risk Analysis (QRA) for selected scenarios of jet fire, flash fire and vapour cloud explosion to estimate consequence distances for damage potential or injury is not carried out as the same is beyond the scope of the present discussion. However, QRA studies carried out for selected scenarios for similar crude oil, LPG and natural gas transport from buried pipelines suggest following estimates for consequence distances.

6.3.1 Jet Fire on Immediately Ignition

Thermal radiation causing 1st degree burn in 30s exposure from jet fire is likely to be as follows:

Radiation Level	**Thermal Radiation Distance from Jet Fire**	
	Catastrophic Rupture of Buried Pipeline	Minor Leak (25 mm) in Buried Pipeline
4.0 kW/m^2	Nearly 102 to 110 m	Nearly 40 to 48 m

6.3.2 UFL and LFL Distances and Flash Fire Envelope

In case of no immediate ignition of released crude oil or natural gas on ground surface from leakage/ rupture of pipeline buried below 1.2 m below grand surface, vapour cloud will be formed of volatile fractions of crude oil (up to C_5 fractions) and natural gas and the UFL and LFL concentrations is likely to occur at following distances:

Concentration	**UFL and LFL Concentration Distance**	
	Catastrophic Rupture of Buried Pipeline	Minor Leak (25 mm in Buried Pipeline)
UFL	Nearly 15 to 22 m	Nearly 5 to 7 m
LFL	Nearly 40 to 51m	Nearly 15 to 21 m

On finding an ignition source, hydrocarbons vapour will undergo flash fire. Flash fire envelope is likely to be as given below:

Flash Fire Envelope	**Distance**	
	Catastrophic Rupture of Buried Pipeline	Minor Leak (25 mm) in Buried Pipeline
Farthest Lateral Extent	Nearly 10 to 13 m	Nearly 2.5 to 3.4 m
Farthest Vertical Extent	Nearly 40 to 51 m	Nearly 15 to 21 m

6.3.3 Vapour Cloud Explosion on Delayed Ignition

Hydrocarbons vapour within the range of UFL and LFL will form an explosive mass and on ignition if some confinement is present will result in an overpressure wave of 0.1 bar intensity up to a distance of nearly 80 to 90 m in case of catastrophic rupture of the pipeline. No vapour cloud explosion is possible in case of minor leak in the pipeline.

6.4 RISK MITIGATION MEASURES

The important risk mitigation measures for pipeline system are given below:

- Buried crude oil and natural gas pipelines in same ROW should be provided with suitable coating, wrapping and catholic protection system for corrosion prevention.

- SCADA system should be installed to monitor pipelines during operation.

- Pipeline should be pressure tested at 1.5 times the maximum pressure once in a year. Test pressure should be held at least for 24 hours:

- Ground patrolling by walking in ROW should be done regularly by personal survey to reduce chances of sabotage of pipeline and encroachment of ROW.

- Communication system between Baghjan OCS, starting point of 3 pipelines and STF (end point of Baghjan-STF crude oil pipeline) CGGS & OTP (end point of Baghjan-CGGS & OTP gas pipeline) and Makum OCS (end point Baghjan – Makum crude oil pipeline) should be properly tested before commencing pipeline operation.

- Periodic intelligent pigging and pipe-to-soil potential survey should be carried out in accordance with codes and best industry practice to monitor pipeline health.

- Pig launching and receiving facilities provided at the beginning and end of each pipeline should be suitable for intelligent pigging.

- All welds in the pipelines should be radio graphed.

- Pipeline marker signs should be placed in ROW and specially where pipeline crosses highway and water body.

6.5 FIRE FIGHTING FACILITIES FOR PIPELINE PROJECTS

Transport operations of crude oil and natural gas using underground pipelines have inherent risk of fire and explosion hazards due to their inflammable and explosive nature. Even though the 3 pipelines will be buried 1.2 m below the ground surface and has very low probability of accidental leakage but

possibility of crude oil and natural gas leakage can be much more due to sabotage of the pipelines as pointed out in Section 5.10.1 in Chapter 5. Fire Protection System will have to be provided for buried pipelines as per TAC, OISD-117 and 189 standards.

The 3 pipelines will start at Baghjan OCS. Baghjan-STF crude oil pipeline will terminate at STF, Baghjan-CGGS & OTP natural gas pipeline will terminate at CGGS & OTP and Baghjan-Makum pipeline will terminate at Makum OCS. OIL will have proper fire fighting facilities including fire tenders, foam extinguishers, firemen, fire supervisors at Baghjan OCS, Barekuri OCS, Makum OCS and STF to handle any accidental emergency for underground pipelines anywhere in the ROW. In addition, OIL already has a competent and well trained Crisis Management Team constituted at its Field Office at Duliajan and the same can take control of emergency for the buried pipeline in TD Area within 1 to 3 hours depending upon the location of accident. Section 7.2 in Chapter 7 gives details of Crisis Management Team of OIL.

6.6 MEDICAL FACILITIES

Even though chances of accident occurring during operation of 3 underground pipeline projects for expansion in transport requirement of crude oil and natural gas production are negligible since observation of necessary safety requirements will be strictly followed and excellent track record of OIL in this respect. However, first aid would be made available at Baghjan OCS, Barekuri OCS, Makum OCS and STF installations and a 24 hour standby vehicle (ambulance) would also be available at the Occupational Health Centre (OHC) presently functioning round the clock at Duliajan OIL Complex for quick transfer of any injured personnel to the nearest hospital, in case an accident occurs and medical emergency arises. Prior arrangements will be made with the civil hospitals at Duliajan, Tinsukia and Dibrugarh to look after the injured persons in case of medical emergency during operation of 3 pipeline projects.

Table 6.1

Damage Due to Incident Radiation Intensity

Incident Radiation Intensity (kW/m^2)	**Type of Damage**
62	Spontaneous ignition of wood
37.5	Sufficient to cause damage to process equipment. 100% fatality in 60 s exposure.
25	Minimum energy required to ignite wood at infinitely long exposure (non piloted)
12.5	Minimum energy required for piloted ignition of wood, melting of plastic tubing, etc. First degree burn in 10 s exposure.
4.0	Sufficient to cause pain to personnel unable to reach cover within 20 seconds, blistering of skin (1^{st} degree burns) is likely in 30 s exposure.
1.5	Will cause no discomfort for exposure upto 60 seconds.