ACCIDENT MODELLING AND RISK ASSESSMENT IN MANAGING PIPELINE INTEGRITY OF OIL & GAS INDUSTRIES

Author: - Dr. Jagdish P. N. Giri, Chief Chemist
Affiliations: - Oil & Natural Gas Corporation Limited (ONGC) – Sectoral HSE, Chennai

Abstract: -
In recent past oil & gas industries have adopted preventive policies, acceptable risk levels and introduced strict code of conduct to minimize occurrence of pipeline accidents. Alternatively, a mathematical approach of modeling accidents and carrying out risk assessment shall be an effective method of increasing the preparedness. Considering the hazards posed by various accident scenarios during transportation, it is a common practice to carry out risk assessment for ensuring safe working practices. The paper facilitates a better idea of hazard management, analysis of the consequences and risks involved. The research is a prime facie to assist regulatory authorities for legal sanction of new installations or expansion of the existing plants nearby that locality based on the safe hazard-free zoning.

The technical paper aims at to develop accident modeling and carry out risk assessment with a focus on pipeline transportation. Objectives of the research are as follows:
- To identify various hazardous scenarios,
- To carry out risk assessment for different atmospheric conditions namely: dispersion, thermal radiation and over-pressure effects,
- To arrive at safe distance for expansion and layout of pipeline networking considering the societal risk & Individual risk

The consequence assessment and accident modeling have been done for two pipeline network located at different places. The hazard distances computed are unique for both the network, implying that they vary with atmospheric conditions. For dispersion, it can be concluded that there is an increase in Lower Flammability Limit (LFL) region with an increase in wind velocity (3%) and atmospheric temperature (4% - 6%). For jet fire releases, there is an increase in the hazard distance (6% - 9% for 12.5KW/m2 thermal load intensity) with an increase in wind velocity. For fireball, a reduction in hazard distance is observed due to increase in relative humidity (2%) and atmospheric temperature (12%) for the same thermal load intensity. Hazard distance for shock waves was found to be dependent on the pressure at which the mass is released and not on atmospheric conditions. Risk value can be reduced by adopting the recommendations in regard to storage and pipeline transportation network. The calculated values will act as guidelines for the existing pipeline network or expansion of the same.
Key words: - Accident Modeling, Risk Assessment, Hazard-free zoning, Hazardous Scenarios, Atmospheric Conditions, Dispersion, Thermal Radiation, Over-pressure Effect, Lower Flammability Limit, Hazard Distance, Shock Waves etc.

Contents:
Introduction
Scope & Objectives
Accident Consequence Analysis -
  - Dispersion,
  - Jet Fire,
  - Fire Ball &
  - Boiling Liquid Expanding Vapor Explosion (BLEVE)
Risk Assessment –
  - Consequences of Dispersion,
  - Consequences of Jet Fire,
  - Consequences of Fire Ball &
  - Consequences of Boiling Liquid Expanding Vapor Explosion (BLEVE)
Conclusions,

1. Introduction
Oil and gas industries gain importance in the field of industrial civilization as it plays a vital role in the economic growth of the developing countries. Both the upstream and downstream sectors of oil and gas industries conceive engineering processes, which have high degree of complexities. They pose high threats to the society as the risk level involved is huge. To mention a few, major accidents such as Bhopal gas disaster (1984), LPG release at Visakhapatnam (1997), Bombay high accident (1999), Jaipur fire incident (2009) show that the consequences arise from such accidents are very high. Further, it is important to note that these accidents occurred even while a strict code of conduct and industrial regulations are in place and enforced by Industrial (Oil Industry) safety Directorate - OISD.

Selection of process plants of Oil & Gas Industry requires a careful assessment as it may result in a serious societal damages caused by accidents. Many developing countries have applied preventive policies, acceptable risk levels and introduced strict code of conduct to minimize occurrence of such accidents. Alternatively, a mathematical approach of modeling accidents and carrying out risk assessment shall be an effective method of increasing the preparedness of the oil and gas industries for such untoward incidents. Considering the hazards posed by various accident scenarios in the plant, it is a common practice to carry out risk assessment for ensuring safe working practices. The current study facilitates a better idea of hazard management, analysis of the consequences and risks involved in the Oil & Gas processing plants. The attempted technical analysis is a prime facie to assist the administrative authorities for legal sanction of new installations or expansion of the existing plants nearby that locality based on the safe hazard-free zoning.
2. **Scope and objectives**

Scope of the present technical analysis is to develop accident modeling and carry out risk assessment for oil and gas industries with a focus to gas transporting pipeline network. Objectives of the study are as follows:

- To identify various hazardous scenarios of Oil and Gas transporting pipeline network, that is considered as case studies.
- To carry out risk assessment for different atmospheric conditions namely: dispersion, thermal radiation and over-pressure effects
- To arrive at safe distance for expansion and layout of new plants considering the societal risk & Individual risk

3. **Consequence analysis**

In the present study, case studies of two gas processing stations and gas transporting pipeline networks are considered for the accident modeling and risk assessment. Pipeline network are chosen to be located in two different geographic locations with varying atmospheric conditions. Based on the preliminary hazard analyses carried out on the chosen case studies, a few of the critical failure cases that may cause severe consequences are selected. They are namely: i) dispersion; ii) jet fire; iii) fireball; iv) Boiling Liquid Expanding Vapor Explosion (BLEVE) and v) pool fire. Appropriate accident models are developed in order to carry out the consequence analysis and risk assessment of both the plants; failure cases and consequences are considered common for both the plants. Various scenarios are analyzed for different weather conditions and the respective hazard distances are derived for different discharge rates.

3.1. **Dispersion** - It includes discharge of pressurized liquid with a significant momentum; release may be either in single or two phases. Discharged fluid will travel along with the wind till it is completely dispersed. Flammability of Gas, which is also a toxic material, depends upon the upper and lower flammability limits (LFL); within these limits,

3.2. **Jet fire** - Jet fire is formed due to the ignition of continuous discharge from an orifice or from a pipeline. Jet fire causes thermal radiation, which produces heat to the visible boundaries near the flame area

3.3. **Fireball** - Fireball is formed mainly due to the ignition of vapor cloud mass resulting from the sudden release of pressurized fluid. They are short-lived flames.

3.4. **Boiling Liquid Expanding Vapor Explosion (BLEVE)** - BLEVE is formed due to the catastrophic failure of a pressurized vessel containing fluid above its normal boiling point; rise in temperature of the fluid may be caused by any external source of heat that arise during the process. Catastrophic failure of the high-temperature fluid may lead to the formation of fireball or unconfined vapor cloud explosion
Risk Assessments
For different failure cases individual and societal risks are calculated. Mathematically individual risks are the ratio of number of fatalities and number of people at risks. For different weather conditions, individual risks depend on:
1. Time period of occurrence of failure,
2. Direction of Gas release,
3. Probability of the release occurring in any specific direction of the given weather.
4. Probability of fatalities in the given release direction etc.

Societal risk is defined as the number of number of the people suffered from the accidental consequences. For calculating societal risk, population distribution data need to be considered as the vital input.

Consequences of dispersion - The LFL distances are determined for different failure cases those arise during different seasons in a year. Maximum hazard distance that may arise due to the considered failure cases is computed. This is helpful in planning the location of inventory and stocking to maintain a safe distance from the critically hazardous equipment. The dispersion hazard distances, computed for the Gas Processing units shall also govern the extension of the current plant or installation of new equipment in the existing plant. Further, variation of lower flammability limit with the effect of wind velocity is studied for an average value of atmospheric temperature and relative humidity. Percentage reduction in the hazard distance for change in the wind velocity is also taken into consideration. It is observed that LFL distance decreases with the increase in wind velocity for a stable atmospheric stability class; for lower mass flow rate, decrease in the hazard distance is even higher (about 8%). It is also seen that for constant values of wind velocity, atmospheric stability class and temperature, relative humidity does not influence the LFL region.

Consequences of jet fire - Thermal radiation for different levels of intensities and failure cases are computed. Maximum hazard distances for the maximum thermal load are determined for the individual processing unit. For an average value of atmospheric parameters valid at the locations of both the units, effects of thermal radiation arising from jet fire for different releases are computed. It is seen that there is an increase in the hazard distance for thermal radiation due to jet fire with the increase in wind velocity. Maximum increase of hazard distance, which is about 9%, is seen for the 40% pipeline failure. It is also seen that the variation in relative humidity does not influence the thermal radiation distance significantly. It is dependent on the pressure and amount of mass released. Since the jet fire is caused due to ignition of momentarily release of pressurized gas, it is not influenced by the ambient temperature as well

Consequences of fireball - Based on the analysis, it is observed that for different thermal load intensities, wind velocity does not influence the hazard distances of fireball as the duration of fireball is significantly lesser. The catastrophic failures of storage bullets and road tankers are considered for the analysis. Influence of the varying relative humidity on the hazard distances are
computed for catastrophic failures leading to fireball. Percentage reduction in the hazard distances for the varying values of relative humidity indicates that the hazard distance decreases with the increase in relative humidity for both the units. For a catastrophic failure of the storage bullet, hazard distance is found to be more. Influence of atmospheric temperature on the variation of thermal intensity shows that there is a decrease in the hazard distance with the increase in atmospheric temperature.

**Consequences of BLEVE** - Hazard distance due to BLEVE arising from the catastrophic failures of storage bullet indicates that the hazard distance depends on the initial conditions of release of GAS. Based on the hazard evaluation, distance of 130 is found to be hazardous for the storage bullets; distance closer than these values shall result in a catastrophic failure. It is also seen that a shock load of 0.1 bars will cause repairable damage and the distance affected due to catastrophic failure of storage bullet is found to be 240 m.

**Conclusions:**
The consequence assessment and accident modeling have been done for two pipeline network located at different places. The hazard distances computed are unique for both the network, implying that they vary with atmospheric conditions. For dispersion, it can be concluded that there is an increase in Lower Flammability Limit (LFL) region with an increase in wind velocity (3%) and atmospheric temperature (4% - 6%). For jet fire releases, there is an increase in the hazard distance (6% - 9% for 12.5KW/m2 thermal load intensity) with an increase in wind velocity. For fireball, a reduction in hazard distance is observed due to increase in relative humidity (2%) and atmospheric temperature (12%) for the same thermal load intensity. Hazard distance for shock waves was found to be dependent on the pressure at which the mass is released and not on atmospheric conditions. Risk value can be reduced by adopting the recommendations in regard to storage and pipeline transportation network. The calculated values will act as guidelines for the existing pipeline network or expansion of the same.

**References**

Dr. Jagdish P. N. Giri, Chief Chemist
Affiliations: - Oil & Natural Gas Corporation Limited (ONGC) – Sectoral HSE, Chennai