EXECUTIVE SUMMARY

Major industrial accidents such as the Seveso disaster in Italy (1976), the Bhopal gas tragedy in India (1984), the Piper Alpha disaster in the North Sea (1988) and the Deep Water Horizon oil spill in the Gulf of Mexico (2010) not only had massive environmental impacts, but had serious and long term effects and consequences. Process Safety involves prevention of fire, explosion, and accidental toxic chemical releases in oil and gas installations.

Risk assessment is one attempt to identify and to evaluate the risk in order to develop control measures that reduce the risk. The assessment is either conducted in qualitative or quantitative approach depending upon the requirements. One of the key step in risk assessment is frequency analysis. In this study an attempt is made to enhance the frequency estimation combining existing data and statistical tool.

The study objectives for this research work are:

- To identify the HSE hazards (HAZID/HAZOP) and threats that can be applied to credible accidental scenarios;
- To carry out fire, explosion and flammable gas dispersion modelling to assess the physical effects for the selected scenarios:
- To assess the frequency by FTA / ETA or from generic historical databases in order to assess the consequences on people, equipment and structures;
- To estimate the risk of fatal injury arising from the risk of flammable hydrocarbon and toxic releases, and mapping them on risk contours / transect and F-N curves;
- To establish a method to generate precise failure frequency data for the QRA.

Many Quantitative Risk Assessment (QRA) models are put into practice by different countries and leading Oil & Gas companies throughout the world. For example, the CCPS-CPQRA model describes the methodology for Quantitative Risk Analysis. The Netherlands government's Centre for Prevention of Disaster

(CPR) adopts a model for QRA that models the physical effects and provides a probability assessment in various guidelines. The Indian government standard on risk assessment IS 15656:2006 is a code of practice that provides the guidelines for hazard identification and risk analysis.

The key elements of quantitative risk assessment of consequence analysis, and frequency analysis of accident scenarios are critically evaluated. In order to understand the consequences and estimating frequency, seven flammable gas facilities were selected for this study - three LPG facilities, two NG facilities and two Hydrogen facilities that handle Hydrogen in a gaseous and liquid state. The facilities are situated in India, Oman and Qatar.

Case studies were created for each of the facilities:

Case Study 1: LPG storage and handling facility in an automobile ancillary unit.

Case Study 2: Gaseous hydrogen storage and handling facility in a Power Plant.

Case Study 3: LPG storage and handling facility in an automobile plant.

Case Study 4: Liquid hydrogen storage and handling facility at space research Centre.

Case Study 5: LPG storage and distribution system at High rise building.

Case Study 6: Natural gas gathering terminal and pipeline facility.

Case Study 7: Natural gas station manifold and pipeline facility.

The key results of this study include:

- A detailed analysis of hazard identification techniques adopted by Oil and Gas industries, especially LPG, Hydrogen and Natural Gas were studied. HAZID and HAZOP were used as a hazard identification tool and comprehensive checks list with guide words developed for hazard identification of NG facilities.
- Consequence analysis and modelling were carried out for identified scenarios. These models provided predictions for the vulnerable zones around the facilities based on the thermal intensity and over-pressure effects. The results are described in detail in Chapter 4. Risk contours are used for further land use planning based on failure frequency.

- The limitation of frequency assessment by various tools are discussed and how to generate reliable frequencies based on generic and/or historical databases. Different generic and historical databases are referred and their limitations are discussed. Development of failure frequency method are briefed.
- Failure frequency modelling is carried out by PCAM with the Bayesian Network in order to improve the effectiveness of updating reliable frequencies. Risk Contours, Frequency and number of people loss in an accident scenario, individual risk and societal risk calculations were applied for various selected case studies.

In summary it is concluded that a QRA can be a useful tool for land use planning, layout of equipment and facilities. The safety of a plant or facility is determined to a large extent during process, plant and installation design. On the other hand, different generic and historical databases and their limitations were discussed in chapter 2 and chapter 4.

However, recent accident statistics and analysis show that fatal accidents occurring in the Oil & Gas industry are on increasing trend, therefore more steps need to be taken in order to prevent or mitigate the risks. The detail sensitive analysis provided in chapter 8 is based on recent accident statistics. In order to overcome the limitations of generic or historical databases, the Bayesian Network is combined with the PCAM and evaluated to update the failure frequency for risk computation. The frequency updating methodology using the Parts Count Approach Method with Bayesian Network model enhances the accuracy of frequency estimation which benefits in assessing the quantitative risk.