CHAPTER 6
CONCLUSIONS

6.1 GENERAL

Risk Assessment is one of the main tools used in process industries, such as Oil and Gas, to minimise risk to acceptable level (ALARP). The purpose of the risk assessment study is to guide engineering solutions, design safety, emergency preparedness and planning [22]. So the process industries should consider safety during the design phase. Great importance has to be given during this stage to enhance plant safety [62]. Decision making is taken by top management and shareholders based on the results of the risk values, so due care must be taken while conducting these studies. Hence the acceptable risk criteria and actions for mitigating risk may vary. Continuous development of techniques is essential in order to improve the accuracy of the analysis, and to enable better decision making.

Following are the main outcomes of this work.

- HAZID and HAZOP were used as a hazard identification tool to identify and recognize the hazardous scenarios of flammable gas facilities. Comprehensive checks listed with guide words enhanced hazard identification were developed.
- Consequence analysis such as fire, explosion and dispersion of toxic gas modelling were carried out. These models provided predictions for the vulnerable zones around the facilities based on the thermal intensity and over-pressure effects in case of any hazardous outcomes.
- Fault Tree Analysis, Event Tree Analysis and other techniques were applied to assess the frequencies. The limitation of frequency assessment was discussed and how to obtain more reliable frequencies was developed.

Frequency was assumed based on generic or historic databases usually in order to carry out the risk assessment [20].

However, accidents occurring in the Oil and Gas industry were observed to be in on increasing trend in previous decades.

6.2 OIL & GAS INDUSTRY PERFORMANCE

Figure 6.1 shows the number of fatalities occurring in the USA per 100 oil rigs. Accidents rates decreased during 2005 (this may have coincided with a global cut in production) but the overall trend is still increasing. In the same 10-year period, fatal accident rates were on increasing trend, while at the same time upstream Oil and Gas facilities underwent safety studies [58]. These need to be reviewed and vigorous improvements made to the methods, techniques and processes.

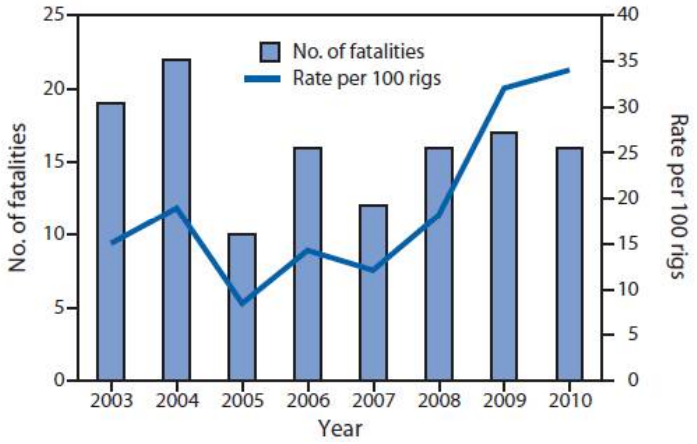

Fig 6.1: US fatalities per oil rigs accident statistics

An analysis of the UK offshore industry injury and ill health data is provided at Figure 6.2 by UK HSE in order to measure the performance for continual

improvement purposes [38]. The figures show that injury and ill health statistics for a period of 5 years for different functions and operations.

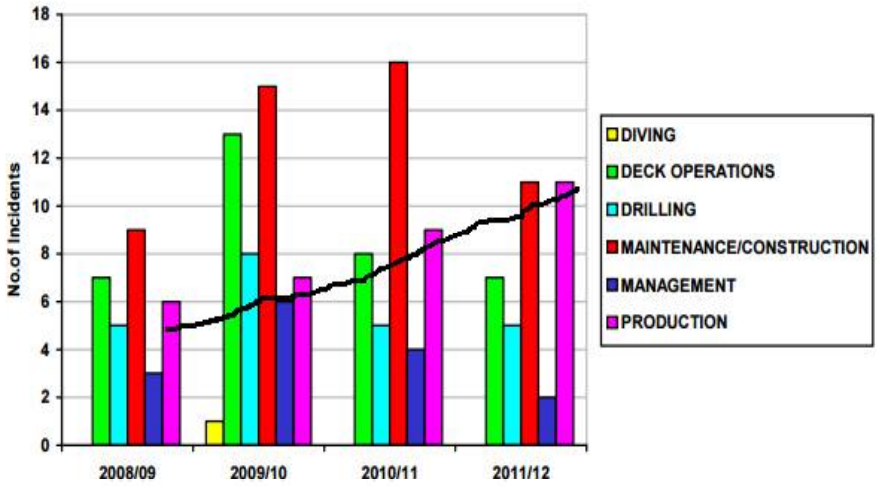

Fig 6.2: UK Offshore Industry incident classification

Each year, injuries are categorised based on the type of operation or functions such as diving, deck operations and drilling, maintenance or construction, management and production operations. From the analysis it was found that the maintenance and construction operations are accountable for the major portion of incidents. However, the production rates are on increasing trend. This shows that the major incidents occur in the Oil and Gas industries despite many developments. It is imperative that safety design studies such as risk assessment and risk management techniques are to be evaluated further and steps to be taken to improve their effectiveness.

RPS Energy is an Oil and Gas consultant that has conducted analysis of accidents occurring in the Oil and Gas industry [69]. Table 6.1 shows their analysis of accidents that resulted personal injury.

Table 6.1: Fatal accident Statistics in Oil and Gas Industry

Accident	Fatalities	Year
P36 Sinking of semisubmersible	11	2001
Shongquing-Sour gas blow out	243	2003
Neelam field, helicopter	27	2003
Skida LNG explosion	27	2004
Texas city explosion refinery	15	2005
Bombay High-Ship collision	22	2005
Usumacita, Jack up collision	22	2007
Nigeria pipeline explosion	100	2009
Jaipur Gasoline explosion	12	2010
Cango, gasoline RTA overturned	230	2010
Jurong Oil tank fire accident	No data	2016
Saudi Arabia Petrochemical Plant	12	2016

Over the last 30 years there have been large numbers of fatalities occurring in the Oil and Gas industry. These are caused mainly as a result of the challenges faced by the industry such as severe process conditions (e.g. extreme pressure and temperature), large and more complex facilities, deeper water operations and colder climates affecting the process safety and operational issues. Even though many safety design studies are conducted and operational safety issues are assessed, there is still room for improvement. Hence the risk assessment steps need to be evaluated and enhanced for greater effectiveness. Failure Frequency Modelling carried out by PCAM and combined with Bayesian Network analysis for available components

and parts definitely improve the effectiveness of updating failure frequencies, and therefore provide more accurate and reliable predictions.

Risk Contours, Frequency and fatalities loss in an accident scenario, individual risk and societal risk calculations were applied for various selected case studies.

The failure assessment methods such as FTA, ETA, Bayesian Network and Fault Tree Analysis were studied, with the Bayesian Network being combined with other techniques to enhance reliability of frequency data.

6.3 CONCLUSIONS

This research is an attempt to provide a brief of risk assessment, the methodology, and how the findings of this research could be applied to enhance facility sites and planning for emergencies. Previously, spread sheets and manual calculations were made to estimate blast over-pressures and radiation intensities from fires explosions, but now sophisticated software models are used to assess the risk for process plants, especially for Consequences Analysis.

- Hazard identification techniques vary. Many different techniques are adopted by various industries and hazards identified are based on single techniques. The hazard checklist method with guide words may overcome the limitations to identify a greater number of potential hazards.
- Frequency data assumptions used in quantitative risk assessments always has an uncertainty. Many times the generic data used for analysis are subjective, limited or some industry's data are not available/insufficient. In this study, the PCAM with Bayesian Network was developed to generate failure frequencies.
- New processes and products result in new hazards and risks to human beings and the environment. The risk assessment study results are compared with the accepted international criteria. Based on the results,

safety precautions are recommended to the respective facilities and these results are used for future land usage planning and layouts.

- Evaluation of available safety and fire protection systems in the plant were found to be adequate and well maintained to take care of any emergency.

Hence it is recommended that frequency analysis for any QRA study use methodology of using Parts Count Approach Method combined with Bayesian Network model improve the frequency failure data so that quantified risk shall be reliable and challengeable.

6.4 SUGGESTIONS FOR FURTHER RESEARCH WORK

a) Frequency Assessment is mainly carried out for equipment, piping and other components of natural gas facilities. This should be extended for other flammable gases such as hydrogen.
b) Comprehensive maintenance database system should be developed which includes data from preventive or breakdown maintenance, accidents / incidents breakdown, plant shutdown etc., This will be useful to find the local specific failure rate.
c) Accurate models using CFD are to be used for consequence modelling for fire, explosion accidents to predict the thermal or overpressure effects.
d) Human error prediction and control should be incorporated in failure frequency causes and same may be applied by the Bayesian Network method.