Quantitative risk analysis of a fuel storage tank

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ABSTRACT

Quantification of risks has become an indispensable element with modern day systems as it provides an insight into the magnitude of the probable loss prior to the commencement of projects. A methodology for quantifying the explosion risk associated with atmospheric liquid fuel storage tanks was developed utilizing the bowtie and fault-tree analyzes. Possible threats that could lead to an explosion and influence of preventive and protective measures were determined taking account of literature data. The expected loss in LKR was determined by introducing an impact radius and taking in to account the monetary value of the assets inside the afflicted area.

KEYWORDS: Quantitative Risk Analysis, Explosion Analysis, Multi Hazard, Impact Radius

INTRODUCTION

With the rapid economic growth and intense fuel consumption all over the world, risk analysis has become essential for security management in fuel tanks and depots as a result of continuous increment in its total capacities. In addition, the past fire and explosion accidents in fuel depots, around the world were caused by the similar reasons repeatedly, out of which a large number could be prevented by scientific studies or reasonable guidance.

Quantitative risk analysis is defined as the process of numerically analyzing the combined effect of identified individual project risks and other sources of uncertainty on overall project objectives. Although qualitative risk analysis must usually be performed across all the risk categories, the quantitative risk analysis is more focused on the most impactful risk scenarios. The purpose of this research is to develop a method to analyze the risks involved with fuel storage tanks in a quantitative basis to provide the proprietors a sound understanding about the potential financial loss, in case of storage tank failure.

METHODOLOGY

This risk assessment focuses on fire and explosion that may take place in an atmospheric liquid fuel storage tank. The major threats involved with a fuel storage tank fire and explosion are evaluated as the initial step of the analysis. Identification of probable threats and evaluating their probabilities are done by referring to historical data. As per the extension of the existing analyzing techniques and as the continuation of the assessment method, the preventive & protective measures (layers of protection) taken by the proprietor will be contemplated when determining the final failure probability. Its identified that the magnitude of the explosion and the impact radius is directly proportional to the energy stored in the system.

$$\frac{Magnitude\ of}{the\ explosion} \propto \frac{Impact}{radius\ (R1)} \propto \frac{Impact}{radius\ (R1)} \quad \text{---(1)}$$

After evaluating historical data available on fuel tank explosions, the following relationship for the impact radius was derived.

$$R = 4.884 \times 10^{-5} \times \begin{matrix} Mass\ of \\ the\ fuel \\ sample \end{matrix} \times \begin{matrix} Specific \\ energy\ of \\ the\ fuel \end{matrix} \quad (2)$$

A high-risk zone where
all the assets and human life will perish upon an explosion and a medium risk zone extended up to 2.5 times the radius of the high-risk zone was identified. Expected loss was determined by accounting the monetary value of the assets inside the impact area. The quantitative risk was identified as a function of expected loss and final failure probability.

$$\begin{matrix} Quantitative \\ Risk \end{matrix} \times \begin{matrix} Final\ failure \\ probability \end{matrix} \times \begin{matrix} Expected \\ loss \end{matrix} \quad --(3)$$

RESULTS AND DISCUSSION

The developed risk assessment was applied to a 30000 gallons atmospheric fixed roof tank containing conventional gasoline. Moreover, a high-risk impact radius of 19.2m was obtained.

	Risk zone	
	High	**Medium**
Range	19.2m from the center of the tank	From 19.2m to 48m away from the tank
Percentage of compensation	100%	50%
Assets value (Millions LKR)	130	250
Avg number of employees	4	15

Table 1: Asset values in the impact areas

Expected loss due to an explosion can be calculated from following equation.

$$\begin{matrix} Expected \\ Loss\ (EL) \end{matrix} = V1 + z.N1 + 0.5(V2 + z.N2) \quad ---(4)$$

$$= 130 + 1 \times 4 + 0.5(250 + 1 \times 15)\ Million\ LKR$$

$$= 266.5\ Million\ LKR$$

When the probability of failure on demand values of the implemented protective layers were integrated with the explosion probabilities for a fixed roof tank, a final failure probability of 3.441×10^{-5} per year was realized. The quantitative risk was determined to be Rs.9170 per year as per the equation (3).

CONCLUSIONS

The assessment results obtained for gasoline storage unit showcased an impact radius of 19.2m and a quantitative risk of 9170 LKR per year. The impact radius obtained seems realistic, since, for a small-scale unit as such, the safety radius is usually taken as 15m as a rule of thumb. But the quantitative risk seems to be on the lower side mainly due to the influence of the application of protective layers.

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