J. Appl. Environ. Biol. Sci., 5(6)268-272, 2015
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ISSN: 2090-4274
Journal of Applied Environmental and Biological Sciences
www.textroad.com

Fuzzy Risk Assessment of Fire and Explosion in the Crude Oil Storage Tanks by Fuzzy Hierarchical Analysis

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Received: February 4, 2015
Accepted: April 29, 2015

ABSTRACT

Risk assessment for oil storage tanks is very important due to different potential hazards and economic losses. Use of fuzzy logic in risk assessment in a process has considerable advantages. Fuzzy methods are user-friendly and time-saving. In addition, fuzzy models are reliable and can yield more precise and detailed results in future studies. The present study aimed at fuzzy risk assessment of fire and explosion in the crude oil storage tanks by fuzzy hierarchical analysis in Arvandan Oil & Gas Company. Sample collection was performed by HAZOP method, brainstorming, library studies, and storage tanks incident reports. Fuzzy risk analysis and all calculations were performed in MATLAB. Likelihood and severity were defined according to trapezoidal fuzzy number likelihood (TPFNL) and trapezoidal fuzzy number severity (TPFNS). Fuzzy analytic hierarchy process was used to obtain weight of each risk item and combination of the items by using a risk hierarchical framework. Triangular fuzzy numbers were used as a model for weighing the relative indices. The results indicated that the final score of fire and explosion risk is in average area. The highest risk score was for pressure vacuum safety valve (PVSV).

KEYWORDS: fuzzy risk assessment, fire, explosion, storage tank, Arvandan.

1- INTRODUCTION

Huge industrial disasters have claimed many lives such as Flixborough disaster [1] where 28 people died, LPG explosion in Mexico City [2], and big explosion in Pasadena, Texas [2], among others. Some incidents occurred in the past are still happening in the present days where thousands of people die or suffer injuries. These incidents sometimes damage environment and economies. Calamities take place in different forms but their common feature is fire, explosion, and toxic release [1]. Storage and use of flammable, explosive, and toxic chemicals can result in intolerable disasters whose consequences are the functions of nature and chemicals in installations [1]. Process safety is one of the most important components of industrial practices which should be measured by risk assessment methods. However, risk assessment is always subjected to uncertainty and inaccuracy. Fuzzy logic is capable of solving uncertainty and inaccuracy in risk assessment and helps to attain a better idea of risk indices and hazard predictions [3]. Therefore, risk assessment for oil storage tanks is very important due to different potential hazards and economic losses. Although several investigations have been performed in order to develop qualitative and quantitative methods for recognition and assessment of risks, few works have been done in a given country, equipment or its components in industries in order to determine failure rate and estimate likelihood of disaster occurrence. Use of fuzzy logic in risk assessment in a process has considerable advantages. Fuzzy methods are user-friendly and time-saving. In addition, fuzzy models are reliable and can yield more precise and detailed results in future studies [3]. Wang et al. (2013) determined fire and explosion occurrence in crude oil storage tanks by using fuzzy fault tree analysis. They first recognized fire and explosion hazards and possible reasons in storage tanks and then drew fault analysis tree and assessed risk. They found over 43 basic events [4]. Also, Khaleghi et al. (2013) performed a fuzzy risk assessment and grouping based upon event tree analysis and protective layers analysis in gas transfer systems in one of oil fields located in Persian Gulf. In this study, three scenarios were evaluated for small, average, and complete pipe ruptures and the results showed that fuzzy risk indices in determination of small and average leakage risks relative to classic risks are 30 and 8 percent, respectively. This indicates that fuzzy risk assessment has a better capability of solving uncertainty and inaccuracy in assessment compared with classic risk assessment methods [5]. Shi et al. (2014) proposed the FFTA based on improved AHP. They presented four conclusions: (1) The FFTA for experts' elicitation is an effective quantitative hazard assessment method to assess the safety and reliability of a system; (2) the weights of various experts are important factors that influence the

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evaluation results of FFTA; (3) the mixture of oil vapor and air beyond the explosive ratio should be prioritized for eliminating the FEA-SOST occurrence likelihood; and (4) The fault tree could be extended to other oil depot because the basic events identified here are more or less common to all tank units [6].

Taken together, the present study aimed at determination of final risk level of fire and explosion in crude oil storage tanks and provision of control strategies. In this regards, the following objectives were followed:

- Specification of risk score for each basic risk item (BRI) in fire and explosion in crude oil storage tanks;
- Weighing each BRI by Fuzzy Analytic Hierarchy Process (FAHP);
- Determination of controlling practices for the most important BRIs; and
- Specification of the final risk score for fire and explosion with regard to very favorable, favorable, average, unfavorable, and very unfavorable indices.

The practical objectives of the present study were to specify safety status of crude oil storage tanks and prevent from fire and explosion in crude oil storage tanks. The study was performed in Arvandan Oil & Gas Company. The company is located along Karoon River and Ahvaz-Khorramshahr Road.

2- METHODOLOGY

As the research samples are the risk items effective in occurrence of fire and explosion, sample collection was performed by HAZOP method, brainstorming, library studies, and storage tanks incident reports. Fuzzy risk analysis was performed in MATLAB and all the calculations were written in MATLAB programming language. Fuzzy weight and fuzzy analytic hierarchy process were obtained in Excel Software.

Risk score can be achieved as followed:

$L \otimes S = R$

where R, L, S, and $\otimes$stand for risk score for each dangerous event, risk likelihood, severity or consequence of risk, likelihood of occurrence and severity (fuzzy state multiplication), respectively. Generally, the relation considers that if likelihood and severity are fuzzy numbers, risk will be a fuzzy number, as well.

After making decision about likelihood and severity levels orally, another decision should be made to express mathematical relations to use membership functions obtained from fuzzy numbers. In this study, likelihood and severity were defined according to trapezoidal fuzzy number likelihood (TPFNL) and trapezoidal fuzzy number severity (TPFNS) [7].

To obtain weight of each risk item and combination of the items, fuzzy analytic hierarchy process was used by using a risk hierarchical framework. Also, triangular fuzzy numbers were used as a model for weighing the relative indices and trapezoidal fuzzy numbers were selected for modeling fuzzy risk assessment parameters [8].

3- RESULTS AND CONCLUSION

Table 1 shows operational parameters of the storage tank.

Table 1: operational parameters of the crude oil storage tank

parameter	Amount
Design temperature	85°C
Design pressure	50 Mbar
Operational temperature	60.2°C in winter and summer
Operational pressure	Atmospheric
Internal diameter	14000 mm
Tank height	16500 mm

Table 2 shows all risks in a single framework expressed as a $TPFN_{LS}$.

Table 2: risk scores for basic risk items

$X^*_{i,j}$	$TPFN_L$				$TPFN_S$				$TPFN_{LS}$			
$x^4_{1,1}$	0.1	0.25	0.25	0.4	0.3	0.5	0.5	0.7	0.030	0.125	0.125	0.280
$x^4_{2,1}$	0.1	0.25	0.25	0.4	0.6	0.75	0.75	0.9	0.060	0.188	0.188	0.360
$x^4_{3,1}$	0.1	0.25	0.25	0.4	0.6	0.75	0.75	0.9	0.060	0.188	0.188	0.360
$x^4_{1,2}$	0	0	0.1	0.2	0.6	0.75	0.75	0.9	0.000	0.000	0.075	0.180
$x^4_{2,2}$	0	0	0.1	0.2	0.6	0.75	0.75	0.9	0.000	0.000	0.075	0.180
$x^4_{3,2}$	0.3	0.5	0.5	0.7	0.1	0.25	0.25	0.4	0.030	0.125	0.125	0.280
$x^4_{1,3}$	0.1	0.25	0.25	0.4	0.3	0.5	0.5	0.7	0.030	0.125	0.125	0.280
$x^4_{2,3}$	0	0	0.1	0.2	0.3	0.5	0.5	0.7	0.000	0.000	0.050	0.140
$x^4_{1,1}$	0.6	0.75	0.75	0.9	0.6	0.75	0.75	0.9	0.360	0.563	0.563	0.810
$x^4_{2,1}$	0.8	9	1	1	0.8	9	1	1	0.640	81.000	1.000	1.000
$x^4_{3,1}$	0.3	0.5	0.5	0.7	0.3	0.5	0.5	0.7	0.090	0.250	0.250	0.490
$x^4_{4,1}$	0.3	0.5	0.5	0.7	0.6	0.75	0.75	0.9	0.180	0.375	0.375	0.630
$x^4_{5,1}$	0.3	0.5	0.5	0.7	0.6	0.75	0.75	0.9	0.180	0.375	0.375	0.630
$x^4_{6,1}$	0.6	0.75	0.75	0.9	0.6	0.75	0.75	0.9	0.360	0.563	0.563	0.810
$x^4_{1,2}$	0.1	0.25	0.25	0.4	0.6	0.75	0.75	0.9	0.060	0.188	0.188	0.360
$x^4_{2,2}$	0.3	0.5	0.5	0.7	0.6	0.75	0.75	0.9	0.180	0.375	0.375	0.630
$x^4_{3,2}$	0.3	0.5	0.5	0.7	0.6	0.75	0.75	0.9	0.180	0.375	0.375	0.630
$x^4_{4,2}$	0.3	0.5	0.5	0.7	0.3	0.5	0.5	0.7	0.090	0.250	0.250	0.490
$x^4_{5,2}$	0.3	0.5	0.5	0.7	0.3	0.5	0.5	0.7	0.090	0.250	0.250	0.490

The scores for risk assessment indices for fire and explosion in crude oil storage tanks are as follows:

- For very favorable status: X = 0.0246
- For favorable status: X = 0.0703
- For average status: X = 0.2131
- For unfavorable status: X = 0.4663
- For very unfavorable status: X = 0.6203

It should be noted that risk score of the storage tank is always between 0.0246 and 0.6203. The lower limit in very favorable status is 0.0246; to obtain the higher limit of very favorable status and lower limit of favorable status, the mean of their scores were derived (0.04745). Therefore, the lower limit of favorable status and higher limit of very favorable status are 0.0246 and 0.04745, respectively. Likewise, the coverage limits for favorable, average, unfavorable, and very unfavorable statuses were 0.1417, 0.3397, 0.3397, and 0.5433, respectively.

Figure 1: Comparison of final risk statuses with risk criteria

Very unfavorable	Critical area
Unfavorable	Hazard area
Average	Caution area
Favorable	Safe area
Very favorable	Completely safe area

0.5433

0.4663

0.3397

0.3353

0.2131

0.1417

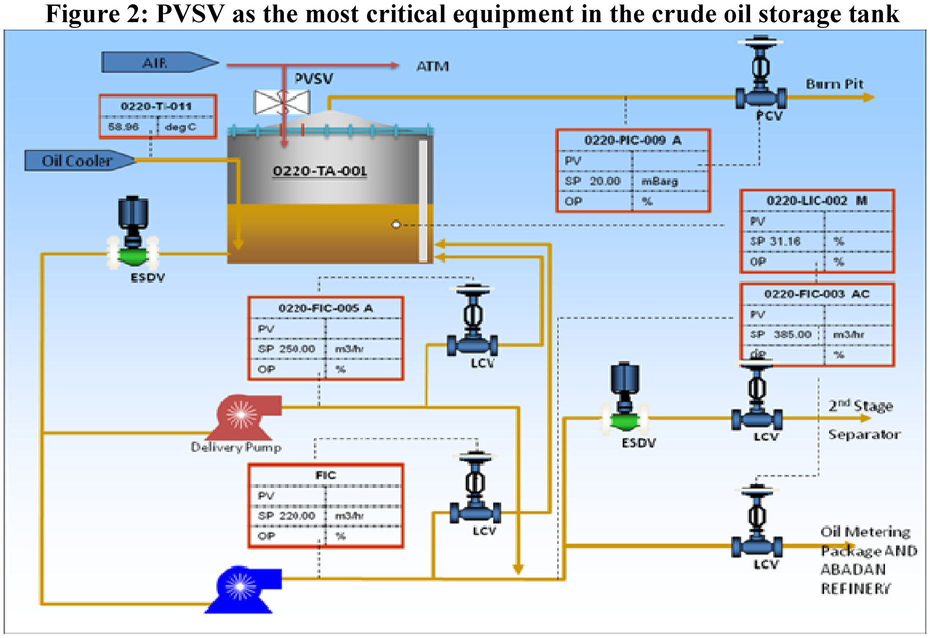
0.0703

0.04745

0.0246

It can be concluded that the final score of fire and explosion risk is not in favorable area; it is in average area. The highest risk score was for pressure vacuum safety valve (PVSV). Therefore, this valve is considered a critical equipment with a very important role in prevention from fire and explosion in crude oil storage tank. So, correction measures should be taken for this valve in the crude oil storage tank (Fig. 2).

Figure 2: PVSV as the most critical equipment in the crude oil storage tank



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