PROBABILISTIC ANALYSIS IN THE RELEASE OF LIQUEFIED PETROLEUM GASES

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Abstract

In this paper we analyzed the probabilities of accident development in case of liquefied hydrocarbon gas emission taking into account the logistic scheme of accident development. It was found that the probability of ignition of the release is determined by the probability of combustible substance coincidence with the ignition source. It should be borne in mind that the probability of ignition source manifestation depends on the area of the affected object (cloud of gas-air mixture or gas liquid).

Keywords: liquefied gas, risk, probability, accident, logistics scheme, spill combustion, gas-air mixture

I. Introduction

For risk analysis RD 03-48-01 [1] offers 6 methods of analysis. If the theory of risk corresponded to the probability theory, the best method of analysis would be quantitative analysis. Unfortunately, risk theory almost completely ignores the existing probability theory.

To demonstrate the dubiousness of the examination requirements, let us consider a method of analysis that uses an event tree logic diagram.

The logical scheme of the accident development associated with the release of combustible substances at an outdoor facility is presented in Fig. 1.

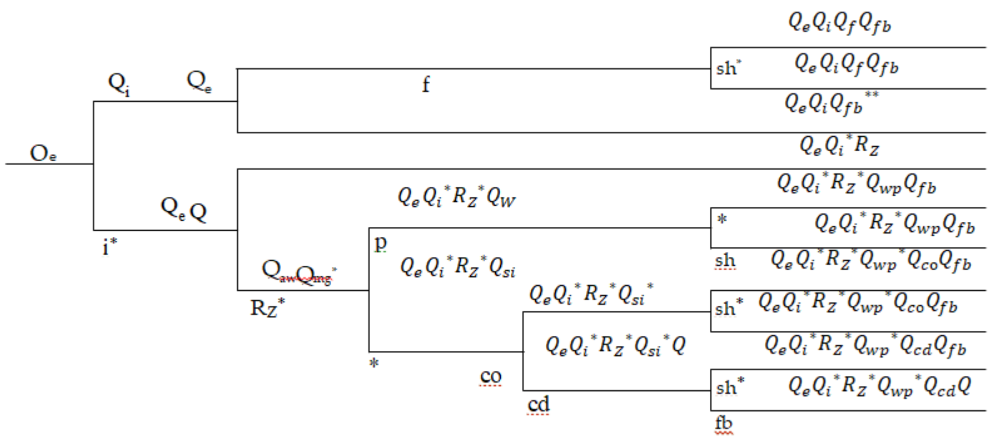

Figure 1: *Logic diagram of an accident involving the release of flammable substances at an outdoor facility*

Decoding of designations on the diagram:

A1 - instantaneous ignition of the flowing product followed by flaring combustion;

A2 - flare combustion, thermal effect of the flare leads to destruction of the nearby tank and formation of a fireball;

A3 - instantaneous release of product with formation of a fireball;

A4 - no instantaneous ignition, the accident is localized due to effective fire prevention measures or due to vapor cloud dissipation;

A5 - instantaneous flashover did not occur, fire prevention measures were not successful, spill ignition;

A6 - destruction of a nearby tank under the influence of excessive pressure or heat during burning of the spill or formation of a fireball;

A7 - combustion of a vapor-air mixture cloud;

A8 - destruction of a nearby tank under the influence of excessive pressure or heat during burning of a spill or formation of a fireball;

A9 - combustion of a cloud with development of overpressure in open space;

A10 - destruction of a nearby tank under the influence of excessive pressure or heat during burning of a spill or fireball formation;

Calculation of the probability Q(Ai) of each of the variants of realization of the logic circuit. For this purpose the following relations are used:

$$Q(Ai)= Q_e Q_i Q_f Q_{fb} Q_{fb}^*, \tag{1}$$

Qe - probability of emergency release of a combustible substance;

Qi - probability of instantaneous ignition of the flowing product;

Qf - probability of flare combustion of the jet of the expiring product;

Qfb - probability of destruction of a nearby tank under the influence of a fireball;

Qfb* - probability of preservation of the nearby tank under the influence of the fireball;

$$Q_{fb}^*= 1- Q_{fbh}. \tag{2}$$

$$Q(A2)= Q_e Q_i Q_f Q_{fb}, \tag{3}$$

$$Q(A3) = Q_e Q_i Q_{fb}^{**}, \tag{4}$$

Q_{fb}^{**} - is the probability of tank collapse with fireball formation.

$$Q(A4) = Q_e Q_i^* R_Z, \tag{5}$$

Qi is the probability that instantaneous ignition of the expiring product will not occur;

P3 - probability that the fire prevention means have fulfilled the task or there was a dispersion of the vapor-air mixture cloud.

$$Q(A5)= Q_e Q_i^* R_Z^* Q_{wp} Q_{fb}^*, \tag{6}$$

P3*=1-P3 probability of failure to fulfill the task by fire prevention means;

Qsi - probability of spill ignition;

$$Q(A6)= Qe\ Q_i^*\ R_Z^*\ Q_{si} Q_{fb}^*, \tag{7}$$

$$Q(A7)= Qe\ Q_i^*\ R_Z^*\ Q_{si} Q_{fb}^*\ Qco, \tag{8}$$

Q_{si}^*=1-Qsi;

Qco – probability of ignition of the vapor-air mixture cloud.

$$Q(A8)= Qe^*\ Qi^*\ R_Z^*\ Qsi\ Qfb^*\ Qco \tag{9}$$

$$Q(A9)= Qe^* Qi^* R_Z^*\ Qsi\ Qfb^*\ Qcd^*, \tag{10}$$

Qcd = 1 Qco – probability of combustion of vapor-air mixture cloud, with overpressure development.

$$Q(A10) =Qe^* Qi^* R_Z^*\ Qsi\ Qfb^*\ Qcd^* \tag{11}$$

The probability of depressurization of the installation Qe is determined by the equation Qe=Ne/(N installation T), here Ne is the total number of accidental releases of flammable product at installations of this type (the result of static studies), Nst is the number of observed units of installations, T-period of observation, year.

Analysis of the structure of the formula determining the probability of depressurization of the unit indicates that the result of the analysis has the dimension of 1/year.

All subsequent parameters called "probability" (instantaneous ignition, flaring, dispersion, etc.) have no dimensionality.

Probability of instantaneous ignition of the flowing product Qi=0.05

Probability of flare combustion Of=0.0574.

Probability of fireball Qfb at destruction of the nearby tank under the influence of fire (overpressure) depends on the properties of the product and the possibility of its overheating.

II. Methods

According to the data of Taubkin S.I. [2] and Marshall W. [3], a fireball is formed by instantaneous release of a large mass (at least 10 tons) of liquefied gas or superheated liquid. The degree of liquid superheating should be such that at least 35% of the mass of the combustible substance passes into the vapor state.

Overheating of liquid is possible in a tank, e.g. in case of fire inside the bund only if the tanks are hermetically sealed and have no communication with the atmosphere. If the tanks in the project facility are communicating with the atmosphere, a fire inside the bund will cause the product in the tank to heat up. The temperature of the product rises to boiling point at atmospheric pressure. Further temperature rise of the liquid is not possible because the liquid vaporizes at atmospheric pressure. All heat supplied from outside to the product is spent on vaporization of the liquid. For this case Qfb=0.

Probability R3 of fire prevention due to effective fire prevention measures or weather conditions.

$$R3=Nna/(Ne-Ni), \quad (12)$$

Nna - number of accidents in which no ignition of combustible substances occurred.

Ni - number of cases of instantaneous ignition of the expiring product during its accidental release.

Probability Qsi of ignition of flammable liquid spillage

$$Qsi=Nsi/(Ne-Ni-Nna), \quad (13)$$

Here Nsi is the number of spill ignition events in accidents.

Probability Qco of combustion of a mixture cloud formed as a result of release and subsequent vaporization of combustible substances.

$$Qco=Nco/(Ne-Ni-Nna-Nsi), \quad (14)$$

Here Nco - number of cases of cloud combustion in accidents at the plants of this type. Probability Qcd of combustion of vapor-air mixture with development of overpressure is determined by the formula

$$Qcd=Ncd/(Ne-Ni-Nna-Nsi), \quad (15)$$

Here Ncd is the number of cases of combustion of vapor-air mixture with overpressure development.

If statistical data necessary for calculation of probabilistic parameters included in the formulas are not available, the probability of realization of different accident scenarios is calculated by the formula Q(Ai)=Qe Q(Ai)st, where Q(Ai)st-statistical probability of accident development on the i-th branch of the logical scheme. These data for a release of liquefied petroleum gas (LPG) are determined from Table 1.

Statistical probability of different scenarios of accident development with LPG release (data from GOST R 12.3047-98).

Table 1: *The liquefied petroleum gas data*

Scenario	Probability	Scenario	Probability
Torch	0.0574	Cloud explosion	0.0119
Fireball	0.7039	Hot water dispersion	0.0292
Spill burning	0.0287		
Cloud combustion	0.1689	Total	1

Analysis of the statistical probability distribution of LPG release accident scenarios reveals interesting points:

1. The share of scenarios related to ignition of the combustible substance is too high. Out of all emissions only 3% are dispersed and the remaining 97% are ignited. This situation does not correspond to the actual state of affairs. Analyzing the presented statistics, one comes to the conclusion that it is inexpedient to fight against the possibility of ignition of combustible substances. Why to use explosion-proof equipment, install lightning arresters, install grounding systems, if anyway 97% of cases of release ends up with ignition. Let's imagine a situation when to the frequency of 10-41/year of ignitions will be added another 3%. The result will not change.

2. The proportion of hot water dispersion scenarios assumed at 3% does not correspond to the probability of fire source visibility.

3. GOST gives statistical information on the probability of realization of different scenarios for LPG, but where can we find similar information for flammable liquids and gases?

4. The GOST table assigns a statistical probability of 0.0574 to the flaming accident scenario. This data should be used in the calculation of individual risk depending on the value of the conditional probability of harm to humans from flaring hazards. Where is the method for determining the conditional probability of people being hit by a flare? This technique can only be found in journal articles, but it cannot be used because it does not claim to be "timely".

5. GOST provides 2 scenarios of hot water cloud combustion: simple combustion and combustion with overpressure development. From literature sources we learn that a mixture of methane gas with air cannot explode [4], [5]. What is combustion with pressure development can be understood from FSS 105-03, but what is simple cloud combustion, what are its affecting factors, how does it differ from the fire of a flammable liquid spill? It is known that flammable liquids do not burn, burning vapors above its surface. Perhaps by cloud burning we mean the burning of liquid vapors in a spill fire?

Calculation of individual risk, performed in strict accordance with the methodology of GOST, gives its value with the dimension "1/year". In paragraph 6.7 GOST requires that the calculated risk values comply with the requirements of paragraph 6.2. Clause 6.2 - quote: "Fire safety of technological processes is considered unconditionally fulfilled if:

- Individual risk is less than 10^{-8};
- Social risk is less than 10^{-7};

(Note: The permissible values of individual and social risks are given in dimensionless format!)

The operation of technological processes is unacceptable if the individual risk is greater than 10^{-6} or the social risk is greater than 10^{-5}

What does GOST mean by "individual risk?"

Quote: "individual risk: Probability (frequency) of occurrence of fire and explosion hazards arising from an accident at a certain point in space. Characterizes the distribution of risk"

Clause 6.7 of GOST

1. Requires fulfillment of the conditions of paragraph 6.2, in which they forgot to specify in which point of space the value of individual risk should be determined.

2. It sets the permissible level of individual risk in an uncertain point of space as a dimensionless value, and the calculation method presented in this GOST gives the result with the dimension "1/year". The question arises, how can we compare quantities with different

dimensionality?

3. For comparison, we give the definition of "individual risk" presented in the "Methodological Guidelines for Risk Analysis of Hazardous Production Facilities", quote: "individual risk is the frequency of an individual person being affected as a result of exposure to the studied accident hazard factors". If GOST under the individual risk takes into account the probability (frequency) of occurrence of hazardous factors, then the "Methodological Guidelines" take into account the frequency of human injury. But these are completely different concepts.

The methodology presented in GOST is very similar to a house that forgot to make a roof. It is impossible to live in it!

What should be done when it is necessary to address such materials, because there is no statistical data. Our proposal is that the probability of ignition of an emission is determined by the probability of combustion of a combustible substance with an ignition source. It should be borne in mind that the probability of occurrence of the ignition source depends on the area of the affected object (hot water clouds or liquid liquid spills).

III. Result

Based on a logical partitioning scheme for an accident involving the release of combustibles, it is found that the probability of ignition of a release is determined by the probability of combustible combining with an ignition source.

References

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