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ANALYSIS OF FIRE PROBABILITIES OF BLOWOUT ACCIDENT FROM OIL RESERVOIR

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Abstract

The work analyzes the fire hazard categories of oil field facilities. It is shown that the analysis of the results of an accident with the release of all contents from an oil tank and calculation of the average release, and therefore the damage, reveal an 8.8-fold deviation from that adopted by the regulatory document. A fireball, as in the development of an accident, at oil field development sites cannot be realized, because properties of the products are incapable for instant evaporation even under preheating conditions.

Keywords: oil, reservoir, accident, thermal radiation, danger level, probable damage, spill diameter, fireball

I. Introduction

In case of fire, the parameters of the intensity of thermal radiation and the duration of exposure are used to determine the level of danger. The methodology for determining individual risk in a fire is presented in [1]. The safe level of thermal exposure to a person is determined by the intensity of thermal radiation not exceeding 4 kW/m^2. With a significant potential of the flammable liquid involved in the fire, the probability of injury to a person remote from the spill boundary is zero. A fire represents a process that results in a long-term realization of the potential of a combustible substance, in contrast to an explosion, in which the realization of the potential is fleeting process. Depending on the speed of ongoing processes, their power varies significantly. The greater the speed, the greater the power of implementation, and the losses (human and material). Analyzing fire as a process, we come to the paradoxical conclusion that flammable liquids do not burn. Their combustion is truly impossible, since it is an oxidation-reduction process, which is impossible inside a liquid. There is no oxidizing agent. The combustion of a liquid is a rather complex process, consisting of several successive stages. In relation to oil, which consists of a large number of hydrocarbon components, characterized by different boiling points and levels of saturated vapor pressure, the combustion process has its own characteristics. The main stages of this process are as follows: Heating of the liquid in order to increase the vapor pressure. Heating of the liquid must ensure its such a temperature in which a gas-air mixture with a concentration of flammable substance above the its surface is formed above its LCLC. An external ignition source ensures ignition of the mixture. The combustion of the gas-air mixture above the surface of the liquid ensures its further heating and intensifies the process of vapor release. The top layer of liquid warms up and combustion intensifies. At the initial stage of combustion, the lightest components evaporate from oil, the boiling point of which is significantly lower than the ambient air temperature. With the start of combustion, the process of oil distillation begins, as a result of which the lightest components pass into the vapor phase (and burn there), while heavier components accumulate in the liquid residue. The boiling point of the remaining components increases as the light components evaporate. If the onset of combustion corresponds to an oil temperature of 20°C, then after a certain period of time it increases to 60, 100°C, reaching a temperature of 300-400°C at the end of the process, when components with a high boiling point have accumulated in the residue. In case of tank fire, the water layer poses a serious danger. Water is always present in oil in small doses. Under the influence of gravity, it settles to the bottom of the tank and accumulates there to significant volumes. It is under excess pressure from the top layer of oil. By the end of burnout, the oil temperature reaches 300-400o C. The water heats up over the area of contact with the oil, reaching temperatures above 100° C. A further decrease in the oil level in the reservoir leads to rapid overheating of the water. The water instantly boils, a steam-water piston is formed, which throws burning oil out of the tank. A cloud of dispersed burning liquid is formed, which is thrown onto the surface of the earth, destroying all living things. Such a development of the accident is accompanied by a large number of people affected not only at the hazardous production facility, but also beyond. To protect tanks from fire, regulations require them to be equipped with stationary foam generators. According to the State Fire Service of the Nizhnevartovsk region, over 15 years, not a single case of successful protection has been recorded during fires in tanks equipped with foam generators. Foam generators failed at the initial stage of fire development, as a result of which all tanks burned out completely. Let us consider the fire parameters depending on the size of the evaporation surface. For example, we select a tank with a volume of 5000 m3, filled with oil, placed in an embankment. The diameter of the tank is 23 m, the height is 12 m. The dimensions of the embankment are 33x33 m. The release of the specified volume of oil onto the terrain without embankment provides an area of evaporation (at a specific oil consumption of 10 l/m2) of 500000 m2. The results of calculating the radius of the affected area R1 are presented in Table 1.

Table 1: *The results of calculating the radius of the affected area R1*

Fire option, Pa	Evaporation square, m^2	Mirror diameter, m	Flame height, m	Radius of the affected area, m
In the tank	415.5	23	22.23	11.5
In the embankment	1088	37.23	31.1	18.62
Unlimited surface	100137.5	357.07	149.54	178.54

Table 1 analysis of the results of calculating the parameters of a fire occurring under conditions of different restrictions revealed the effectiveness of localizing an oil spill in an embankment. The radius of the affected area is reduced by 9.6 times. Here is another example of the realization of the same potential under different conditions. Due to the results of implementation are the most dangerous fire balls (fire- in the terminology of V. Marshall [2]), as a type fire. GOST R 12.3.047-98 [3] defines a fireball as a large-scale diffusion flame of a burning mass of a fuel vapor cloud rising above the surface of the earth. Many protect institutes determine the parameters of fireballs and their consequences when developing projects for the development of oil fields. The main condition of the occurrence of a fireball is a salvo release of liquefied gas capable of instantaneous evaporation under atmospheric conditions in an amount of at least 35% of the mass. The specified conditions can be implemented when releasing liquefied gases (propane, butanes, and their mixtures). An oil release cannot lead to instantaneous evaporation of a significant mass, because the proportion of highly volatile components in it that are capable of release under ambient conditions environment, does not exceed 1% of the mass. Until the fields begin to create installations for processing APG with the release of natural gas liquids or propane-butane fraction, there risk of fireballs are excluded. Due to the lack of results from studies of fireballs carried out by Russian scientists, to substantiate our position we use the information presented in the book by Marshall B [2]. Conditions for the formation of this powerful phenomenon are presented in Table 2.

Table 2: *Conditions for the formation of this powerful phenomenon*

Classification of flammable substance on Marshall	Example	Flash point, ^0C	Vapour pressure, 20 ^0C, atm	Vapour fraction, mass	Probability of occurence		
					Flash	Fire spill	Fireball
Flot liquid	Lubricating oil		0.0001	Insignificant	Zero	Only in case of fire	Low
Flammable liquid	n-xylene	40	0.008	0.0005	Zero	High	Low
LFL	Octane	13	0.013	0.0015	Moderate	High	Low
LFL	Diethylene	45	0.58	0.024	High	High	Low
Cryogenic liquid	LHG	Low minus 160	0.1 (-160 ^0C)	0.04	High	High	Low
Liquefied flammable gas	LHG (propane, propylene, butane)	-107	1	0.4	High	Sometimes there is no liquid phase	High
Compressed flammable gas	Methane, Ethane, ethylene			1.0	High	Zero	High

As follows from the analysis of the data presented in the table, a fireball is realized when at least 40% of the mass of liquid gas or superheated liquid evaporates. Combustible liquids and flammable liquids do not form a fireball. Let's consider another example of the implementation of regulatory instructions: When determining the volume of emission from a unit during its complete depressurization, the standards require choosing the most unfavorable case in all respects. Let's consider the result of an analysis of an accident involving the release of all contents from an oil tank. The field tank performs the function of protecting external consumers from the issuance of substandard products. The reservoir operation cyclogram is shown in Fig. 1.

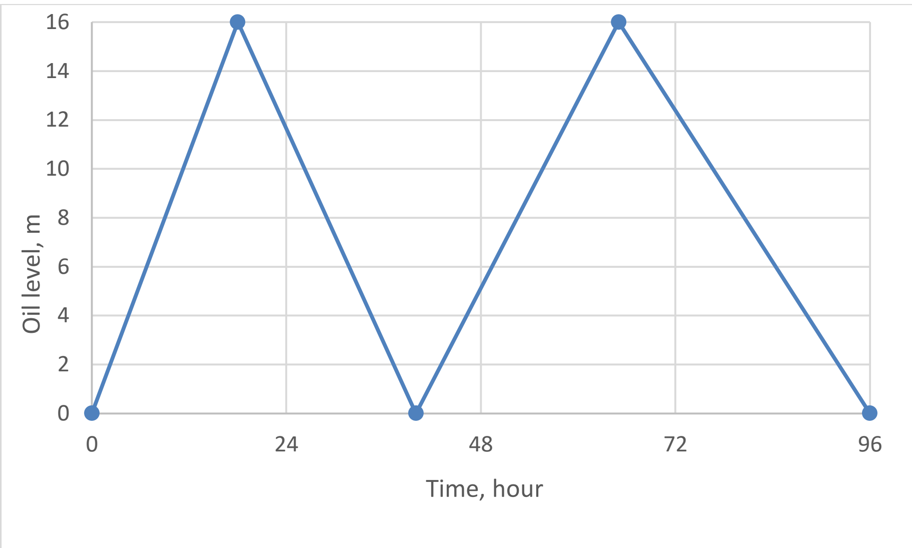

Figure 1: *Tank operation cyclogram*

The tank is filled within 24 hours. At the same time, quality control of commercial products is carried out. If the quality meets the requirements of the technical specifications, the tank switches to pumping oil into the main oil pipeline. Pumping continues for 24 hours. After this, the cycle is repeated. Guided by the requirements of air safety regulations, in case of emergency depressurization of a tank in the consequences of an accident, its entire volume must be taken into account. From the analysis of the cyclogram it follows that the lifetime of the maximum level is zero. The calculation of accident indicators should be carried out using statistical methods based on the laws of probability theory. The probability of 100% filling of the tank is determined by the ratio of the duration of existence of this filling to the duration of the cycle. In our example, the lifetime of 100% occupancy is zero. The cycle duration is 48 hours. Dividing zero by 48, we get the probability of such filling equal to zero. Taking into account 100% filling of the tank during an accident in a probabilistic representation will give a zero result of damage. To determine the average statistical volume of flammable liquid released onto the terrain in such an accident, we will draw up a table that determines the level of probable damage depending on the percentage of the tank being filled. Of course, the maximum or minimum filling of the reservoir correspond to a probability equal to zero, since in both cases the duration of extreme filling is zero. With a filling fraction of 0.5, the duration of this state is 0.5 and soon. Tank statistics at throughout the entire cycle of its work are presented in Table 3.

Table 3: *Tank statistics at throughout the entire cycle of its work*

Tank fill percentage	Filling probability	Probable damage	Normalized damage
1	0	0	1
0.9	0.1	0.09	1
0.8	0.2	0.16	1
0.7	0.3	0.21	1
0.6	0.4	0.24	1
0.5	0.5	0.25	1
0.4	0.4	0.16	1
0.3	0.3	0.09	1
0.2	0.2	0.04	1
0.1	0.1	0.01	1
0	0	0	1
Total	2.5	1.25	11
Average value	0.227	0.114	1
Ratio of average damage values		8.8	

II. Methods

All data is presented in relative units. It turned out that the calculation of the average emission, and therefore the damage, revealed an overestimation of the Damage accepted by the regulatory document by 8.8 times. We encounter such "errors" in almost all elements regulatory calculations approved "in accordance with the established procedure". The maximum value of the emission volume, determined according to the laws of statistics, turns out to be equal to 0.5 of the tank volume. This condition corresponds to an arithmetic average filling volume of 0.5 and a maximum probable damage value of 0.25. The average value of probable damage is 0.114. To determine the size of a flammable liquid spill, there are 3 methods in the current methodological and regulatory documents: FSS 105-03 [3-6] determine the area of a liquid spill using a specific flow rate of 10 l/m^2. Thus, the area of spill

$$F=100V \tag{1}$$

Where, F is measured in m^2, and the volume of the spill V in m^3. The spill diameter is determined from the equation area of the circle, that is

$$D= (4F/\pi)\ 0,5 \tag{2}$$

The RSES methodology [1] determines the spill diameter using the equation

$$D = (25,5\times V)0,5 \tag{3}$$

The methodology for risk analysis of main oil pipelines (MOP) [5] determines the spill area according to the equation

$$F=53{,}3\ (V)0{,}89 \qquad (4)$$

The spill diameter is determined by equation (2). A comparison of the results of calculating the diameter of the spill, performed using the specified methods, is presented in the graphs of Fig. 2.

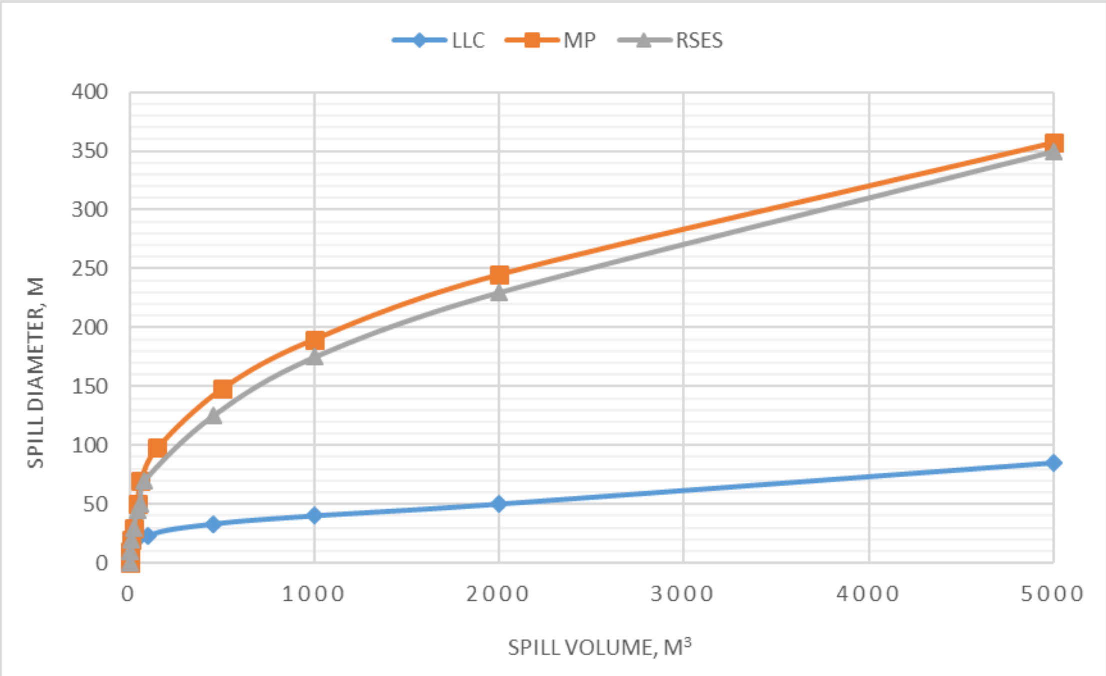

Figure 2: *Comparison of spill diameter due to various methods*

The compared methods have the status of normative documents. The result of calculating the diameter of a flammable liquid spill using various methods is different. The question arises, which of these methods should be preferred?

Where is the guarantee that the methodology chosen by the project organization will coincide with the choice of the expert organization. If different methods are used when developing the "Risk Analysis" section and during its examination, then the results should be considered "non-reproducible". A practical guide for the designer is that if there are several guidance documents on the same issue, any one of them can be used. The fact that the choice of the expert does not coincide with the choice of the project organization is not a problem for the project institute. This is a problem for developers of regulatory documents. As it follows from the analysis of the data presented in the table, a fireball is realized when at least 40% of the mass of liquid gas or superheated liquid evaporates. Combustible liquids and flammable liquids do not form a fireball.

III. Results

1. The fire hazard category of oil field facilities is determined by standards based on the indicators of explosion of gas-air mixtures.

2. Analysis of the results of an accident with the release of all contents from an oil tank and calculation of the average release, and therefore the damage, reveal an 8.8-fold deviation from that adopted by the regulatory document.

3. A fireball, as in the development of an accident, at oil field development sites cannot be realized, because properties of the products are incapable for instant evaporation even under preheating conditions.

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