Fire and explosion measures for tanks protection selection algorithm based on quantitative assessment of big breathing

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Abstract. Research objective: Scientific substantiation and development of an algorithm for selecting reservoir fire protection measures based on the big breathing (filling loss) quantitative assessment. Method of research: Theoretical generalization and analysis of approaches for choosing big breathing volume calculating methods, comparative analysis of modern methodological approaches for tank breaths quantitative assessment, as well as using methods for calculating BLEVE effect probability. Results of the study: Analysis of approaches for choosing methods showed that each method has its own calculation specifics, which are reflected in results. Using a comparative analysis of methodological approaches was determined that volumes of big breathing calculated for each method differ by more than 30%. In this regard, algorithm for choosing calculation methods with further forecasting of fire situation is proposed. The algorithm consists of three stages. At the beginning, it is necessary to calculate the filling loss volume, on the basis of them the level of damaging factors is carried out. Depending on the possible situation, protective measures are choosing.

1. Introduction
During filling/emptying of tanks with oil products, the vapor-air mixture is released into the environment. This leads to a permanent deterioration of the environmental condition of the territory of objects, and can also lead to explosion and fire situations. About half of all losses in reservoirs occur due to big breathing. Many authors have devoted their research to this problem [[1]-[8]]. For example, in [[1]], we consider the influence of climate change on the volume of big breathing. The study [[2]] suggests creating a model that allows us to quantify the emissions of a vapor-air mixture into the atmosphere. A. Bahadori in his research [[3]] suggests using two methods for predicting losses from big breathing. Work [[1]] shows that changes in climate conditions have a significant impact on the dynamics of big breathing. The study [[4]] shows that as a result of the daily temperature difference and atmospheric pressure, there is a change in the value of losses, which directly affects the risk of fire and explosion situations at oil industry facilities. Therefore, storage facilities must be equipped with both active and passive protection.
The main task of the article is developing an algorithm for the reasonable selection of measures for fire and explosion protection of the tanks based on the quantitative assessment of big breathing.

2. Materials and methods
The number of losses of petroleum products and their quality cause the possibility of explosive and fire-dangerous situations due to big breathing when the ignition source appears. At the moment, there is no single method for calculating the volume of breathing tanks. Among the most used are the following [9]-[13] (Table 1).

Table 1. Analysis of approaches to the choice of the calculation method used.

| Source data | Construction of the tank | Properties of petroleum products | Climate features |
|-------------|--------------------------|---------------------------------|------------------|
| Type of breathing valve | Density of the liquid phase, kg / m³ | Temperature, K |
| The color of the tank | Vapor flash point, K | Precipitation, mm |
| The filling time | Composition of petroleum products | Average annual temperature, K |
| Tank volume | Vapour concentration in emissions, % | Atmospheric pressure, Pa |

Figure 1. Comparative analysis of results obtained by methods [9]-[13].

As can be seen from table 1, each method has its own specifics and purpose of calculation, which, apparently, affects results. Using the same initial data for a typical object, the calculation of oil product losses per year for each method is performed. The comparative analysis (Figure 1) is based on the method [13], which uses the largest number of input parameters (Table 1). This method takes into account the largest number of influence factors and, as a rule, increases the accuracy of calculations.

3. Results and discussion
The results of the comparative analysis (Figure 1) showed that the volume of filling loss can differ from the main one by more than 30% in both the larger and smaller sides.

Given this variability in the calculation results, an algorithm is needed for choosing calculation methods with further prediction of fire hazard. For this purpose, an algorithm for selecting protective measures is proposed (Figure 2).
Figure 2. Calculation methods selection algorithm for fire hazard prediction.

Based on the quantitative assessment of the volume of losses from big breathing, according to the algorithm (Figure 2), the size of the zone of the lower and upper concentration limits of the flame propagation (hereinafter referred to as the UELC, LELC) for a vapor – gas mixture is estimated. Depending on the concentration, various scenarios are considered. For various scenarios, damaging factors levels are calculated and fire situation is predicted. On the basis of which certain protective measures are proposed. The proposed algorithm was tested for tanks with a capacity of 5000 m$^3$.

3.1. Stage 1
The following initial data were used for calculations:
Tank with a capacity of 5000 m$^3$. The operation is 90% complete. The measurement value is kg / kg. Results: [9]-1643.2; [10]-1032.3; [11]-820.14; [12]-800.5; [13]-1203.8. Method [13] - will serve as the basis for further calculations.

3.2. Stage 2
The zone with the lower concentration limit of flame propagation is estimated according to GOST R 12.3.047-2012, which offers formulas for calculating the radius and height of this zone: $R_{LELC} = 22.7$ m – Radius; $Z_{LELC} = 0.76$ m – Height.

It is proposed to use the same approach to determine the UELC zone, then $R_{UELC} = 11.7$ m, height $Z_{UELC} = 0.4$ m.

Given the fact that there are three possible versions of events depending on which zone you may receive a source of ignition:

- The zone with the concentration of the vapor-gas mixture below the LELC: environmental pollution;
- The zone with the concentration of the vapor-gas mixture above the LELC: environmental pollution;
- The zone with the concentration of the vapor-gas mixture above the UELC: a fireball is possible, with levels of damaging factors according to GOST R 12.3.047-2012: $D_s = 64.8$ m; $t_s = 5$ s.
The main fireball striking factor is a thermal radiation. The intensity of thermal radiation decreases with the distance from the fireball. According to the Order of EMERCOM of the Russian Federation from December 14, 2010 N 649 calculation results situation near a fireball of 300 m is shown in Figure 3 (a).

The thermal radiation dose decreases with the distance from the fireball, according to GOST R 12.3.047-2012 the results of calculating the situation near the fireball up to 300 meters are shown in Figure 3 (b).

In addition to human exposure, it is possible to affect neighboring objects. The most dangerous effect is the occurrence of the BLEVE effect of a neighboring reservoir [14]. The adjacent tanks is located, according to SP 155.13130.2014, at a distance of 25 meters (given thickness δ = 9 mm, steel Vst3ps5 the critical temperature of 650 °C with a metal thickness of 9 mm is reached in 14 minutes). For reaching gasoline boiling point in the tank 266.475 MJ is required. The time required for heating gasoline to boiling phase will be ~ 28 × 10^6 h (The area of the absorbing surface of the reservoir is 1416.14 m²). It follows that BLEVE effect probability is close to zero. During fireball existence the reservoir material will not reach the critical temperature of the drop in the strength limit [15].

3.3. Stage 3
The selected protective measures based on damaging factors predicted levels. They are carried out depending on the scenario with the worst consequences. For reducing oil product losses and
environmental pollution, tanks should be equipped with floating roofs or pontoons (according to the first scenario).

In the second scenario, protective measures are appropriate: the use of tools and materials that do not create sparks on impact, as well as the use of means to protect against static electricity; for explosion protection of buildings and structures located nearby, the main design solution is the use of easily throwable structures.

For protecting objects and people from the fireball, it is advisable using protective measures taking into account the possible distance to the radiated object (Figure 4).

4. Conclusion
In this work, an analysis of approaches for methods choosing was performed. It showed that each method has own specifics and purpose of calculation, which are reflected on results. Using a comparative analysis of methodological approaches, it was determined that big breathing volume calculated for each method differs by more than 30%. In this regard, an algorithm for selecting calculation methods with further forecasting of fire situation is proposed. The algorithm consists of three stages. It is necessary to calculate the volume of losses from big breathing, on the basis of which level of damaging factors is estimated. Depending on the possible situation, the choice of protective measures is made. Using of proposed algorithm will reduce petroleum vapors emissions. This will reduce environmental pollution. The algorithm will allow quantifying the amount of loss from big breathing. If a fire or explosion occurs, the algorithm will allow assessing the possible situation and to choose protective measures.

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