Study of ignition of binding substances used in foundations of tanks

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Abstract. The reservoirs of tank farms and oil storages are structures of increased fire danger, the accidents in which lead to severe economic, environmental and social consequences.

The article details the cause of tank fires during the repair work. One of the ignition causes is bitumen mastic, used for waterproofing foundations and walls of the tank. Increasing the autoignition temperature makes it possible to increase the fire safety of vertical steel tanks. For this purpose, work was done to add various binders to the bitumen mastic.

The results of calculating the self-ignition temperature of bitumen and limestone mixture, the results of calculating the autoignition temperature of bitumen and pumice mixture, and the results of calculating the autoignition temperature bitumen and sodium salt mixture are presented. As a result of the estimation of the self-ignition temperature of bitumen with additives, the addition of limestone is the optimal way to reduce the fire hazard of waterproofing on the bitumen base of the foundation of vertical steel tanks for oil storage.

To verify the reliability of the autoignition temperature values obtained by calculation, laboratory studies were carried out for a mixture of bitumen and limestone.

1. Introduction

Reservoirs of tank farms and oil storages are structures that ensure not only the storage of oil and petroleum products at raw materials bases and refineries, but also ensure the safety and uninterrupted delivery of the product through trunk pipeline systems. At the same time, tanks are constructions of increased fire danger, accidents with which lead to severe economic, environmental and social consequences.

Due to the differential settling of the foundation, under the influence of external loads (hydrostatic pressure of the liquid, excess, vacuum, wind pressure), deformations of various sizes and shapes occur on the wall of the vertical steel tank. They are non-static in nature, and when the values and directions of external loads change, they are also changed.

These deformations can cause endurance cracks to appear on the wall, in particular over weld seams. If there is a floating covering in the tank, the deviations of the tank wall from the vertical may cause hanging and falling of the floating coating on the foundation when the container is emptied [1-5], it can lead to a fire.

As practice shows, the destruction of reservoirs occurs most often not at the first hydraulic test, but after several years of operation. Differential settlement often occurs almost immediately after the...
The main causes of tank fires are:
- violation of norms and requirements of fire and industrial safety at work;
- fire works during the repair work of the tank.

The article details the cause of tank fires during the repair work. One of the causes of ignition is bitumen mastic, used for waterproofing of the foundation and walls of the tank [8-10].

2. Data Preprocessing
Increasing the autoignition temperature makes it possible to increase the fire safety of vertical steel tanks. For this purpose, work was done to add various binders to the bitumen mastic.

The results of analysis of the main groups of additives for fire hazard properties are given in Tab. 1. To meet the conditions for increasing the autoignition temperature of bitumen with additives, hydrophilic-plasticizing additives and superplasticizers, which are initially combustible substances, were eliminated.

Table 1. Analysis of bitumen mastic additives

| Group of additives                       | Main agent          | Density, kg/m³ | Auto-ignition temperature, ºC | Flash point, ºC |
|-----------------------------------------|---------------------|----------------|-------------------------------|-----------------|
| Active mineral supplements (natural)    | Limestone           | 2700-2900      | NG                            | NG              |
| Active mineral supplements (artificial) | Fly ash             | 2300           | NG                            | NG              |
| HPA (hydrophilic-plasticizing additives)| Sodium salt         | 1008,5 (solution) | NG                            | NG              |
| MFA (microfoam forming additives)      | Lignosulonate       | 1230-1260      | 590                           | 140             |
| Superplasticizers                       | C-3                 | 2380-2420      | 480                           | 108             |

*NG – the material does not support combustion

Self-ignition temperatures for other groups of additives were calculated using the calculation method. Calculations were carried out for a mixture of bituminous mastic with 5-25% content of additives.

It was possible to raise the autoignition temperature from 386 ºC to 523 ºC for a mixture of bitumen with limestone (Figure 1).
Figure 1. Results of calculating the autoignition temperature of bitumen and limestone mixture

It was possible to raise the autoignition temperature for bitumen and pumice mixture at the same 25% content of the additive to 500 ºC (Figure 2).

Figure 2. Results of calculating the autoignition temperature of bitumen and pumice mixture

This parameter under the same conditions could be raised to 461 ºC for a mixture of bitumen with sodium salt (Figure 3).
Figure 3. Results of calculating the autoignition temperature of bitumen and sodium salt mixture

All the diagrams are shown in Figure 4 for a comparative evaluation.

Figure 4. Estimation of the autoignition temperature of bitumen with additives

Autoignition temperature of bitumen mastic in pure form is 368 °C. Based on the calculation it can be seen that the addition of non-combustible additives to bitumen mastic helps to reduce the fire hazard of the product obtained, by raising the autoignition temperature. So the addition of sodium salt in a ratio of 1:3 with respect to bitumen allows to raise the autoignition temperature to 461 °C, in the same proportion, the addition of fly ash increases the autoignition temperature to 500 °C, and limestone to 523 °C.

3. Experiments

Based on the calculations, we accept the addition of limestone as the best way to reduce the fire hazard of waterproofing on the bitumen base of the foundation of vertical steel storage tanks.

Laboratory studies were carried out for a mixture of bitumen and limestone to verify the reliability of the autoignition temperature values obtained by calculation. All experiments were carried out on certified equipment.

The determination of the autoignition temperature consists in preliminary and basic tests. Preliminary tests determine the most inflammable amount of the substance introduced into the reaction vessel. Basic tests discover the lowest temperature of the reaction vessel at which self-ignition of the most readily
self-igniting amount of the substance is observed. The self-ignition temperature is found for six to eight samples of the test substance, differing by 0.05-2.0 cm³, and dependence diagram of the autoignition temperature versus the sample size of the substance is plotted.

The main tests (five samples) for autoignition are carried out with the most inflammable amount of the substance at a temperature of 5 °C below the minimum autoignition temperature obtained in a series of preliminary tests.

The arithmetic mean of two temperatures differing by 5 °C, with one of which the self-igniting of the most inflammable amount of the substance is observed, and the other is the failure is accepted as the self-ignition temperature of the test substance.

Six types of samples with different limestone contents were prepared in the volume of bituminous mastic to measure the self-ignition temperature. The types of samples are given in Tab. 2.

| Sample No | Waterproofing bituminous mastic | Limestone |
|-----------|--------------------------------|-----------|
| 1         | 95                              | 5         |
| 2         | 90                              | 10        |
| 3         | 85                              | 15        |
| 4         | 80                              | 20        |
| 5         | 75                              | 25        |
| 6         | 70                              | 30        |

The autoignition temperature of the mixture was fixed by three thermocouples. The results of the experiments are shown in Figure 5.

The error in the results of calculated and experimental studies of the autoignition temperature of bitumen mastic and limestone mixture was 1-3% (for different types of samples). It confirms the efficiency of proposed mixture of waterproofing vertical steel storage tanks for oil and oil products foundations consisting of bitumen mastic and limestone application. Full-scale tests confirmed previously obtained numerical values.

![Figure 5. Results of experimental tests for estimating the autoignition temperature of bitumen and lime mixture](image-url)
Water-proof ability of the samples obtained was also evaluated. It has been proved that the moisture-tightness of bitumen with any content of additives remains unchanged. However, the increase of limestone in the bitumen by more than 15% decreases the tensile strength for transverse and longitudinal fault of the mixture. Therefore, the recommended maximum permissible percentage of limestone mixed with bitumen should not exceed 20%.

The obtained samples were examined for their effect on the process of corrosion formation. To assess this issue, the samples were applied to a metal surface and submerged by the treated side into the soil, which was moistened for 7 days. After 7 days, the samples from the surface were removed, and visual results indicated that the addition of limestone to the bitumen mastic does not accelerate corrosion processes.

4. Conclusion

Thus, it was determined that active mineral additives for water-proof bituminous mastics increase the autoignition temperature of the resulting mixture. A mixture of bitumen mastic with limestone has the best fire-hazard properties.

The optimal composition of bitumen mastic and limestone mixture, with a ratio of 5:1 is also determined and allows increasing the autoignition temperature of the mixture to 500 ºC without water-proof properties loss.

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