Comparative study of corrosion resistance of sprinkler sprinklers of domestic and foreign production

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Abstract
This document presents the results of tests of corrosion-resistant sprinkler irrigators. The influence of the method of manufacture and the composition of the alloy housings on the resistance to aggressive media is shown. A comparative analysis of the requirements and test methods of domestic and foreign certification authorities was conducted. Revision of the sprinklers structure that were sent for certification to FM Global was carried out.

Keywords: fire safety, sprinklers, corrosion resistance, corrosion-resistant sprinkler irrigators.

1. Introduction
Currently, in the construction and operation of buildings and the construction of various applications, one of the most important tasks is to ensure fire safety [1]. Very important thing in achieving fire protection of a construction object, is the presence of an Automatic fire suppression systems (AFSS) [2], [3], [4].

One of the elements of these systems are sprinklers, the design features of which largely determine the effectiveness of the entire fire extinguishing system when it is triggered. These elements must have a specified operational resource [5], including corrosion resistance to the effects of aggressive atmospheric factors.

When sprinkler systems are operating under normal indoor conditions, the specified characteristics of the sprinklers are usually satisfactory and provide the required service life [5]. However, in conditions with increased exposure to corrosive environments, the problem arises of reducing their operational life. As a result, AFSS’s fail due to the destruction of the sprinkler bodies and there is a risk that they will be ineffective in the event of a fire. In addition, there is a threat of leakage of fire extinguishing substance (HFC) through a irrigated irrigator under pressure, which can lead to loss of material values [6], [7], [8].

The bulk of the elements of sprinklers are made of copper, bronze and brass alloys [9], [10], [11]. Under the influence of aggressive media, corrosive destruction of metal parts occurs, microcracks appear in the material of the body, which, at high pressure, cause destruction of the sprinkler [12].

Today, with certification of sprinklers in the Russian documentation, they are being tested for resistance to aggressive media according to GOST 51043-2002, but these tests are voluntary and are not carried out by most Russian manufacturers [13], [14]. While in Europe and America, corrosion resistance tests are part of a mandatory certification test program.

According to the national standards of Russia and the United States, sprinklers are tested for resistance to the effects of ammonia, sulfur dioxide, hydrogen sulfide, salt mist and other media [15], [16], [17].
The purpose of this study was to conduct a comparative study of the corrosion resistance of the sprinklers of Russia and foreign production in order to establish compliance with the requirements of Russian and foreign norms.

1 Sample Preparation
For the tests, sprinklers of Russia and foreign manufacturers were purchased, whose trademarks are not named for ethical reasons. Foreign sprinklers were used as control, because they received foreign certificates of compliance.

To sprinklers, in addition to resistance to aggressive media, there are a number of requirements in terms of strength, tightness and tension under load (Standart R 51043-2002, 2002). The main tests of these characteristics were carried out before checking the corrosion resistance of the sprinklers. It was found that they meet the requirements.

2 Test samples for exposure to sulfur dioxide
Tests for resistance to sulfur dioxide were carried out in conditions corresponding to Standart 51043-2002, paragraph 8.5 [18].

![Figure 1](image_url)

**Figure 1.** Samples of irrigators exposed to sulfur dioxide vapors: frames №1, 4-7 - domestic-type irrigators; frames №2,3 - sprinklers of foreign production

All samples are preserved in the integrity of the filter mesh, but there was a slagging of the sprinkler outlet. All enclosures preserved integrity. Socket tongues are also not destroyed (Figure 1).

3 Salt mist test specimens
As a result of the salt fog effect, all samples retained the filter grids, but the sprinkler outlet was slagging. All enclosures preserved integrity. The tongues of the sockets have not been destroyed (Figure 2) [19], [20], [21].

The corrosion rate of the reference sprinkler, which was calculated from the mass loss of the sample free of corrosion products, was 2 times higher than that of domestic-made irrigators (Table 1).
Figure 2. Type of samples after testing: a - Russian sprinkler with a large outlet (l/o); b - Russian sprinkler with a small outlet (s/o); c - foreign sprinkler

Table 1. Weight loss of sprinklers after saline test

| Parameters           | Initial mass, g | Final mass, g | Weight loss, g | Weight loss, % |
|----------------------|-----------------|---------------|----------------|----------------|
| Foreign sprinkler    | 62,06           | 62,015        | 0,045          | 0,073          |
| Russian sprinkler l/o| 68,585          | 68,565        | 0,02           | 0,0297         |
| Russian sprinkler s/o| 67,665          | 67,645        | 0,02           | 0,0295         |

4 Testing sprinkler sprinklers in ammonia

The tests for resistance to ammonia vapors were carried out under conditions corresponding to GOST 51043-2002, paragraph 8.4 (Russia Patent number 002646726, 2018). The results of these tests are presented in Figures 3-4. In the domestic production of frames (Figure 3), the tongues of the socket were destroyed when foreign-made frames did not suffer (Figure 4) [22], [23].

Figure 3. Russian sprinklers after test № 1 in ammonia environment
5 Strength testing of sprinklers after exposure to aggressive media

The test results for the strength of the outlet, handles and hull of the irrigators affected by ammonia vapors are presented in Figure 5. The irrigators of a foreign manufacturer, brass and copper irrigators of Russian production with a thickness of 1 mm and 1.2 mm were tested. The sprinkler with a large outlet and a thickness of 1.2 mm, which was exposed to ammonia, lost its integrity under pressure from the OTV and flowed.

6 Results of metallographic analysis

Samples of the domestic manufacturer, in order to increase the corrosion resistance were subjected to aging in a muffle furnace at a temperature of 400 °C for 60 minutes. The results are presented in Figure 6, sample No. 1 - before firing, sample No. 2 - after.
The microstructure of sample No. 1 is dendritic, two-phase, corresponds to the structure of cast brass (Figure 6 a, c, e). Grains of the $\alpha$ - phase and $\beta'$ - phase are observed in the structure. Also in the structure, there are excretions of iron compounds ranging in size from 1 $\mu$m to 4 $\mu$m, located along the microsection area. The content of inclusions is <1.5% (by area of microsection). The $\alpha$-phase grains have both a rounded and elongated shape. The length of the elongated $\alpha$-phase grains of a round shape have an average size of 15 microns. The proportion of the $\alpha$ - phase is $\sim$ 70% (by area of the microsection).

The microstructure of sample No. 2 is two-phase, recrystallized (Figure 6 b, d, f). The structure contains grains $\alpha$ and a small amount of $\beta'$ - phase. Also in the structure, there are excretions of iron compounds ranging in size from 1 $\mu$m to 6 $\mu$m, predominantly of the cruciform shape, and small excretions of lead, evenly distributed over the microsection area. The content of inclusions is <1.5% (by area of microsection).

Repeated tests of calcined samples in ammonia vapors did not give a satisfactory result. Sprinklers received unacceptable damage, mainly destruction of the outlets.

![Figure 6. Microstructure of samples: sample No. 1 (a, c, e), sample No. 2 (b, d, f); a, b - x100, c, d - x200, e, f - x500](image)

On the basis of the obtained experimental data, it can be said that from the studied samples, the best results on corrosion resistance were demonstrated by imported sprinklers, the bodies of which were made of brass, and the thinnest parts of copper [24], [25].

In the course of the work, it was found that the corrosion resistance of the irrigators is influenced by both the composition of the alloy of the frames and the method of their manufacture [26].

As a result of the corrosion resistance sprinkler tests, it turned out that Russian products demonstrate satisfactory performance when tested for hydrogen sulfide, sulfur dioxide and salt fog, but fail to withstand tests when exposed to ammonia vapors [27-29].

Thus, in order to increase anti-corrosion effectiveness, it is advisable to take the following measures:
- optimize the sprinkler design in the direction of thickening the sprinkler arches;
- change the alloy and the body and its individual elements;
- to consider the adjustment of the production technology of frames.

As a result of the study, it was established that the system of international certification provides for more stringent requirements for irrigators than the Russian ones. When tested for corrosion resistance in comparison with a control sample certified abroad, domestic irrigators showed satisfactory results in environments: sulfur dioxide, salt fog, hydrogen sulfide; and not satisfactory - in ammonia vapors. The alloy of the outlets of the sprinklers was replaced, which made it possible to achieve their resistance to ammonia vapors.

Modified samples were sent for certification tests in FM Global (USA).
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