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**FIRE PROTECTION OF METAL STRUCTURES WITH INFLATING COATINGS (OVERVIEW)**

*In the article, the analysis of fire-resistant intumescent coatings, which are currently used in Ukraine and abroad, as well as prospects for the development of new intumescent coatings with improved properties, is carried out.*

*The quality of intumescent coatings is usually determined by the following main characteristics:*

*• flame retardant efficiency of the material,*

*• technological application and recovery,*

*• resistance to the effects of the external environment and the warranty service life of the coating (integrity of coatings: cracking, delamination and adhesive strength to the metal surface),*

*• operating conditions of the coating.*

*After analyzing the works of scientists and the characteristics of fire-resistant coatings, it is possible to conclude that the majority of reactive coatings (those that swell) of metal structures that exist today correspond to groups T3 (highly dangerous) and T4 (extremely dangerous) due to the toxicity of combustion products.*

*The process of swelling of such coatings during a fire begins already in the first minutes of their exposure to fire. Accordingly, the release of dangerous toxic products of thermal oxidation destruction from these swollen coatings poses an extreme danger to humans. Therefore, the scientific task of developing new reactive flame retardant coatings for metal building structures with improved properties is urgent.*

*The use of intumescent fireproof coatings is one of the most effective methods of fireproofing metal structures. This method is used when it is necessary to simply, quickly and economically increase the fire resistance limit of the structure up to 90 minutes. The combination of new, more advanced components in the development of intumescent fire-resistant coatings will eliminate the shortcomings of existing compositions and improve their properties. Special attention is planned to be paid to the creation of new flame retardant compositions based on styrene-acrylic water dispersion with improved technological properties.*

***Key words:*** *intumescent fire-resistant coatings, metal structures, polymers, water-based coatings, metal fire protection.*

***Formulation of the problem.*** Recently, there has been an increase in the number of fires, as a result of which significant material damage occurs and many people die. This is due to the increase in the number of objects operated using building structures and materials that are characterized by a low ability to resist the influence of fire. One of the most common building structures are metal structures. Metal structures do not spread fire, but have high thermal conductivity and transfer heat to other structures. Under the influence of fire and high temperatures, they can lose their load-bearing capacity and collapse due to rapid heating to critical temperatures. Therefore, one of the components of the fire resistance of buildings and structures is the protection of structures from the effects of fire and high temperatures[1-6].

Under modern conditions, there are many methods of fire protection of metal structures. The most common are the following:

- application of plaster, concrete, brickwork (constructive method);

- application of fire-resistant paints, coatings, sprays, etc to the surface of the structure);

- increasing the cross-section of the supporting elements;

- installation of fire protection screens at a distance from the structure to be protected, or cladding with sheet and tile materials;

- a combination of different methods (combined method).

You can protect the structure from direct fire and high temperature by creating heat-insulating layers on its surface with low thermal conductivity, which must have the ability to withstand high temperatures. The fire resistance limit of the protected metal is significantly increased. Accordingly, the bearing capacity of the metal is preserved for the required period of time. The use of fire-resistant coatings, which are applied to the protected surface in a thin layer, is the most common method of fire protection of metal structures.

Such modern intumescent coatings are aqueous or highly filled thin-layer compositions diluted with organic solvents. The procedure of applying them to the structure that needs to be protected is not much different from the methods of applying ordinary paint and varnish products [7-9].

Coatings of the thin-layer type provide a good aesthetic appearance of building structures and, as a rule, do not require additional surface treatment with protective paints and enamels, unless this is provided for by the operational requirements [10].

The main characteristics of such paints are presented in the table 1.

**Table 1. Characteristics of the main types of intumescent paints**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Properties** | **Water** | **Organodiluted** | **Epoxy** | **With thermally expandable graphite** |
| **Application conditions** | Above 5 °C;  humidity does not affect | Above 0 °C;  humidity to  80% | Above 5 °C;  humidity up to 80% | Above 0 °C;  humidity up to 80% |
| **Operation** | indoors | indoors | Indoors and outdoors | Indoors and outdoors |
| **Volatile organic compounds (VOCs)** | Practically absent | Up to 35% | Up to 20% | Up to 65% |
| **Drying time** | 8 hours | 8 hours | 24 hours | 10 hours |
| **Toxicological factors** | Minimal impact | Harmful to health and the environment | Average level of impact | Harmful to health and the environment |
| **Recommended nominal fire conditions** | Standard | Standard | Standard and  hydrocarbon | Standard and short-term hydrocarbon |

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• resistance to the effects of the external environment and the warranty service life of the coating (integrity of coatings: cracking, delamination and adhesive strength to the metal surface),

• operating conditions of the coating.

After analyzing the works of scientists and the characteristics of fire-resistant coatings, it is possible to conclude that the majority of reactive coatings (those that swell) of metal structures that exist today correspond to groups T3 (highly dangerous) and T4 (extremely dangerous) due to the toxicity of combustion products.

The process of swelling of such coatings during a fire begins already in the first minutes of their exposure to fire. Accordingly, the release of dangerous toxic products of thermal oxidation destruction from these swollen coatings poses an extreme danger to humans. Therefore, the scientific task of developing new reactive flame retardant coatings for metal building structures with improved properties is urgent.

***The aim of the work.*** This work examines the analysis of intumescent coatings existing today in Ukraine and Europe and possible ways of developing new intumescent fireproof coatings with improved technological and adhesive properties.

***Analysis of the problem and ways to solve it.*** The most common fire-resistant coatings for metal structures today are intumescent coatings. They are also called reactive coatings:

Representatives of such coatings are fire retardant paints "DEFENDER M", "Endotherm", "Fenix ​​STV", "Ammokote MW" and others.

DEFENDER M is a one-component water-based, fire-resistant, intumescent composition designed to increase the fire resistance of steel structures, industrial and civil construction facilities (TETs, GRES, AES, TRK, MK, etc.), including facilities for food industry (not in contact with food products), operated indoors (or outdoors under a canopy) with a non-aggressive environment, air humidity no more than 80%, and are not exposed to direct exposure for up to 90 minutes.

Endotherm 170205 is a one-component water-based fire retardant mixture. This component composition is intended for the formation of a fire-resistant coating, which swells under the influence of high temperatures and forms a heat-insulating layer that protects structures from heating. The mixture increases the fire resistance of metal structures up to R60 at public and industrial construction sites.

Fenix STV is a one-component water-based fire retardant (paint). Fenix STV paint is a heat-expanding fire protection and is a suspension of gas-forming and foam-forming fillers with targeted additives in a synthetic film-forming solution.

The paint is designed to increase the fire resistance limit to R90 of load-bearing steel building structures that are operated at civil and industrial facilities of various purposes, including energy facilities, thermal and nuclear power plants.

Before applying these coatings to the surface to be protected, it is necessary to apply various types of protective primers first. This is due to the fact that fire-resistant coatings have increased corrosive activity of components, in particular water.

As swelling additives, substances are used that emit a large amount of non-combustible gases and vapors during decomposition (dextrin, starch, sorbitol...). , phosphoacrylate, melamine salts, salts of phosphoric and boric acids, polyphosphoroamide, etc.) during decomposition [11].

Polymers are used as binding components. Moreover, they should be prone to the reaction of cyclization, condensation, crosslinking of non-volatile carbonized products. Examples of such polymers are polyester, epoxy resins, etc.

In our country, many fire-resistant coatings for metal structures that swell have certificates: Endoterm, VPM-1, VPM-2, VPM-3, VPD (Ukraine), "TN-GB" (China), "Nullifire S-607HB" " (Great Britain), "PYRO-SAFE FLAMMOPLAST SP-A2", "Hensotherm 3KS" (Germany), "Polylack A" (Hungary), "AZNAR" (Tunisia), "Interchar 963" (Netherlands) and others.

A large number of intumescent, water-based or solvent-based flame retardant paints have been developed for indoor use. The most effective of them are characterized by approximately fifty-fold swelling and provide an increase in the fire resistance limit of metal structures to 45-60 minutes.

Chlorinated rubber, acrylic dispersions, as well as various resins: carbamide-formaldehyde, phenol-formaldehyde, alkyd, epoxy-polyester, epoxy and others are used as a binding component in intumescent fire-resistant coatings.

Based on polyvinyl chloride and perchlorvinyl, paste of the PVCO brand and perchlorvinyl enamel KhV-5169 are known and used.

There are fire retardant coatings based on an organic binding solvent. Representatives of such coatings are: "Endotherm RK", "Endotherm HT-150", "Endotherm DMF-551", "Endotherm L". The limit of fire resistance of metal structures protected by these coatings increases to 1 hour.

Also, a number of fire-resistant compositions for the protection of metal structures based on liquid glass, sodium phosphoric acid, urea, flame retardant-amofos, etc. have been developed. They include UVK-2 coating consisting of: orthophosphoric acid, urea formaldehyde resin, ammonia, melamine, formaldehyde, methanol, urea, ammonium phosphate, glycerin, boric anhydride, glass fiber, perlite sand.

A number of flame retardant coatings have been developed abroad, mainly organic coatings. Intumescent fireproof coating P-60 (Mullifire) provides a limit of fire resistance of metal structures up to 1 hour. A finishing layer of Top Scaler material with a thickness of up to 1.5 mm is pre-applied to preserve the appearance of the coating.

Mullifire Ltd has developed System-S60 water-based intumescent fireproofing. The limit of fire resistance of metal structures increases to 90 min. with a coating thickness of up to 10 mm.

In Great Britain, the most widely used fire retardant coatings are intumescent. The Berger Industrial Coatings company presented Uniterhm alkyd coating, which provides increased fire resistance of metal structures for up to 1 hour.

In Finland ("Winter" warehouse) a coating based on aminoformaldehyde copolymers using phosphogypsum and polyphosphates as a gas generator and flame retardants was developed. Other compositions were developed on the same basis: DS-324 and "Piromors" (Germany), "Winter" (Finland).

On an organic basis, coatings have been developed for the protection of metal and wooden structures in Bulgaria. The coating is applied to the surface in 3 layers: chlorinated rubber primer, fireproof intumescent layer, colorless perchlorvinyl varnish. With a layer thickness of 6.5 mm, this fire-resistant coating provides fire resistance of metal structures up to 86-94 minutes.

Fire-resistant coatings and paints on a polymer basis "Foume-Coats" (USA), UNUTERM 38091, HERBERTS GmBH (Germany), "Biro-Coats" (Germany), "Poluplast-K" (Hungary) and others are now certified in Ukraine and are used to increase the fire resistance of steel and aluminum structures.

From the point of view of environmental friendliness, the most common are water-dispersed paint materials (VD-PM), the production and use of which is not related to the use of toxic and fire-hazardous organic substances. The use of VD-FM allows to reduce labor protection requirements, fire and explosion hazard of painting works. Such materials solve the task of not only decoration of buildings and structures, but also protect structures from moisture, sunlight, mechanical or chemical damage.

The most promising in this regard are materials based on aqueous dispersions of acrylic copolymers. Acrylic paints occupy a significant share of all water-soluble paints. Among them, due to their functional properties and relatively low cost, paints based on acrylic binders with vinyl-acrylic, styrene-acrylic, acrylo-silicone film formers have become the most widely used. One of the main properties of acrylic paints is the low permeability of the coating to carbon dioxide. Therefore, they successfully protect reinforced concrete from corrosion.

Reducing the flammability of paint compositions is carried out due to the use of flame retardants - substances that reduce flammability. The following types of flame retardants are used: halogen-, phosphorus-, boron- and nitrogen-containing compounds; oxides, salts and complex compounds of various metals; organic compounds that include several heteroatoms. Flame retardants can be introduced into polymers both in the form of individual substances and several compounds at the same time [12-14].

Currently, more than 15% of all flame retardant additives that increase the effectiveness of flame retardant compounds are salts and esters of phosphoric acids. The action of phosphorus and its compounds as flame retardants is associated with the following factors: the specific influence of phosphorus compounds on the processes occurring in the condensed phase during the combustion of polymers.

Phosphorous flame retardants or their transformation products serve as agents and catalysts of a kind for reactions of cleavage of macromolecular chain substituents, cyclization and other reactions of polymers. At the same time, chemical transformations of polymers are aimed at increasing the yield of non-volatile coke residue and reducing combustible pyrolysis products; by the formation of a surface vitreous or viscous molten layer of polymetaphosphoric acid. This layer serves as a physical barrier for the transfer of heat from the flame to the polymer and the diffusion of reagents and affects the heterogeneous oxidation of the carbonized product of polymer pyrolysis [15, 16].

In the presence of phosphorus compounds, pyrolytic reactions of dehydrogenation, dehydration, dehydrohalogenation of organic substances are facilitated. Similar reactions contribute to the formation of a carbon framework.

Phosphorus compounds, which can decompose to acids when heated, are effective flame retardants. Fully neutralized metal salts of phosphoric acid are not effective.

The formation of phosphoric acids during the pyrolysis of polymers containing phosphorous flame retardants is possible according to the following reaction:

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During the thermal destruction of ammonium salts of orthophosphoric acid, respectively, diphosphoric, triphosphoric and polymetaphosphoric acids are formed:

As phosphorus-containing flame retardants, ammonium mono-, di-, and polyphosphates are the most applicable. The most relevant of phosphorus-containing flame retardants today is ammonium polyphosphate (PPA). The main characteristic of PPA for a flame retardant composition is the content of nitrogen and phosphorus, which should be within 14-15% of nitrogen and at least 70% of phosphorus, respectively. A lower phosphorus content will not allow reaching the required height (multiplicity) of the foamed layer. Ammonium polyphosphate exists in two forms: with crystalline phase I (degree of polymerization n < 1000) and crystalline phase II (n > 1000). The first type is characterized by a linear structure, a lower decomposition temperature and high water solubility, therefore phase II polyphosphate with a high degree of polymerization is used in the production of paints.

There are many problematic issues with the use of intumescent flame retardant coatings that need to be addressed, such as:

- the need to use such coatings only together with the use of various varnishes due to very weak resistance to atmospheric effects (water and chemically active substances). Varnishes are aimed at preventing the interaction of coatings with the environment;

- before applying to the surface to be protected, it must be treated with a primer;

- many compositions have components with a low ignition temperature. Accordingly, the fire hazard of the process of preparation and coating the surface increases;

- when applying some coatings to the surface, it is necessary to protect the respiratory organs in connection with the use of organic solvents and other substances;

- low adhesive strength when the temperature-humidity regime changes in conditions of high temperatures, destruction and decomposition in the event of fire with the release of toxic substances;

- release of dangerous toxic products of thermal oxidation destruction from swollen coatings.

The basis for manufacturing can be various components, both organic and inorganic. But such coatings do not always meet the requirements regarding adhesive strength, decorative properties, chemical and atmospheric resistance, and durability.

The use of water-based compositions is one of the possible ways to solve the problem of creating protective and decorative materials that combine a complex of high strength and flame retardant properties. Due to unique properties, such as high strength, low thermal conductivity, chemical and atmospheric resistance, high adhesion to other materials, polymer composite materials, including epoxy, are widely used in a number of industries.

***Conclusion.*** The use of intumescent fireproof coatings is one of the most effective methods of fireproofing metal structures. This method is used when it is necessary to simply, quickly and economically increase the fire resistance limit of the structure up to 90 minutes. The combination of new, more advanced components in the development of intumescent fire-resistant coatings will eliminate the shortcomings of existing compositions and improve their properties. Special attention is planned to be paid to the creation of new flame retardant compositions based on styrene-acrylic water dispersion with improved technological properties.

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**ВОГНЕЗАХИСТ МЕТАЛЕВИХ КОНСТРУКЦІЙ ПОКРИТТЯМИ,**

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В статті проведено аналіз вогнезахисних покриттів, що спучуються, які в даний час використовуються на території України та за її межами, а також перспективи розроблення нових спучуваних покриттів з поліпшеними властивостями.

Якість спучуваних покриттів прийнято визначати за наступними основними характеристиками:

• вогнезахисна ефективність матеріалу,

• технологічність нанесення і відновлення,

• стійкість до впливів зовнішнього середовища і гарантійний термін служби покриття (цілісність покриттів: розтріскування, розшарування та адгезійна міцність до металевої поверхні),

• умови експлуатації покриття.

Проаналізувавши роботи вчених та характеристики вогнезахисних покриттів можна зробити висновки, що більшість існуючих на сьогодні реактивних покриттів (ті, що спучуються) металевих конструкцій відповідають групам Т3 (високонебезпечні) та Т4 (надзвичайнонебезпечні) за токсичність продуктів згоряння.

Процес спучення таких покриттів під час пожежі починає відбуватись вже на перших хвилинах вогневого впливу на них. Відповідно і виділення небезпечних отруйних продуктів термоокилювальної деструкції з цих спучених покриттів несе надзвичайну небезпеку для людини. Тому, наукове завдання розроблення нових реактивних вогнезахисних покриттів для металевих будівельних конструкцій з покращеними властивостями є актуальним.

Використання вогнезахисних покриттів, що спучуються, є одним з найефективніших методів вогнезахисту металевих конструкцій. Даний метод застосовують, коли необхідно просто, швидко та економічно вигідно підвищити межу вогнестійкості конструкції до 90 хвилин. Поєднання нових, більш досконалих компонентів при розробці вогнезахисних покриттів, що спучуються, дозволить виключати недоліки існуючих складів і покращити їх властивості. Особливу увагу планується приділити створенню нових вогнезахисних складів на стирол-акриловій водній дисперсії з покращеними технологічними властивостями.

***Ключові слова:*** вогнезахисні покриття, що спучуються, металеві конструкції, полімери, водна основа покриттів, вогнезахист металу.