UDC 614.842

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EXPERIMENTAL DETERMINATION TECHNIQUE OF EXTINGUISHING EFFICIENCY OF AQUEOUS SOLUTIONS OF MINERAL SALTS

According to the results of the conducted experimental research related to the extinguishing of hydrocarbon flame of fire Class using the aerosols of aqueous-based solutions of inorganic salts the determination technique of extinguishing efficiency of water-based fire-extinguishing agents is developed (WEA). The main principles which enable to conduct real evaluation tests of fire-extinguishing capability of WEA, are resulted in this paper. By using special equipment it is possible to measure the productivity of application of WEA aerosol (Q, $l \cdot s^{-1}$), duration ($\Delta\tau$, s) and overall consumption (V, ml) for the extinguishing of nucleation site for ignition, and based on the results it is possible to determine the relative measure of fire-extinguishing capability (RMFEC, $kg \cdot m^{-2}$) and coefficient of fire-extinguishing efficiency upgrading (K_1).

Key words: fire-extinguishing efficiency, aerosols of water-based fire-extinguishing agents, fire retarders, inorganic salts.

Problem relevance. Due to its unique cooling and insulating capability, water remains the most widespread agent of extinguishing fires. However, the cooling effect of water can be substantially improved when applied as aerosol [1-4]. Though, for the chemical inertness of water to most agents and materials, it hasn't any inhibiting action on flame [5]. Techniques of WEA water spray, that provide the realization of both unique physical and chemical properties of water and inhibiting action of dissolved salts, become widely spread in the world [6, 7]. Salts of *s*-metals and ammonium are mostly used as dissolved agents – fire retarders. Most of these mineral salts are soluble in water and can be used in fire-fighting as concentrated solutions. In particular, fire-extinguishing capability of some inorganic potassium salts forms the basis for development of WEA on the basis of K_2CO_3 and KNO_3 [8] for extinguishing A and B classes of fire. Some publications related to the development of new fire-extinguishing agents on the basis of transitional metals salts have recently appeared [9]. The extinguishing efficiency of these are predefined by the special chemical properties of *d*-metals as electron acceptors. As a result, it provides these fire-extinguishing compositions with high capability of ceasing the spread of flame [10, 11]. However, nowadays the methods for determining the fire-extinguishing efficiency of various water-based mineral salts solutions. In most cases, the researchers use either national standards of all-Union State Standard 3789 and all-Union State Standard 4041, for determining the fire-extinguishing efficiency of WEA. These standards the requirements are regulated which concern definitions of normative (I, $l \cdot m^{-2} \cdot s^{-1}$) and critical ($I_{cr.}$, $l \cdot m^{-2} \cdot s^{-1}$) intensity of feed of working solutions of foaming agents and determining of parameters of the foam extinguishing of combustible materials ignitions, or by specially developed methods [12]. For example to the establishment of critical intensity of presentation of workings solutions of general and special foam compounds in extinguishing self-ignition of class B liquids by foams of low and middle expansion ratio. However, none of these parameters can adequately describe fire-extinguishing efficiency of WEA, as dissolved mineral salt, in the case of extinguishing, executes an inhibitory function, unlike the foams that have an insulating function.

Object of the article is to develop a realistic, effective and reproducibility method for experimental determination of fire-extinguishing efficiency of mineral salts water solutions, that would consider the inhibitory function of WEA.

The main part. According to our [11] and other authors' [8, 13] research results, the method for experimental determination of fire-extinguishing efficiency of WEA is developed. The

method contains the following sections: «Implementation area», «Referenced codes and standards», «Terms and determinations», «Principle of testing method», «Facilities of test», «Test conditions», «Preparation and testing», «Estimation of results», «Safety rules at testing» and «Appendixes».

The section «Implementation area» considers the requirements to the method of testing and evaluation of fire-extinguishing capability of water-based fire-extinguishing agents at extinguishing class B fires. The methodology provides the determination of fire-extinguishing efficiency of water-based fire-extinguishing agents, according to the productivity of supply, duration and consumption on extinguishing the seat of fire.

The section «Referenced codes and standards» considers the normative documents that were used for compiling the current document, namely: all-Union State Standard 3789-98 «General purpose foam generating agents for extinguishing fires. General technical requirements and methods of testing»; all-Union State Standard 3675-98 «Portable fire-extinguishers. General technical requirements and methods of testing»; all-Union State Standard 4041-2001 «Special purpose foam generating agents for extinguishing fires of water insoluble and water-soluble combustible fluids. General technical requirements and methods of tests»; all-Union State Standard 4063-2001 « Motor gasoline. Technical conditions»; all-Union State Standard of a 3412-96 «System of certification of UkrSEPRO; Requirements to the testing laboratories and the order of their accreditation»; all-Union State Standard 2272-2006 «Fire safety. Terms and determinations»; The order of the Ministry of Emergency Situations of Ukraine № 312 from 07.05.2007 «About the claim of rules on labour safety in agencies and subdivisions of the Ministry of emergency situations of Ukraine»; The order of the State committee of Ukraine in industrial safety, labour safety and mines inspectorate № 205 from 19.09.2008 «About the claim of rules on labour safety during the work with combustive and lubricating materials and special liquids».

The section «Terms and determinations» considers the terms and determinations:

A fire-extinguishing agent is an agent or intimate mixture that is suitable for application in extinguishing appliances according to its physical and chemical properties.

A water-based fire-extinguishing agent (WEA) is a solution of water-based mineral salts that is suitable for application in extinguishing appliances according to its physical and chemical properties.

A standardized fire source is the special fire seat, used to design the fire during the testing.

The productivity of supply (Q, $l \cdot s^{-1}$) is a power fluid consumption for the certain period of time.

Duration of extinguishing ($\Delta\tau$, s) is the duration of fire liquidation for the proper standardized fire source at the set productivity of supply of power fluid under testing conditions.

A relative measure of fire-extinguishing capability (RMFEC, kg/m^2) is a mass power fluid consumption of WEA for liquidation of fire of the proper standardized fire source in area 1 m^2.

A coefficient of increase of fire-extinguishing efficiency of WEA (K_1) is a dimensionless size, inversely proportional to the amount of water, necessary for one extinguishing process.

Section «Principle of testing method» contains the list of tasks for determining the fire-extinguishing efficiency of water-based fire-extinguishing agents according to the productivity of supply, duration and consumption on extinguishing the seat of fire.

The section «Tests facilities» concerns the application of extinguishing appliances and parameters of tests: 1) pressure spray «Record 2200 ESO»: the swept volume capacity – 500 ml, alternative jet (∅ 1,2÷2,0mm); 2) compressed-air cylinder, equipped with reducing gear or compressor for creation of pressure in the corps of test device within the limits of 6-8 atm; 3) measuring cylinder with measuring range 100–1000 ml and scale division 1 ml; 4) scale bar with measuring range to 1000 mm; 5) Bourdon pressure gauge with measuring upper limit 1,6 MPa (16 kgc·cm–2); 6) a stop-watch with measuring range 3600 s and scale division 0,2 s; 7) class B proper standardized fire source (a round tin with combustible liquid (fuel)); 8) fuel is water-insoluble non-polar hydrocarbons (fuel-oil or A-76 or A-80 gasoline according to all-Union State Standard 4063) or water-soluble polar hydrocarbons (nitrogen- or oxygenate hydrocarbons); 9) equipment for photo- and video fixation of experiment (cameras, cine- and video cameras).

The section of «Test conditions» sets the conditions of experiment (open-space, the wind speed near the fire less than 0,5 $m \cdot s^{-1}$, the air temperature 10°C–25°C; the temperature of power fluid of WEA is about 17,5 ± 2,5°C, the temperature of fuel 17,5 ± 2,5°C).

The section «Preparation and testing» describes the sequence of conducting the experiment. On the first stage, the productivity of supply of the probed solution of WEA is determined, namely volume (V, ml) and mass (m, g) of the used solution for the certain interval of time (10±0,1) s at system pressure of 6 atm.

In accordance with the size of the tin, which is different in every particular experiment, the diffuser branch sprayer is set, which provides the coverage area for tin surface with the stream (fig. 1).

On the second stage of tests, the ignition of fire seat is conducted and the consumption of the tested solution on extinguishing and duration of extinguishing are determined.

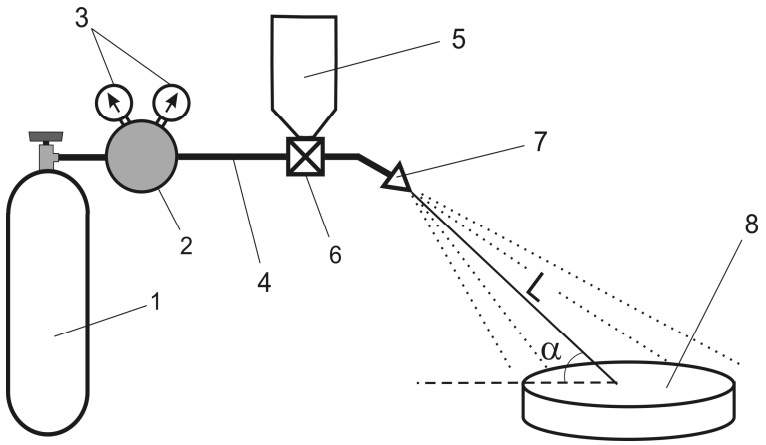

Fig. 1. *Installation diagram for testing the fire-extinguishing efficiency of WEA: 1 – compressed-air bottle; 2 – reducing gear; 3 – manometers; 4 – connecting hose; 5 – content for supply the water-based fire-extinguishing agent; 6 – diffuser branch system as pneumatic sprayer «Record 2200 ESO»; 7 – diffuser branch sprayer (∅ 1,2÷2,0 mm); 8 – class B proper standardized fire source (L – distance from a sprayer to the centre of tin; probed matter goes at an angle* α *= 30–90 degrees).*

The tin of fire seat is set on an even plane of the floor and is filled with water and fuel with water to fuel ratio of 2:1 (for non-polar hydrocarbons) or pure fuel (for polar hydrocarbons).

The content of the testing equipment is filled with power fluid of water-based fire-extinguishing agent, the valve of the high-pressure tank is opened, the pressure is set by reducing gear (6 atm).

Fuel in a tin is ignited. After (30 ± 1) s of free burning, water-based fire-extinguishing agent is added on the surface of burning liquid with the sprayer at the angle of 30–90 degrees. (see fig. 1). The extinguishing duration, which is the time interval between the beginning of solution supply and flame blowout, is recorded. The discharge is mass or volume of the fire-extinguishing agent spent for flame blowout. The valve of the testing device is secured and depressurized.

Three replicate tests are carried out. The result is considered positive, if duration of extinguishing does not exceed 30 s. If the positive result is obtained in the first two experiments, the third one is not carried out.

The section « Estimation of results» carries out the processing of experimental results. For this purpose, arithmetical mean of three experiments results is taken. Possible divergence between the results of experiments, taken by one operator at the permanent terms of test at significance level of 0,95 ± must not exceed 15 % in relation to arithmetical mean.

Fire-extinguishing efficiency of water-based fire-extinguishing agent (WEA) was estimated by the coefficient of increase of fire-extinguishing efficiency (K_1). The coefficient is determined as ratio of water volume to water-based fire-extinguishing agent, spend for extinguishing.

The «Presentation of the results» section regulates fixing of research results, which are written in a report that must contain information in according to s. 5.2.8.3 of all-Union State Standard 3412-96, namely: name and address of laboratory which conducted the test; date; object; method; testing results; estimation of results; photo – or video materials.

The section «Safety rules at testing» regulates requirements in relation to the observance of safety rules. Laboratories that conduct which the test must be equipped with ventilation system. The workplace of operator must match the requirements of electrical safety according to the all-Union State Standard 12.1.019 and the hygienic requirements of all-Union State Standard 12.1.005. During testing, it is necessary to guarantee the requirements of labour safety according to the order of the Ministry of emergency situations of Ukraine № 312 and the order of the State committee of Ukraine in industrial safety, labour safety and mines inspectorate № 205.

The section «Appendixes» concerns the layout chart of the mount for investigating of fire-extinguishing efficiency of water-based fire-extinguishing agents (see fig. 1).

Conclusions. The offered technique is developed in Lviv state university of vital activity safety and ratified in accordance with the established procedure and can be used in scientific research for experimental establishing of the fire-extinguishing efficiency of any dissolved mineral salt.

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МЕТОДИКА ЕКСПЕРИМЕНТАЛЬНОГО ВИЗНАЧЕННЯ ВОГНЕГАСНОЇ ЕФЕКТИВНОСТІ ВОДНИХ РОЗЧИНІВ МІНЕРАЛЬНИХ СОЛЕЙ

В роботі за результатами проведених експериментальних досліджень, пов'язаних із гасінням вуглеводневого полум'я класу В аерозолями водних розчинів мінеральних солей, розроблено методику визначення вогнегасної ефективності водних вогнегасних речовин (ВВР). Наведені основні положення, які дають змогу проводити реальні випробування для оцінювання вогнегасної здатності ВВР. За допомогою спеціального обладнання вимірюють продуктивність подачі аерозолю ВВР (Q, л·с$^{-1}$), тривалість ($\Delta\tau$, с) та загальні витрати (V, мл) на гасіння осередку займання, і на основі цього визначають відносний показник вогнегасної здатності (ВПВЗ, кг·м$^{-2}$) та коефіцієнт підвищення вогнегасної ефективності (K_1)

Ключові слова: вогнегасна ефективність, аерозолі водних вогнегасних речовин, інгібітори горіння, мінеральні солі

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МЕТОДИКА ЭКСПЕРИМЕНТАЛЬНОГО ОПРЕДЕЛЕНИЯ ОГНЕТУШАЩЕЙ ЭФФЕКТИВНОСТИ ВОДНЫХ РАСТВОРОВ МИНЕРАЛЬНЫХ СОЛЕЙ

В работе по результатам проведенных экспериментальных исследований, связанных с тушением углеводородного пламени класса В аэрозолями водных растворов минеральных солей, разработано методику определения огнетушащей эффективности водных огнетушащих веществ (ВОВ). В этом документе приведены основные положения, дающие возможность проводить реальные испытания для оценки огнетушащей способности ВОВ. При помощи специального оснащения измеряют продуктивность подачи аэрозоля ВОВ (Q, л·с$^{-1}$), продолжительность ($\Delta\tau$, с) и общее расходование (V, мл) на тушение очага воспламенения и на основании этого определяют относительный показатель огнетушащей способности (ОПОС, кг·м$^{-2}$) и коэффициент повышения огнетушащей эффективности (K_1).

Ключевые слова: огнетушащая эффективность, аэрозоли водных огнетушащих веществ, ингибиторы горения, минеральные соли.

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