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PREPRODUCTION TESTING OF EXTINGUISHING EFFICIENCY OF A NOVEL WATER-BASED FIRE-EXTINGUISHING AGENT ON BASIS OF $K_2[CuCl_4]$ COMPOUND

The results of laboratory research related to fire-extinguishing action on hydrocarbon flame by aqueous solutions of potassium tetrachlorocuprate(II) at different concentrations are presented in the article. The short-lived influence on front of hydrocarbonaceous flame by aerosol of the aqueous solution (40%) of complex salt of copper(II) – $K_2[CuCl_4]$ leads to full extinction of burning. A minimum expense of 40% aqueous solution of the potassium tetrachlorocuprate(II) on extinguishing of fire source (B2 class) amounts to 1.1 L/m^2. It is ascertained that in case of extinguishing of the inflammations of the various hydrocarbons by means of $K_2[CuCl_4]$ aerosol (40% aqueous solution) consumption of this water-based fire-extinguishing agent were 4.2 (ethanolamine's flame) or 3.2 times (hexane's flame) less than by water aerosol.

Keywords: fire-extinguishing, aerosols, water-based fire-extinguishing agent, burning inhibitors, complex salts of copper(II)

Introduction. Search of the novel chemical agents and investigation of hydrocarbons flame extinguishing efficiency are one of the priority aims of fire-fighting. Nowadays, water is commonly used as a fire-extinguishing agent due to its cooling and the insulating properties. Those properties can be substantially improved by water aerosol application [1-3]. Nevertheless, water does not possess flame inhibiting action [4].

On a global scale for the fire protection of the different objects the application of water spray techniques of water-based fire-extinguishing agents (WEA) are widely spread. This fully provides the realization of both unique physical and chemical properties of water and inhibiting action of dissolved salts [5, 6]. Lately, salts of alkaline metals and ammonia were used flame retarders [7-11].

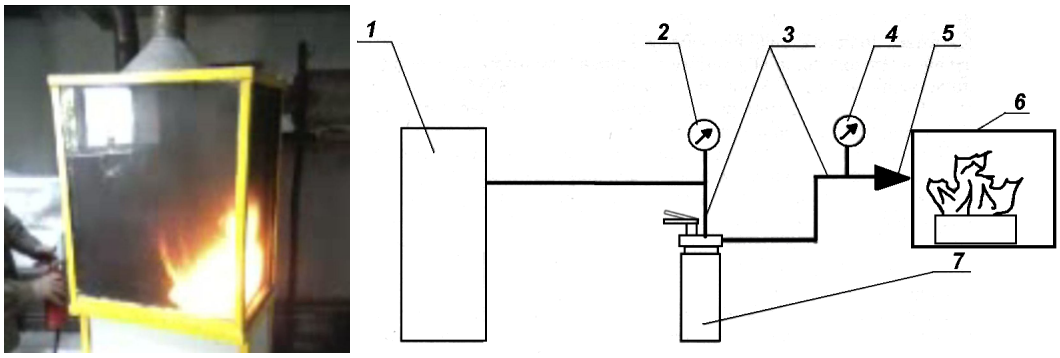
Analysis of early researches and publications. Previously, the data on elaboration of the novel fire-extinguishing agents on basis of transition metal salts were published [12–19]. The fire extinguishing efficiency of aqueous solutions aerosols are determined by special chemical properties of *d*-metals as electrons acceptors. This characteristic what in the ensures the high ability to interrupt the flame spreading. Salts of the *d*-metals, namely $CoCl_2$, $NiCl_2$, $MnCl_2$ and $FeCl_2$ *etc.* were applied as water-based fire-extinguishing agents. Among inhibitors of burning, the complex salts of iron and potassium deserve special attention [20]. In particular, the concentrated aqueous solutions of potassium ferricyanide ($K_4[Fe(CN)_6]$) and potassium ferrocyanide ($K_3[Fe(CN)_6]$) are effective fire-extinguishing agents [21]. Thus, 30% aqueous solution of red blood salt efficiently represses flame.

In this regard, the elaboration of novel water-based fire-extinguishing agent on basis of copper salts is promising since the Cu(II) atoms evince uncommon ability of bonding with heteroatoms of various inflammable organic compounds and active particles of flame [22].

The aim of the paper is to study the extinguishing ability of copper(II) complexes of different concentrations applied as aqueous sprays and to determine the quantitative criteria of extinguishing of the hydrocarbonaceous inflammation by experimentally.

Experimental results and discussion. *The test techniques of the fire-extinguishing ability of water-based fire-extinguishing agent..* The laboratory tests of WEA were fulfilled in a test chamber installed according to the all-Union State Standard 3789 (Fig.) The installation consisted of test chamber (Fig., *a*) with dimensions of 0.7×0.6×0.45 m (useful volume is 170 L), upper hole (∅ 10 cm) linked to a ventiduct; a fire source inside, a measuring cylinder for WEA flow measurement, WEA or water spray dispensing device (certificated fire extinguisher BB-5 with centrifugal sprayer) and a stop-watch.

The fire source was created by a fire seat of "B" class according to the all-Union State Standard 3675. A round tin was planted on the place surface of the bottom of test chamber (depth and diameter are 0.1 m and 0.15 m, respectively) with combustible liquid (fuel) – *n*-hexane (special fire of "B1" class) and ethanolamine (special fire of "B2" class). The tin is filled with water and fuel with water to fuel ratio of 2 : 1 (for non-polar hydrocarbons) or pure fuel (for polar hydrocarbons).



a *b*

Fig. *The overall view of test chamber with glass case (a) and installation diagram for testing the fire-extinguishing (b): 1 – compressed-air bottle; 2, 4 – manometers; 3 – connecting hose; 5 – centrifugal sprayer; 6 – fire source; 7 – device for supply WEA (fire extinguisher BB-5)*

Separately, the operating solution of WEA (aqueous solution of the potassium tetrachlorocuprate(II) of various concentrations) was prepared and the fire dispensing was filled (fire extinguisher BB-5). The pressure of 6 bar was set in the body of fire extinguisher, using compressed-air cylinder. Dispersion of WEA was performed by means of centrifugal sprayer with nozzle of 1 mm in diameter. The WEA supply productivity was 0.0045 L/s (for comparison, the water supply productivity is 0.0054 L/s).

The fuel in a round tin was set fire manually by torch. On condition of the test chamber door ajar (on 5 cm) and after of free burning (over of 60±5 s), WEA was added directly into the flame by fire extinguisher through the hole from side. Extinguishing, duration which was time interval from WEA introduction into flame to absolute stop of the burning.

Hydrocarbonaceous flame was extinguished by means of $K_2[CuCl_4]$ aqueous solution at different concentrations and tap water. Three quantitative experiments for each test were carried out. The results were regarded as positive if time intervals were within 120 s. If three positive results were received for three consecutive experiments, the fourth experiment was not performed.

Table

The results of the preproduction testing of aqueous solutions of the potassium tetrachlorocuprate(II) fire-extinguishing effect

WEA	*n*-Hexane (B1 class)			Ethanolamine (B2 class)		
	V_{WEA}, ml	$\Delta\tau_{exting.}$, s	K_1	V_{WEA}, ml	$\Delta\tau_{exting.}$, s	K_1
40% aqueous solution $K_2[CuCl_4]$	9	7	3,2	6	5	4,2
20% aqueous solution $K_2[CuCl_4]$	11	9	2,7	10	8	2,4
10% aqueous solution $K_2[CuCl_4]$	21	12	1,4	16	11	1,6
Water	29	17	1	25	15	1

The tests were realized in a closed area under the air flow nearby the fire source les than 0.1 m/s (natural air draught), air temperature 10–25°C, temperature of working solution and fuel was 17,5±2,5°C.

The results of the preproduction testing are presented in Table. A coefficient of fire-extinguishing efficiency increase for WEA (K_1) relatively to water was calculated by formula:

$$K_1 = V_{water}/V_{WEA},$$

where V_{water} or V_{WEA} are the volumes of water or WEA applied for extinguishing the fire source.

The results of the laboratory research revealed that time intervals of fire source extinguishing (special fire of "B2" class) by 40% aqueous solution of the potassium tetrachlorocuprate(II) were equal to 5 s. It was proved that the fire-extinguishing efficiency of 40 % $K_2[CuCl_4]$ aqueous solution in comparison with water increased by 4.2 times (ethanolamine flame) and 3.2 times (*n*-hexane flame), taking into consideration the time interval and flow rate for extinguishing of hydrocarbonaceous flame.

Therefore, the laboratory results of the fire-extinguishing testing demonstrate high performance of hydrocarbonaceous flame suppression by of 40% $K_2[CuCl_4]$ aqueous solution. It was ascertained that minimum flow rate of WEA was 1.8 L/m^2 (B1 class) and 1.1 L/m^2 (B2 class).

Conclusions. The experimental investigations illustrated that short-lived influence upon front of hydrocarbonaceous flame by aerosol of the aqueous solution (40%) of the complex salt of copper(II) – $K_2[CuCl_4]$ led to full extinction of burning. It is ascertained that of the experiment the time interval of flame extinguishing by WEA spray was 5 s. WEA efficiency was 4.2 times (ethanolamine flame) and 3.2 times (*n*-hexane flame), comparing to water. The minimum WEA flow rate (40% $K_2[CuCl_4]$ aqueous solution) was 1.8 L/m^2 (B1 class) and 1.1 L/m^2 (B2 class).

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ЛАБОРАТОРНІ ВИПРОБУВАННЯ ВОГНЕГАСНОЇ ЗДАТНОСТІ НОВОЇ ВОДНОЇ ВОГНЕГАСНОЇ РЕЧОВИНИ НА ОСНОВІ КОМПЛЕКСНОЇ СОЛІ $K_2[CuCl_4]$

В роботі подаються результати лабораторних випробувань вогнегасної дії водних розчинів калій тетрахлорокупрату(II) різної концентрації на вуглеводневе полум'я. Було показано, що нетривала дія аерозолем 40% водного розчину комплексної солі купруму(II) – $K_2[CuCl_4]$ на фронт вуглеводневого полум'я зумовлює його ефективне придушення, аж до повного гасіння. Мінімальний об'єм витрат 40% водного розчину калій тетрахлорокупрату(II) на гасіння осередку займання (вогнища класу В2) становить (1,1 л/м^2). Встановлено, що у разі гасіння займань різних вуглеводнів за допомогою водного аерозолю 40% $K_2[CuCl_4]$ витрати цієї водної вогнегасної речовини у 4,2 рази (для моноетаноламінового полум'я) та у 3,2 рази (для гексанового полум'я) менші за нормативні витрати водним аерозолем.

Ключові слова: вогнегасіння, аерозолі, водні вогнегасні речовини, інгібітори горіння, комплексні солі купруму(II)

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ЛАБОРАТОРНЫЕ ИСПЫТАНИЯ ОГНЕТУШАЩЕЙ СПОСОБНОСТИ НОВОГО ВОДНОГО ОГНЕТУШАЩЕГО ВЕЩЕСТВА НА ОСНОВЕ КОМПЛЕКСНОЙ СОЛИ $K_2[CuCl_4]$

В работе представлены результаты лабораторных исследований огнетушащего действия водных растворов калий тетрахлорокупрата(II) различной концентрации на углеводородное пламя. Было показано, что непродолжительное воздействие аэрозолем 40% водного раствора комплексной соли меди(II) – $K_2[CuCl_4]$ на фронт углеводородного пламени обусловливает его эффективное подавление, вплоть до полного приостановления. Минимальный объем расхода 40% водного раствора калий тетрахлорокупрата(II) на тушение очага воспламенения (очаг класса В2) составляет 1,1 л/м^2. Установлено, что при тушении воспламенения различных углеводородов при помощи водного аэрозоля 40% $K_2[CuCl_4]$ расход этого водного огнетушащего вещества в 4,2 раза (для моноэтаноламинового пламени) и в 3,2 раза (для гексанового пламени) меньше нормативного расхода водного аэрозоля.

Ключевые слова: огнетушение, аэрозоли, водные огнетушащие вещества, ингибиторы горения, комплексные соли меди(II).

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