Zeszyty Naukowe SGSP 2020, Nr 73/1/2020

Anatolii Antonov
State organization "State Ecological Academy of Post-Graduate Education and Management"

Taras Skorobagatko
The Ukrainian Civil Protection Research Institute

Roman Yakovchuk
Lviv State University of Life Safety

Oleksandr Sviatkevych
Lviv State University of Life Safety

DOI: 10.5604/01.3001.0014.0763

Interaction of Fire-Extinguishing Agents with Flame of Diesel Bio Fuel and Its Mixtures

Abstract

Analytical and experimental data on fire hazard of diesel bio fuel, its mixtures with oil-based diesel fuel, and parameters of processes of their burning and interaction with fire-extinguishing agents. Applicability of the types of fire-extinguishing agents having been used for putting-out of diesel bio fuel was revealed and a number of parameters to describe their efficiency when extinguishing diesel bio fuel were determined. It was revealed that in case of diesel bio fuel content in its mixtures with oil-based diesel fuel up to 30% fire-extinguishing efficiency of foam generated from foam solutions nearly does not differ from that when extinguishing diesel fuel containing no additives.

Keywords: fire-extinguishing agent, extinguishing, burning, diesel bio fuel, diesel fuel, ester, fat, critical application rate, fire hazard, mixture

Received: 20.02.2020; Reviewed: 12.03.2020; Accepted: 13.03.2020

Interakcje środków gaśniczych z płomieniem biodiesla i jego mieszankami

Abstrakt

W artykule przedstawiono dane analityczne i eksperymentalne dotyczące zagrożenia pożarowego biodiesla, jego mieszanek z olejem napędowym, jak również parametry procesu ich spalania i interakcje ze środkami gaśniczymi. Wykazano możliwość zastosowania określonych rodzajów środków gaśniczych przy pożarach biodiesla oraz określono szereg parametrów opisujących ich skuteczność.

Słowa kluczowe: środek gaśniczy, gaszenie, spalanie, biodiesel, olej napędowy, ester, tłuszcz, krytyczna prędkość podawania, zagrożenie pożarowe, mieszanka

Przyjęty: 20.02.2020; Zrecenzowany: 12.03.2020; Zatwierdzony: 13.03.2020

ПРО ВЗАЄМОДІЮ ВОГНЕГАСНИХ РЕЧОВИН З ПОЛУМ'ЯМ ДИЗЕЛЬНОГО БІОПАЛИВА ТА ЙОГО СУМІШЕЙ

Анотація

Представлені аналітичні та експериментальні дані щодо пожежонебезпечності біодизельного палива і його сумішей з дизельним паливом, параметри процесів їх горіння та взаємодії з вогнегасними речовинами. Встановлено придатність застосування використаних типів вогнегасних речовин для гасіння біодизельного палива та визначено ряд параметрів, що характеризують їх ефективність під час гасіння біодизельного палива. Виявлено, що за вмісту біодизельного палива в його сумішах з дизельним паливом до 30% вогнегасна ефективність піни, що утворюється з робочих розчинів піноутворювачів, майже не відрізняється від її ефективності під час гасіння дизельного палива без добавок.

Ключові слова: вогнегасна речовина, гасіння, горіння, біодизельне паливо, дизельне паливо, ефір, жир, критична інтенсивність подавання, пожежна небезпека, суміш

Прийнятий: 20.02.2020; Рецензованої: 12.03.2020; Затверджений: 13.03.2020

1. Introduction

1.1 General

The choice of fire extinguishing agents, fire-fighting means as well as firefighting methods and techniques are determined by a number of parameters characteristic to each specific case, in particular, by fire class as a whole and properties of the substances and materials involved in the fire (particularly, by their aggregate state). A specific position among the fires is occupied by ones involving vegetable and animal fats.

1.2 Chemical nature of analysed flammable liquids

Fats as such are ethers that are products of etherification of higher carbon acids (stearic, palmitic, margarine, oleic acid etc.) and glycerol (triatomic alcohol). The chemical properties of fats including specifics related to the course of their interaction with atmospheric oxygen during burning differ significantly from those of other liquids and solids. In particular, in the course of burning of such substances temperatures reach 400°C and more, and at that temperature spattering of burning fat is possible, accompanied with further fire propagation (generally while attempting to put it out with solid water jets) as well as an intensive evolution of fire products. Due to the above mentioned features and to a number of other reasons, firefighting techniques involving hydrocarbons may not be relevant for putting out fats.

1.3 Regulations of normative documents

As is generally known, fighting fires involving commercial kitchen equipment which contains fats is generally conducted with the use of specific fire-fighting agents known as "Wet Chemicals". According to NFPA 17A [1], aqueous solutions of sodium carbonate, acetate or citrate should be used. EN 16282-7 [2] regulates issues concerning installation and operation of fire-fighting systems to protect commercial kitchen equipment. Nevertheless, fires involving fats outside kitchen appliances should be considered as class B fires as specified by [3]. Principal approaches to fighting fires at oil extraction plants which stipulate the use of water spray or foam fire-fighting systems are generally the same (see NFPA 36 [4]) as for fighting fires involving spills of other flammable liquids as specified by NFPA 16 [5].

Bio diesel fuel as such is a mixture of ethers of higher fatty acids and lower monohydric alcohols. In Ukraine requirements to the former, as well as technological processes of their manufacturing, are regulated with standards [6–8]. In order to derive bio diesel fuel they conduct re-etherification of vegetable oils with these alcohols followed by thorough purification of the mixture from water, glycerol and other impurities. This fact along with results of the below described studies indicate that pure bio diesel is more similar to vegetable and animal fats than to conventional diesel fuel according to its fire hazard performance and specific features of interaction of fire extinguishing agents with flame when extinguishing. Nevertheless, these theoretical assumptions did require experimental verification. Moreover, no appropriate data concerning the extinguishing of bio fuel were found in the literature sources.

The importance of the issue is supported with information on fires involving vegetable oils, fats and materials derived from them which took place in the last years.

2. Purpose of the study

The purpose of the study is a generalization of appropriate analytical and experimental data concerning the fire hazard of bio diesel fuel, parameters of its combustion processes and specific features of interaction with fire extinguishing agents in order to substantiate their possible use in practice and to determine fields of further studies.

3. Study of the fire hazard performance

3.1 Determination of actual values

Results of analyses of Internet information [9–11] indicate that the specimens of bio diesel having been manufactured by domestic plants differed significantly by their quality performance, especially by fire hazard performance; their majority have extremely low flash point, which indicates insufficient purification from ethyl alcohol. A study was performed of a specimen of fatty acid methyl esters (FAME) to be used for diesel engines and three specimens of bio diesel manufactured by some domestic plants were. Moreover, similar studies were conducted on a specimen of diesel fuel and its mixtures with FAME at various ratios. Results of the experimental studies vs. performance normalized by DSTU 6081 [6] are presented in Table 1.

Table 1. Results of experimental studies for the determination of fire hazard performance of some bio diesel fuel specimens

Matter	Performance							
	Flash point (open cup), °C		Ignition temperature, °C		Flash point (closed cup), °C		Self-ignition temperature, °C	
	Normalized value	Actual value	Normalized value	Actual value	Normalized value	Actual value	Normalized value	Actual value
FAME	N/A	164	N/A	194	Not less than 120	145	Not less than 320	228
Bio diesel (specimen No. 1)		133		174		112		396
Bio diesel (specimen No. 2)		106		140		88		280
Bio diesel (specimen No. 3)		94		170		45		254

Source: [own study]

As may be seen from the above table, FAME is a flammable liquid. The normative document for FAME [12] standardizes two quality performances that describe fire hazard to some extent, namely closed cup flash point and self-ignition point. The specimen of FAME having been put to test did comply with requirements of the first of these quality performances, but its self-ignition temperature was almost 100°C lower than the standardised value. Fire hazard performance values of the bio diesel specimens differed considerably from each other. In particular specimens No. 1 and No. 2 are classified as flammable liquids, whereas specimen No. 3 is classified as an extremely flammable one. When comparing results of the experimental studies, based first of all on the magnitudes of flash point, it may be assumed that such a difference is due to availability of different residual content of methyl alcohol in them.

3.2 Normative requirements as compared with experimentally determined values

As we have already mentioned above, there are several standards for bio diesel fuel, for instance, EN 14214 [12], DIN V 51606 [13], ASTM D 6751 [14]. Table 2 shows flash points of bio diesel specimens specified by normative documents while Table 3 shows the ones derived experimentally.

Table 2. Normalized values of bio diesel fuel flash point

Performance	Normalized values				
	DSTU 6081	DSTU 7178	EN 14214	DIN V 51606	ASTM D 6751
Flash point, °C	Not less than 120	Not less than 101	Not less than 120	Not less than 110	Not less than 130

Source: [own study]

Table 3. Results of the determination of flash points of some specimens of bio diesel fuel

Experimentally determined values				
Flash point (closed/open cup), °C	FAME	Specimen No. 1	Specimen No. 2	Specimen No. 3
	145/164	112/133	88/106	45/94

Source: [own study]

As seen from Table 2, the minimum flash point of bio diesel fuel may be not less than 101°C. But two specimens of bio diesel manufactured domestically met this requirement. Specific features of its production in Ukraine and insufficient purification of the end product from residual alcohol are likely to lead to significant flash point reduction.

Results of the studies aimed at the determination of fire hazard performance of diesel and bio diesel fuels as well as their mixtures are specified in Table 4.

Table 4. Results of studies for the determination of fire hazard performance of diesel fuel, bio diesel fuel and their mixtures

Composition	Flash point (closed cup), °C	Flash point (open cup), °C	Ignition temperature, °C	Self-ignition temperature, °C
Diesel fuel – 100%	64	60	86	227
Diesel fuel – 90%, bio diesel fuel – 10%	71	72	92	225

cont. Table 4

Composition	Flash point (closed cup), °C	Flash point (open cup), °C	Ignition temperature, °C	Self-ignition temperature, °C
Diesel fuel – 85%, bio diesel fuel – 15%	74	75	93	225
Diesel fuel – 70%, bio diesel fuel – 30%	77	87	111	225
Diesel fuel – 50%, bio diesel fuel – 50%	78	97	115	226
Diesel fuel 100%	145	164	194	228

Source: [own study]

The above table shows that diesel fuel has higher values of flash point and ignition and self-ignition temperatures than conventional diesel fuel, which indicates that its fire hazard is lower. On the other hand, such fuel is a great deal more hazardous than vegetable oil from which it can be manufactured. Flash point as well as ignition temperature of the latter one rise with the content of bio diesel, whereas self-ignition temperature of all the mixtures is nearly the same. This is due to virtually equal values of self-ignition temperatures of the specimens used and indicates the unavailability of formation of any additives, complexes, new chemical compounds etc. when mixing them.

4. Studies of combustion processes

Information pertaining to averaged values of burning process parameters of bio diesel fuel and its mixtures with diesel fuel having been derived with the use of a special protocol are presented in Table 5.

Table 5. Experimentally derived data on flame temperature and mass burning rate of bio diesel fuel and its mixtures with diesel fuel

Title	Highest flame temperature, °C	Mass burning rate, kg/s	Specific burning rate in 34B test fire, kg/(m²s)
Diesel bio fuel as per DSTU 6081 [6]	651.3 (on 68 s)	0.010…0.027	0.009…0.025
Mixture containing 70% of diesel fuel to DSTU 3868 [15] and 30% of diesel bio fuel to DSTU 6081 [6]	866.5 (on 239 s)	0.008…0.031	0.007…0.029
Diesel fuel to DSTU 3868 [15]	897.0 (on 250 s)	0.030…0.039	0.028…0.036

Source: [own study]

The above information shows that the mass combustion rate of bio diesel is two-fold lower than that of diesel fuel. The mass combustion rate of bio diesel fuel is significantly different depending on its burning duration and remains within 0.54 kg/(m^{2}s) to 1.50 kg/(m^{2}s). Increasing the content of bio diesel fuel in its mixture with diesel fuel leads to lowering of the mass burning rate and flame temperature. It has also been found that burning of bio diesel is accompanied with the phenomena characteristic of warming and burning of fats of vegetable and animal nature, in particular, loud crackles and hisses.

5. Interaction of flame with fire extinguishing agents when putting out studied flammable liquids

5.1 Studies for the use of foam solutions

5.1.1 General

As is generally known, burning fat or oil can be theoretically put out with water, powder or foam; nevertheless, when water comes into contact with hot oil intensive splashing of the latter may be expected. It is these phenomena that caused withdrawal from the use of powder extinguishing agents as means of fighting fires involving fats and oils. Their fighting with foam is also complicate due to the destruction of adsorption layers in foam films and boiling of water after reaching of certain temperatures. Consequently using results described in paper [16] it was found that the interaction of foam with burning sunflower oil resulted in its almost immediate destruction; moreover, boiling up of the mixture, intensive evolution of steam and splashing of the flammable liquid took place.

5.1.2 Performance of an "S" class foam concentrate

Results of the studies for the determination of extinguishing duration and critical application rate of foam solution prepared using "S" class foam concentrate ("PO-3NP") while extinguishing diesel fuel, bio diesel and FAME are presented in Table 6.

Table 6. Experimentally derived data on firefighting performance of an "S" type foam solution

Specimen under study	Diameter of test fire, mm	Foam solution application rate, $dm^3/(m^2s)$	Extinguishing duration, s (average value)	Critical application rate of foam solution (I_{cr}), $dm^3/(m^2s)$
Diesel fuel (specimen No. 1)	381.5	0.018	215	0.016
	436.2	0.013	fail	
Diesel fuel (specimen No. 2)	381.5	0.018	203	0.016
	426.3	0.013	fail	
Bio diesel fuel (specimen No. 1)	436.2	0.013	119	0.012
	477.9	0.011	fail	
Bio diesel fuel (specimen No. 2)	426.3	0.013	204	0.012
	477.9	0.011	fail	
FAME	436.2	0.013	196	0.012
	477.9	0.011	fail	

cont. Table 6

Specimen under study	Diameter of test fire, mm	Foam solution application rate, $dm^3/(m^2s)$	Extinguishing duration, s (average value)	Critical application rate of foam solution (I_{cr}), $dm^3/(m^2s)$
Mixture of diesel fuel (specimen No. 2 specimen No. 2, 70%) and FAME (30%)	381.5	0.018	110	0.016
	436.2	0.013	fail	
Mixture of diesel fuel (specimen No. 2 specimen No. 2, 85%) and FAME (15%)	381.5	0.018	123	0.016
	436.2	0.013	fail	

Source: [own study]

Table 6 shows that the critical application rate of the above mentioned foam solution is nearly the same in all the cases and comparatively low for conventional diesel fuel, bio diesel and FAME and its mixtures with diesel fuel. In the course of studies it was also ascertained that specific features of the interaction of medium expansion foam with flame while extinguishing diesel fuel, bio diesel FAME and its mixtures with diesel fuel differ significantly from each other. Consequently, the accumulation of foam at the surface of the liquid takes place in the first place and becomes uniformly dispersed across the surface and does not collapse, i.e. putting out of the test fire takes place due to isolation of the burning matter from oxygen inflow. In the second case the accumulation of foam at the time of its application was taking place slowly, much of it was decaying and spattered hot droplets outside the pan; reaching of the boiling temperature of the liquid was accompanied by its boiling up and entire destruction of foam upon the surface. Putting out of the test fire was due to steam evolution.

5.1.3 Performance of "AFFF" and "FP" class foam concentrates

Results of the studies aimed at the deriving the extinguishing duration and critical application rate of "AFFF" class foam concentrate ("Tridol 6–10°C") while extinguishing the diesel fuel, bio diesel and FAME are presented in Table 7. Results of similar studies using "Fluoropolydol" ("FP" type foam concentrate) are shown in table 8.

Table 7. Experimentally derived data on fire-fighting performance of an "AFFF" type foam solution

Specimen under study	Diameter of test fire, mm	Foam solution application rate, $dm^3/(m^2s)$	Extinguishing duration, s (average value)	Burnback time, s (average value)
Diesel fuel (specimen No. 2)	589.0	0.046	30	690
Bio diesel fuel (specimen No. 3)	589.0	0.046	16	760
Mixture of diesel fuel (specimen No. 2 specimen No. 2, 70%) and FAME (30%)	589.0	0.046	12	750

Source: [own study]

Table 8. Experimentally derived data on firefighting performance of an "FP" type foam solution

Specimen under study	Diameter of test fire, mm	Foam solution application rate, $dm^3/(m^2s)$	Extinguishing duration, s (average value)	Burnback time, s (average value)
Bio diesel fuel (specimen No. 3)	589.0	0.046	17	420

Source: [own study]

These results point to a high fire-fighting capacity of low expansion foam generated from the solutions of the aforementioned foam concentrates. Consequently, extinguishing was reached rather quickly (within 30 s from the moment of initialization of foam application) in all the cases. Burnback time was rather long (7 to 10 minutes).

5.2 Studies using water mist

Figures 1 and 2 show results of the experimental studies aimed at the derivation of fire-fighting performance of water mist while fighting fires involving bio diesel, diesel fuel and their mixtures.

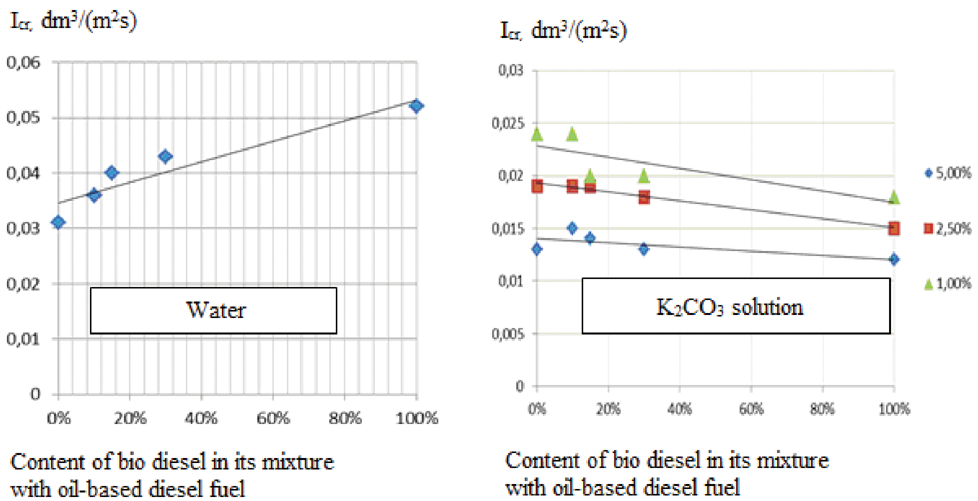

Fig. 1. Results of experimental studies of firefighting performance of water mist (including that containing K_2CO_3) when extinguishing bio diesel fuel, diesel fuel and their mixtures

Source: (own study)

Figure 1 clearly shows that the critical application rate of pure water mist while extinguishing of bio diesel is 0.052 dm^3/(m^{2}s). Its value is 40% higher than that for diesel fuel (0.052 dm^3/(m^{2}s)). This indicates that fighting fires involving bio diesel with water mist is possible but less efficient than fighting the ones involving diesel fuel. At the same time, in addition to bio diesel to diesel fuel leads to lowering of critical application rates (except for water containing no additives).

The critical application rate of 5.0%, 2.5% and 1.0% potassium carbonate containing the latter while extinguishing bio diesel equals to 0.013 dm^3/(m^{2}s), 0.016 dm^3/(m^{2}s) and 0.018 dm^3/(m^{2}s), respectively. This shows that the addition of some potassium carbonate (K_2CO_3) to water makes it possible to raise several times its firefighting performance while extinguishing bio diesel.

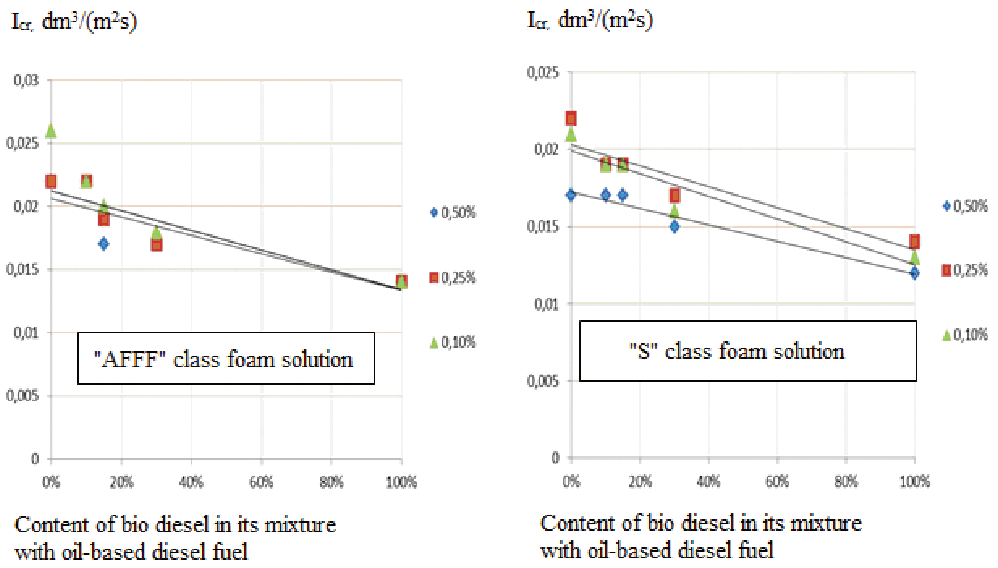

Fig. 2. Results of experimental studies of firefighting performance of atomized "AFFF" and "S" type foam solutions in extinguishing bio diesel fuel, diesel fuel and their mixtures
Source: (own study)

Figure 2 indicates that the critical application rate while extinguishing of bio diesel with aqueous solution containing "AFFF" type foam concentrate in the amount of 0.5%, 0.25% and 0.1% is 0.014 $dm^3/(m^2s)$ for all these concentrations. The same magnitude for "S" type foam concentrate equalled to 0.012 $dm^3/(m^2s)$, 0.014 $dm^3/(m^2s)$, and 0.013 $dm^3/(m^2s)$, respectively.

Consequently it was proven experimentally that fire-fighting performance of water mist while fighting fires involving bio diesel and its mixtures with diesel fuel could be risen approximately 4 times by adding of some potassium carbonate or synthetic or otherwise "AFFF" type foam concentrates to water.

5.3 Studies with use of powder and gas fire extinguishing agents

In addition, the possibility of extinguishing test fires filled with bio diesel and its mixtures with diesel fuel was proven experimentally in case of applying "ABC" class powder at the rate of 0.012…0.016 $dm^3/(m^2s)$; specific consumption of the powder was equal to 0.9 to 1.1 kg/m^2 and had no drastic dependency on the composition of the liquid.

Figure 3 shows plots of extinguishing concentration of some gas extinguishing agents vs. composition of the mixture consisting of bio diesel and diesel fuel.

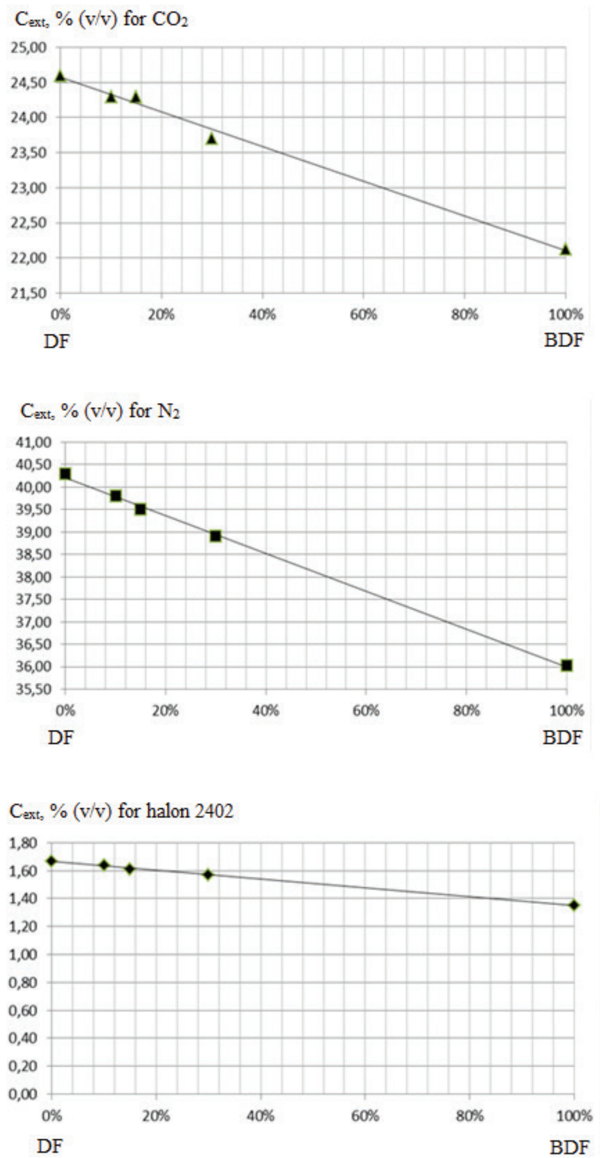

Fig. 3. Extinguishing concentrations of carbon dioxide, nitrogen and halon 2402 versus composition of bio diesel fuel (BDF) and diesel fuel (DF) mixtures

Source: (own study)

Results of studies confirm the applicability of such extinguishing mediums, as carbon dioxide, nitrogen and halon 2402 (burning inhibitor) for putting out bio diesel and its mixtures with diesel fuel. Moreover, in the course of the studies derived were extinguishing concentrations and calculated application rates for putting out the aforementioned liquids. Increasing the fraction of bio diesel in the mixture leads to some diminishment of extinguishing concentrations of both inert gases (carbon dioxide, nitrogen) and burning inhibitor (halon 2402).

Conclusion

Taking the above into consideration, the implemented desk and experimental studies allowed the evaluation of both fire hazard performances of bio diesel (flash point, ignition and self-ignition temperatures) and parameters of their burning processes (burning rate, flame temperature) as compared with diesel fuel. Results of the studies showed that bio diesel was less hazardous when compared with diesel fuel, but specific features of its combustion process included the availability of a number of phenomena characteristic of the processes of warming and burning of fats of vegetable and animal nature.

Possibility of use of conventional fire extinguishing agents (foam solutions, "ABC" powders, and gaseous extinguishing agents) for fighting fires involving bio diesel was proven. Efficient application of water mist for putting out bio diesel and its mixtures with diesel fuel has been proven, as well as the possibility of gaining its efficiency by addition of potassium carbonate or foam concentrates to it. It was also ascertained that fires involving mixtures of these liquids containing up to 30% of bio diesel could be fought with foam while preserving conventionally realized parameters of foam solution application.

We intend to carry out further studies to substantiate normative parameters of application of fire extinguishing agents when fighting fires at the facilities where bio diesel available for the purpose of drafting appropriate normative documents and recommendations for fire protection of such facilities and fighting fires involving them with fire engines.

Referenced publications:

[1] NFPA 17A Standard for Wet Chemical Extinguishing Systems.
[2] EN 16282-7:2017 Equipment for commercial kitchens – Components for ventilation in commercial kitchens – Part 7: Installation and use of fixed fire suppression systems.
[3] EN 2:2014 Classification of fires (EN 2:1992; EN 2:1992/A1:2004, IDT).
[4] NFPA 36 Standard for Solvent Extraction Plants.

[5] NFPA 16 Standard for the Installation of Foam-Water Sprinkler and Foam-Water Spray Systems.
[6] DSTU 6081:2009 Motor fuel. Esters of methyl fatty acids of oils and fats for diesel engines. Technical requirements.
[7] DSTU 7178:2010 Fuel is an alternative. Esters of ethyl fatty acids of oils and fats for diesel engines. Technical requirements and control methods.
[8] DSTU ISO 5509-2002 Animal and vegetable fats and oils. Preparation of fatty acid methyl esters (ISO 5509:2000, IDT).
[9] [Electronic resource]. Download: https://propozitsiya.com/ua/perspektivi-ta-problemi-virobnictva-biodizelyu-v-ukrayini.
[10] [Electronic resource]. Download: http://agro-business.com.ua/agro/mekhanizatsiia – apk/item/885-tekhnolohii-vyrobnytstva-biodyzelia.html.
[11] [Electronic resource]. Download: https://vgolos.com.ua/articles/alternatyvne-palyvo-dlya-sela_107311.html.
[12] EN 14214:2003 Automotive fuels – Fatty acid methyl esters (FAME) for diesel engines – Requirements and test methods.
[13] DIN V 51606:1994 Liquid fuels, diesel fuel of vegetable oil methyl ester (PME), requirements.
[14] ASTM D 6751 Standard Specification for Biodiesel Fuel Blend Stock (B100) for Middle Distillate Fuels.
[15] DSTU 3868-99 Diesel fuel. Specifications.
[16] Bilkun D.H., Borovykov V.O. Skorobahatko T.M. (2009). *Danger of diesel fuel and problems of its extinguishing,* “Scientific Bulletin of the UkrFSRI”, № 2, (20), 52–56.

Antonov A.V. Doctor of Sciences (Engineering), Senior Staff Scientist – Professor of Department of Ecological Audit and Expert Examination of the “State Ecology Academy of Post-Graduate Education and Management”. Graduated from the T. Shevchenko Kyiv National University (specialty is “Chemistry”). Retired colonel of internal service, former Head of a Research Centre of the Ukrainian Research Institute of Fire Safety of the MIA of Ukraine. Sphere of scientific interests includes ecological and fire safety, he is author of more than 150 papers in these spheres.
ORCID: 0000-0001-6750-4172

Skorobagatko T.M. – colonel of civil protection service, Head of the Research Centre of Technical Standardization of the Ukrainian Research Institute of Civil Protection.

Graduated from the Heroes of Chornobyl Institute of Fire Safety of the MIA of Ukraine (specialty is "Fire Safety"). Sphere of scientific interests includes fire safety. Currently, he deals with the researches of fire safety systems of facilities with the presence of large amounts of combustible liquids. He is author of more than 40 papers, has 2 patents for inventions and 2 certificates of copyright for scientific works.
ORCID: 0000-0001-5651-1975

Yakovchuk R.S., Doctor of Philosophy (PhD.) – major of civil protection service, Associate Professor of the Department of Fire Tactics and Emergency Rescue of the Lviv State University of Life Safety. Graduated from the Lviv State University of Life Safety (specialty is "Fire Safety"). Sphere of scientific interests includes fire resistance of building structures, fire safety of facade thermal insulation systems, and computer simulation of fires. Author of more than 30 scientific papers, published in: editions included in the List of Scientific Professional Editions of Ukraine; scientific periodicals of other countries; periodicals indexed in Scopus, Index Copernicus databases and more. Author and co-author of more than 100 conference abstracts at International and All-Ukrainian scientific-practical conferences. Co-author of the patents, teaching manuals and monographs. Currently, he deals with the researches of scientific bases of increase of fire safety of thermal insulation-finishing systems of exterior walls of residential buildings.
ORCID: 0000-0001-5523-5569

Sviatkevych O.V. – lieutenant colonel of civil protection service, Head of the Department of International Cooperation of the Lviv State University of Life Safety. Graduated from the Lviv State University of Life Safety (specialty is "Fire Safety"). Sphere of scientific interests includes fire safety. Specialist in the fields of fire service, CBRN safety and security and civil protection. Mr. Sviatkevych has authored and co-authored publications on national defence, crisis management and fire safety.
ORCID: 0000-0002-0117-5692

Antonov A.V. – Doktor nauk technicznych (inżynier), starszy pracownik naukowy – profesor Wydziału Audytu Ekologicznego i egzaminów eksperckich „State Ecology Academy of Pos-Graduate Education and Management". Absolwent Uniwersytetu Narodowego im. T. Szewczenki w Kijowie (specjalizacja „Chemia"). Emerytowany pułkownik służby wewnętrznej, były szef Centrum Badawczego Ukraińskiego Instytutu Badawczego Bezpieczeństwa Pożarnego MSWiA Ukrainy. Obszar zainteresowań

naukowych obejmuje bezpieczeństwo ekologiczne i przeciwpożarowe, jest autorem ponad 150 artykułów z tych dziedzin.

Skorobagatko T.M. – pułkownik służby ochrony ludności, szef Centrum Badań Normalizacji Technicznej Ukraińskiego Instytutu Badań Ochrony Ludności. Absolwent Instytutu Bezpieczeństwa Pożarniczego MIA Ukrainy (specjalność „Bezpieczeństwo przeciwpożarowe"). Obszar zainteresowań naukowych obejmuje bezpieczeństwo przeciwpożarowe. Obecnie zajmuje się badaniami systemów bezpieczeństwa pożarowego obiektów, w których znajdują się duże ilości cieczy palnych. Jest autorem ponad 40 prac, posiada 2 patenty na wynalazki i 2 certyfikaty praw autorskich do prac naukowych.

Yakovchuk R.S. –major służby ochrony ludności, profesor nadzwyczajny na Wydziale Taktyki Pożarniczej i Ratownictwa Lwowskiego Państwowego Uniwersytetu Bezpieczeństwa Życia. Ukończył Lwowski Państwowy Uniwersytet Bezpieczeństwa Życia (specjalność „Bezpieczeństwo przeciwpożarowe"). Obszar zainteresowań naukowych obejmuje ognioodporność konstrukcji budowlanych, bezpieczeństwo przeciwpożarowe fasadowych systemów ociepleń oraz komputerową symulację pożarów. Autor ponad 30 artykułów naukowych, opublikowanych w międzynarodowych czasopismach naukowych; czasopismach indeksowanych w bazach Scopus, Index Copernicus i innych. Autor i współautor ponad 100 streszczeń konferencji na międzynarodowych i ukraińskich konferencjach naukowo-praktycznych. Współautor patentów, instrukcji dydaktycznych i monografii. Obecnie zajmuje się badaniami podstaw wzrostu bezpieczeństwa przeciwpożarowego systemów ociepleń i wykończeń ścian zewnętrznych budynków mieszkalnych.

Sviatkevych O.V. – podpułkownik służby ochrony ludności, kierownik Wydziału Współpracy Międzynarodowej Lwowskiego Państwowego Uniwersytetu Bezpieczeństwa Życia. Ukończył Lwowski Państwowy Uniwersytet Bezpieczeństwa Życia (specjalność „Bezpieczeństwo przeciwpożarowe"). Obszar zainteresowań naukowych obejmuje bezpieczeństwo przeciwpożarowe. Specjalista w zakresie ochrony przeciwpożarowej, CBRN oraz ochrony ludności. Jest autorem i współautorem publikacji na temat obrony narodowej, zarządzania kryzysowego i bezpieczeństwa pożarowego.