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FIREFIGHTING SYSTEMS IN MILITARY VEHICLES

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Abstract

The article discusses the examples of fire causes in the military vehicles and the consequences they may cause in the military vehicles. It has been observed that the frequent cause for the damage of military vehicles and loss of crew health and life is not the direct impact with the missile, but fires caused e.g. by impact with a missile, mines and firing bottles actions. Therefore, there is the need to use firefighting systems in the military vehicles. The development of the firefighting systems earmarked for the military vehicles has been presented. The contemporary construction solutions for the firefighting system earmarked for the motor and combat departments, as well as selected external parts of the military vehicles as well as basic conditions influencing the firefighting systems of various purposed have been discussed. The advantages and disadvantages of halons used previously as basic extinguishing means, current legal restriction concerning the halon use as well as potential halon equivalents to extinguish fires in the military vehicles have been discussed. The new extinguishing equipment, the means of which will not have negative impact on the crew, vehicle and natural environment – in particular in terms of destroying ozone layer and causing greenhouse effect will require checking the correctness of their functioning, the extinguishing effectiveness and the impact on the natural environment. The testing of the firefighting systems for military vehicles has been already conduced in the Military Institute of Armoured and Automotive Technology in Sulejówek.

Keywords*: firefighting system, military vehicle, optical and thermal sensors, steering devices, firefighting equipment*

1. Introduction

During military activities vehicles and soldiers are exposed to enemy impact, e.g. through his weapons (including shaped charges), mines, Improvised Explosive Devices (IEDs), napalm, initiating bottles, etc. Because of the enemy impact with the weapon on the vehicle, the ignition of explosives and flammable materials in the vehicle takes places. The combustion of flammable substances (e.g. fuel, oil, lubricates, textiles, rubber, wood and plastics) produces among others fire and exhaust gases which can have negative influence on the vehicle crew. Moreover, the fire developed in the vehicle can affect the explosives (such as ammunition, grenades, anti-tank guided missiles) and cause their explosion, which can also lead to crew injuries and death as well as vehicles damage. Therefore, relatively fast fire suppression in the vehicle can save the vehicle crew as well as the vehicle itself. The military vehicle fires, being the result of missile impact, mines and initiating bottles, are frequent cause of military vehicle damage and crew injuries and death, but not the direct missile impact. Figure 1 shows the picture of military vehicles and vehicle crewmember under fire caused by initiating bottle.

Therefore, the firefighting systems, earmarked for extinguishing military vehicles under fire, should be an important element of their equipment as they are of significant influence on the crew and vehicle safety.

2. Development of firefighting systems in military vehicles

Initially military vehicles were extinguished with on-site methods, such as sand, which was thrown onto the vehicle under fire, or the place under fire was covered with blankets or tarpaulin.

Later handheld extinguishers were used. However, such solutions did not bring desired results due to delayed firefighting action start. Crew and vehicles were often burnt.

Fig. 1. Picture of military vehicle and crewmember under fire after impact with initiating bottle [2]

The next step for the firefighting system development was vehicle automated extinguishing process. The automated fire extinguishing process consisted in thermal sensors, which, upon heating, transmitted signals to steering device. Next, the steering device automatically sent signal for explosives to be fired. The explosives action triggered the steering valve opening and the outflow of fire suppression agent from the container into the vehicle. Usually the time for extinguishing the vehicle interior was not more than 10 seconds. Such extinguishing time of the vehicle interior ensured that vehicle was not very burnt. However, there was still significant risk for crew health and life.

Only the 1970s saw the development of the first firefighting system dedicated for vehicle compartment, in which crew and explosives were seated. This firefighting system enabled automated fire extinguishing of the vehicle interior within up to 250 milliseconds. Such fire extinguishing time significantly improved the crew and vehicle safety.

The benefits of this fact triggered the search for firefighting system for selected, exterior elements of vehicles. Fast and efficient extinguishing of vehicles under fire brought also side effects in the form of the risk for the crew health, life and negative impact on the vehicle and natural environment. This is due to the extinguishing means used, which often cause damage of ozone layer and greenhouse effect. The applicable natural environment protection acts necessitated the search for new extinguishing means, which will effectively extinguish vehicle under fire and at the same time will not have negative impact on the vehicle crew and natural environment.

3. General construction and purpose of firefighting systems

The general construction of the contemporary firefighting system in military vehicles is based on sensors, steering and extinguishing devices. The sensors, upon fire detection, send signals to the steering device. The steering device analyses the signal received from the sensor and, upon accepting as fire, automatically sends signal to trigger the extinguishing device. Firefighting device upon receiving signal opens the steering valve and then the extinguishing agent flows out from the container. The extinguishing agent through piping and spray nozzles is directed at the vehicle under fire. Firefighting systems in military vehicles are earmarked for extinguishing fires. Fires can be present in different parts of vehicle. These places with different conditions are characterized and therefore they require different extinguishing methods.

Currently used firefighting systems are earmarked for extinguishing motor and combat compartment (Fig. 2) and selected external parts of the vehicle, e.g. wheels (Fig. 3).

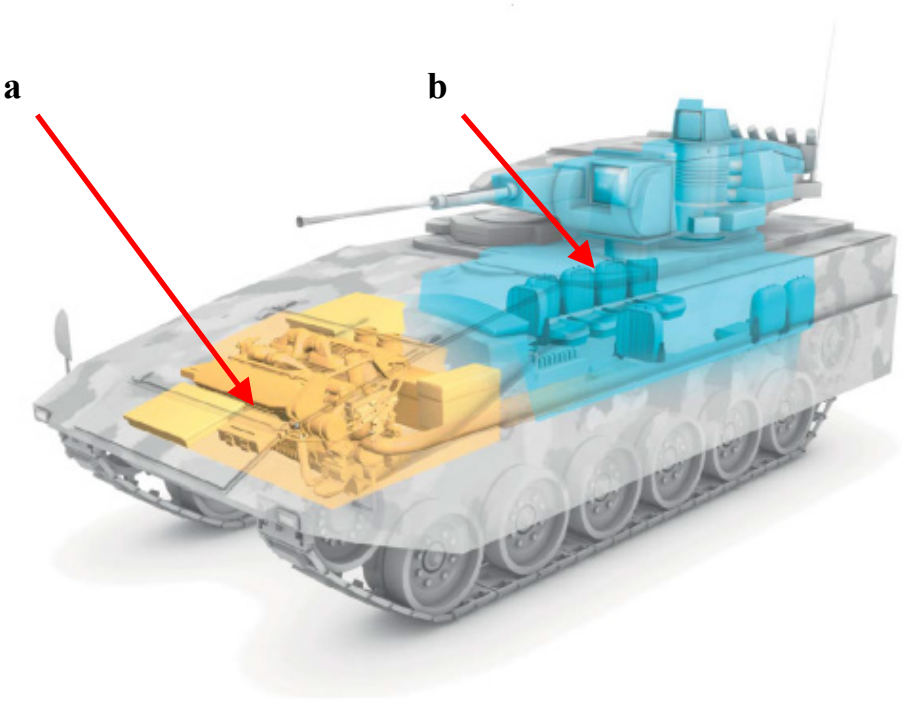

Fig. 2. View of motor (a) and combat (b) compartment of military vehicle [1]

Fig. 3. View of the firefighting system earmarked for extinguishing fire in selected external parts of the military vehicle [1]

The overview diagram of the firefighting system earmarked for extinguishing fire in the combat and motor compartments are presented in the figure 4 and 5 respectively. Figure 6 presents the overview diagram of the firefighting system earmarked for external parts of the military vehicle.

The general construction and the purpose of the firefighting system show that there are three typical places for fire extinguishing in the military vehicles and therefore three respectively dedicated firefighting systems. The main difference between single firefighting systems consists in the use of optical or thermal sensors, the time for fire extinguishing and the type of the firefighting device with extinguishing agent used. The type and amount of the extinguishing agent is

individually selected for the certain motor and combat compartment and selected external parts of the vehicle. The use of certain construction solution for extinguishing device together with extinguishing agent results among others from:

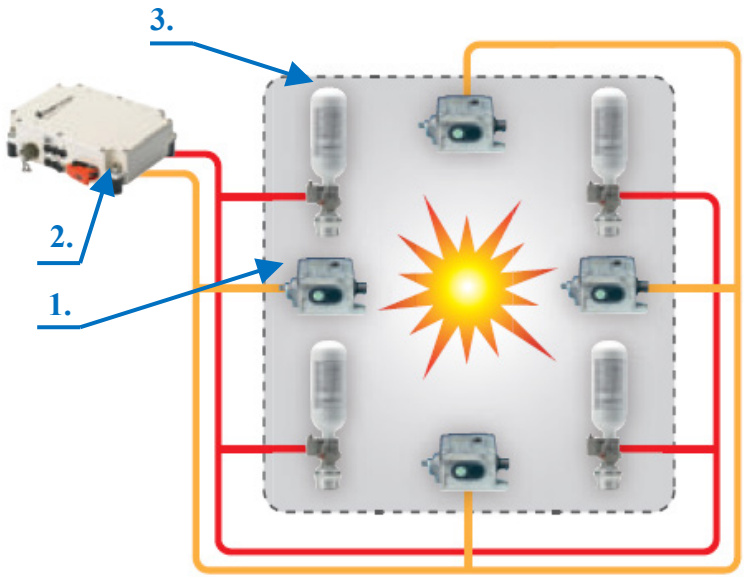

Fig. 4. Firefighting system for combat compartment of military vehicle [1]: 1 – optical sensors; 2 – steering device; 3 – fire extinguishing device

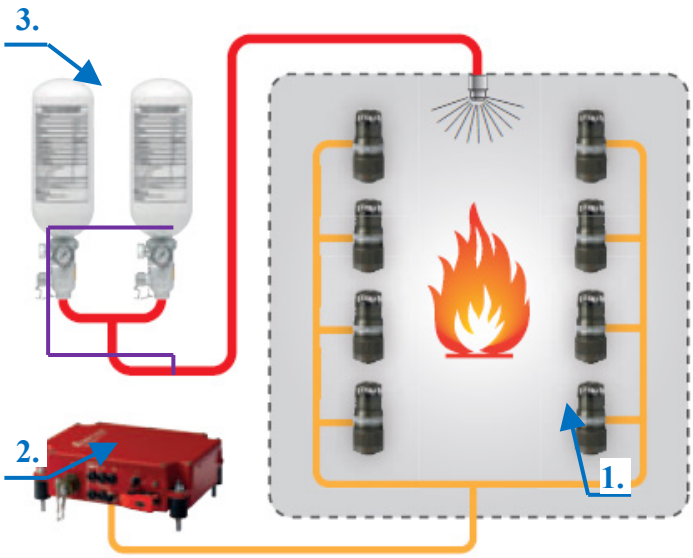

Fig. 5. Firefighting system for motor compartment of military vehicle [1]: 1 – thermal sensors; 2 – steering device; 3 – fire extinguishing device

- Surrounding conditions, in which the military vehicle will be used, e.g. in terms of surrounding temperature range and atmospheric pressure,
- Available space in the vehicle for the firefighting system placement,
- Robustness and resistance to environmental impact,
- Influence of extinguishing agent on crew safety,
- The influence of extinguishing agent on vehicle and natural environment,
- Legal restrictions on negative influence on vehicle crew and natural environment, in particular in terms of destruction of ozone layer and causing greenhouse effect.

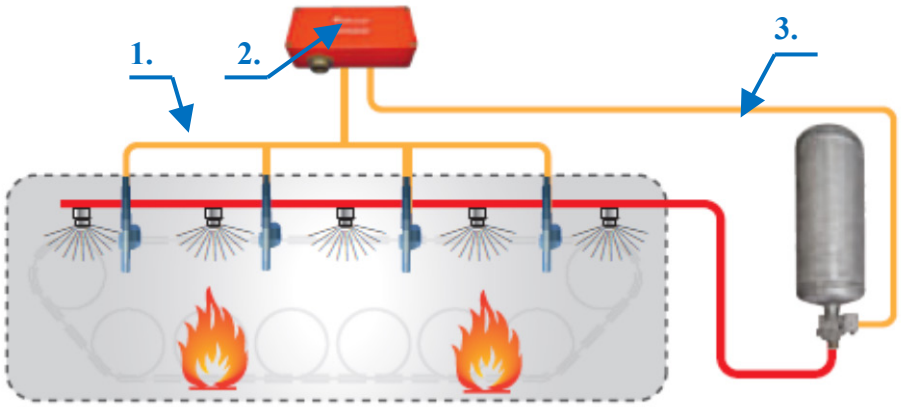

Fig. 6. Firefighting system earmarked for external parts of the military vehicle [1]: 1 – thermal sensors; 2 – steering device; 3 – fire-extinguishing device

The basic conditions influencing the firefighting system earmarked for the combat compartment:

- firefighting system protects combat and command compartment;
- In the combat and command compartment there is military vehicle crew;
- The explosives constitute threat (e.g. ammunition, grenades, antitank guided missiles) and flammable substances (e.g. fuel, oil, lubricants, textiles, rubber, wood, plastics);
- Desired time for fire extinguishing:
  - 150 ms (due to ammunition ignition);
  - 100 ms (due to the crew);
- The extinguishing agent cannot have negative influence on:
  - Vehicle crew;
  - Vehicle elements;
  - Environment.

The basic conditions influencing the firefighting system earmarked for the motor compartment:

- firefighting system protects motor compartment;
- In the motor compartment there is no military vehicle crew;
- The flammable substances (e.g. fuel, oil, lubricants, textiles, rubber, wood, plastics) constitute threat;
- Desired time for fire extinguishing up to 10 seconds;
- The extinguishing agent cannot have negative influence on:
  - Vehicle elements;
  - Environment.

The basic conditions influencing the firefighting system earmarked for the external parts of the military vehicle:

- Firefighting system protects selected external parts of the military vehicle;
- In this compartment there is no military vehicle crew;
- the flammable substances (e.g. fuel, oil, lubricants, textiles, rubber, wood, plastics) constitute threat;
- Desired time for fire extinguishing up to 20 seconds;
- The extinguishing agent cannot have negative influence on:
  - Vehicle elements;
  - Environment.

4. Extinguishing agents and restrictions on their use

Extinguishing agents previously used in military vehicles are:

- Halon 2001 ("mixture 3,5") – used in motor compartments;
- Halon 2402 – used in combat and motor compartments;
- Halon 1211 – used in motor compartments;
- Halon 1301 – used in combat and motor compartments.

The advantages of halons as extinguishing agents:

- Very high extinguishing efficiency - halons are very effective in small concentrations, and therefore proportionally small amount of halon is needed to protect certain space;
- High stability and chemical volume in comparison with the majority of materials – halogens can be stored for long time;
- Low corrosivity – most halogens do not cause corrosion at minimal air humidity;
- Scarce conductivity – halons are suitable for extinguishing live electrical equipment.

Halogen disadvantages – basic problems with halons:

- Toxicity;
- Harmful break-down products;
- Negative influence on natural environment.

Halon-related legal regulations

Due to confirmed harmful impact of halons on the ozone layer in 1980s actions were started globally to stop halon production, to strictly control their emission into atmosphere, to limit their use and finally to withdraw them completely. Currently in Poland, the following legal acts on the ozone layer protection are applicable:

- Vienna Convention for the Protection of the Ozone Layer of 22 March 1985;
- Montreal Protocol on Substances that Deplete the Ozone Layer of 16 September 1987 as amended;
- Regulation (EC) No. 2037/2000 of the European Parliament and of the Council of 29 June 2000 on substances that deplete the ozone layer;
- Act of 20 April 2004 on substances that deplete the ozone layer;
- Halon management strategy of 30 November 2004.

Legal regulations on greenhouse gases

Currently in Poland, the following legal acts on greenhouse gases are applicable:

- The Kyoto Protocol to the United Nations Framework Convention on Climate Change (UNFCCC) of 11 December 1997;
- Act of 22 December 2004 on greenhouse gases and other substances emissions trading;
- Regulation (EC) No 842/2006 of the European Parliament and of the Council of 17 May 2006 on certain fluorinated greenhouse gases.

Halon replacements used for firefighting in military vehicles:

- Classic, used from a long time:
  - Water in form of water mist;
  - foam;
  - Extinguishing powder;
  - Carbon dioxide;
  - Inert gases and their mixtures:
    - Nitrogen (IG-100 / NN100);
    - Argon (IG-01 / Argotec);

- Nitrogen + Argon (IG-55 / Argonite);
- Nitrogen + Argon + Carbon dioxide (IG-541 / Inergen).

– Contemporary, natural and chemical:
  – PerFluoroCarbons (PFC);
  – HydroFluoroCarbons (HFC) ;
  – Fluorinated Ketones (FK).
– Under study:
  – Aerosols (condensated – distributed with HFC gases or produced pyrotechnically);
  – Chemical compounds similar to halons but of lesser harmfulness for natural environment, e.g. alkenes containing bromine;
  – Other extinguishing factors, such as mixtures of organic and non-organic chemical compounds soluble in liquid agents.

5. Requirements for the firefighting systems

Depending on the expected place of fire extinguishing in the military vehicle different requirements are defined. General requirements for three typical fire-extinguishing places in military vehicles are presented in table 1.

6. Studies on firefighting systems mounted in military vehicles

Testing is an important element of checking the correctness of firefighting system functioning in the military vehicles. The testing is to check the compliance of the performed firefighting system with the requirements. The testing is conducted based on developed testing programs and methodologies. Testing can be divided into at least three main groups:

The first one deals with the effectiveness of extinguishing vehicle under fire. During firefighting system, testing there is no possibility to test all possible scenarios for military vehicles under fire. This is due to different fire sources, the place of occurrence and susceptibility of environment, in which the fire occurs. Therefore, several characteristic fire cases are assumed and their extinguishing efficiency is tested. Three cases were selected to test the extinguishing efficiency of vehicle under fire and they are presented in figures 7, 8 and 9.

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The second group of testing was related to the control of firefighting system's robustness and resistance to environmental factors. The environmental tests are conducted with vibration and surge shakers, climate, pressure and dust chambers as well as other equipment necessary to check the compliance of the performed firefighting system with the requirements.

The third group of testing was related to check the safety of crew health and life and the impact of firefighting system on the vehicle and natural environment. It concerns mainly the destruction of the ozone layer and cause of the greenhouse effect.

Tab. 1. General requirements firefighting systems mounted in military vehicles

Item	Requirement	Purpose of the firefighting system		
		Combat compartment	Motor compartment	Selected external parts of the vehicle
	Specifics of fire extinguishing	Closed or open compartment With crew and explosives	Closed or open compartment with motor and motor system	External space with flammable materials, e.g. igniting bottles with fuel, tires
	Mode of action	Automatic/manual	Automatic/manual	Automatic/manual
	Sensor types	optical	thermal	thermal
	System should be resistant to interferences (e.g. lighter flame, flame from rifle, camera flash, mobile phone, sunlight, etc.)	yes	no	no
	Time for fire extinguishing:	250 ms	10 s	20 s
	The firefighting system should:	Efficiently extinguish fire, be safe for crew health and life, should not cause Vehicle or natural environment damage	Efficiently extinguish fire, should not Vehicle or natural environment damage	Efficiently extinguish fire, should not Vehicle or natural environment damage
	Mounting possibilities	Relatively small weight and volume	Relatively small weight and volume	Relatively small weight and volume
	Cost	Low purchase and operation cost	Low purchase and operation cost	Low purchase and operation cost
	Environmental requirements: – Operating temperature range: – Storage temperature range: – Resistant and robust to sinusoidal oscillations – Resistant and robust to – Single surge – Multiple surges: – Lowered atmospheric pressure – Relative humidity in temperature +25°C: – Required inclination and slope system angle:	 From (30°C to +50°C From (50°C to +65°C from 5 to 500 Hz to 5.000 m/s^2 to 200 m/s^2 600 hPa 95% ± 30°	 From (30°C to +50°C From (50°C to +65°C from 5 to 500 Hz to 5.000 m/s^2 to 200 m/s^2 600 hPa 95% ± 30°	 From (30°C to +50°C From (50°C to +65°C from 5 to 500 Hz to 5.000 m/s^2 to 200 m/s^2 600 hPa 95% ± 30°
	Lack of negative influence on vehicle crew in case of extinguishing device being fired through with a bullet	yes	no	no

Note: The requirements presented in Table 1 for the firefighting systems are only examples and can be different depending on the customer's needs and production capabilities of single producer of the firefighting system for military vehicle.

8. Conclusions

To sum up the presented issues it can be seen that:

8.1. Firefighting systems in military vehicles significantly improve the crew and vehicle safety. Therefore, they should constitute the obligatory equipment of military vehicles.

8.2. Firefighting systems, earmarked for military vehicles have different constructions resulting from their purpose (fire extinguishing place).

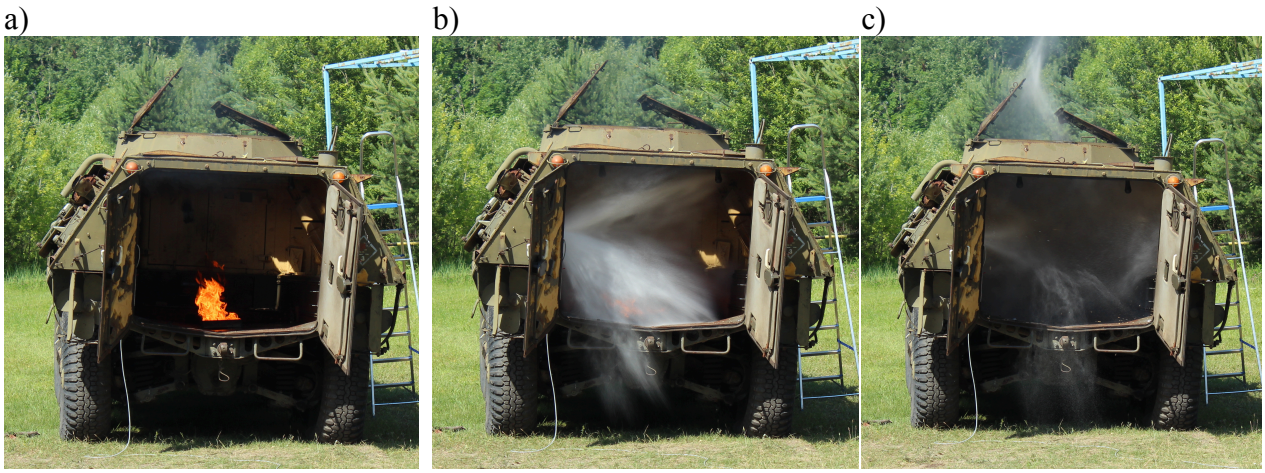

Fig. 7. Pictures of selected sequence for extinguishing standard test fire in the vehicle combat compartment: a – standard fire; b – outflow of extinguishing agent from extinguishing device; c – end of standard fire extinguishing

Fig. 8. Pictures of selected sequence for extinguishing standard fuel test fire leaking under pressure in the vehicle combat compartment: a – extinguishing fuel fire, b – end of standard fire extinguishing; c – smoke outflow from crew compartment after extinguishing fire

Fig. 9. The picture of selected extinguishing/suppression sequence of fuel explosion dispersed after punching of fuel container by the cumulative flow in the vehicle combat compartment: a – fuel ignition by cumulative flow; b – fuel extinguishing; c – smoke outflow from combat compartment upon fire extinguishing

8.3. The system producers sometimes, to stress the firefighting system purpose (fire extinguishing place) use the following terms: Firefighting systems – earmarked for motor compartment and selected external parts of the vehicles, explosion attenuation system or anti-explosion system – earmarked for combat compartment. Author's

experience based on the firefighting system testing clearly shows that these systems do not prevent the explosion but attenuate it.

8.4. The existing, relatively efficient extinguishing agents (halons), due to their negative impact on the natural environment, are to be withdrawn from use in the military vehicles – by 2020.

8.5. Currently there are works to get extinguishing equipment, the agents of which will not have negative influence on the vehicle crew, the vehicle itself and the natural environment, in particular in terms of destruction of ozone layer and causing greenhouse effect.

8.6. This firefighting equipment, together with extinguishing agents, will require testing in terms of the proper functioning, extinguishing effectiveness and impact on the natural environment.

8.7. The article's author together with the team has already conducted the testing of firefighting system earmarked for the military vehicle and can conduct subsequent testing.

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