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EXPERT PAPER 610/BU/17

CUSTOMER Name and address:	**SYSTEMY AUTOBUSOWE ul. Lotnicza 18 04-192 Warsaw**
SUBJECT OF THE PAPER Name and address:	**Evaluation of extinguishing effectiveness of water and its derivatives in putting out fires involving LNG/CNG gases in a bus engine compartment and in putting out fires of hybrid and electric buses.**

Copy no. 1/3

Round seal with the state emblem of the Republic of Poland in the center and the following inscription on the rim: "THE JÓZEF TULISZKOWSKI SCIENCE & RESEARCH CENTER FOR FIRE PROTECTION STATE RESEARCH INSTITUTE".

Józefów, December 2017

Rectangular stamp:
Deputy Director
for Certification and Approvals
/-/ illegible signature
Brigadier Jacek Zboina, PhD, PE

1. Subject of the Paper

Evaluation of extinguishing effectiveness of water and its derivatives in putting out fires involving LNG/CNG gases in a bus engine compartment and in putting out fires of hybrid and electric buses.

2. Purpose and Scope of the Paper

Systemy Autobusowe Sp. z.o.o. as a manufacturer of extinguishing systems for buses requests for an opinion on the extinguishing effectiveness of water in putting out fires of LNG/CNG powered buses and electrical / hybrid buses.

In this situation an expert paper was drafted, which sets out the characteristics of water as an extinguishing agent and its application in the above-mentioned cases. In addition, the opinion of NFPA was presented and cases of such fires in the past years. The paper does not cover other buses powered by other fuels.

3. Basis for drafting of the Expert Paper

3.1 Formal basis of the paper

Commissioning letter of 07.11.2017 no. 8541

3.2 Substantive basis of the paper

Customer inquiry and literature analysis (see bibliography).

4. Characteristics of water

Water is the most widespread and often the best extinguishing agent. Extinguishing effectiveness of water follows from its physical and chemical properties. Due to its high values of specific heat and evaporation heat it extracts heat very well, and thereby considerably cools down burning or heated materials (one liter of evaporated water creates 1700 liters of steam) [1].

Further advantages of water include its ready availability, low cost, ease of transport and delivery to the fire and possibility of long-distance pumping. In order to extinguish a fire with water, various methods of its delivery are used. These include sprinklers, generators, fog nozzles, water cannons or discharges from aircraft.

Aside from advantages, water also has its drawbacks. The biggest one is its reactivity with other substances. Reacting with sodium, potassium, calcium or carbide, it creates an explosive mixture. In the event of fires of inflammable liquids lighter than water and non-solvent in water, in open tanks, boil-over may occur. Also, water should not be used to extinguish fires of oils and fats boiling at high temperatures.

Water is a good conductor of electric current. Application of this extinguishing agent in fires of devices under voltage and next to such devices and live installations may cause electric shock to nearby persons.

In high temperatures, water suffers partial thermal decomposition with liberation of hydrogen, which creates an explosive mixture with air. Therefore it is not recommended to use water to put out fires of materials burning at high temperatures. Water causes extensive damages, so its use is avoided in case of putting out fires of valuable objects [2].

5. Fires of LNG/CNG - powered buses

A description of an exercise with LNG gas follows.

The main purpose of the exercise was development of tactics of rescue & firefighting operations during fires liquefied natural gas LNG, as well as visualization of physical & chemical properties of the above substance. During the exercise, attempts were made to put out burning gas using various extinguishing agents, i.e. water, heavy, medium and light foam, water fog and extinguishers. Despite several attempts the fire was not put out. Finally, extinguishing powder was applied, which fully confirmed its extinguishing efficacy [3].

A frequent cause of fires of LNG/CNG - powered vehicles is neglectful approach or ignorance of mechanics. The best example of this is the event of December 1992 when ignition occurred of methane released from the LNG installation powering a bus during servicing operations connected with repair of the fuel system. In the course of repair of the installation, ethane was released in the workshop premises and alarm signals were triggered by the detection system of hazardous concentrations of flammable gases. The technician then tried to start the bus and drive it out of the garage. Then probably the air conditioning and ventilation system caused ignition of the liberated natural gas that had accumulated primarily inside the vehicle [4].

It is also impossible to entirely avoid hardware defects which can directly contribute to an outbreak of fire. An example of such an event is the fire of 3 April 2016, during which an entire bus burned down completely. The cause of the fire was found to be damage of a hydraulic hose from the fan drive. Hydraulic oil burst into flames in contact with hot exhaust manifold of the engine. The fire quickly encompassed the entire engine bay, and only immediate deployment of extinguishers allowed for quenching of the flames. Unfortunately, temperature was still so high that the fire spontaneously reignited [5].

LNG / CNG fires should not be fought with water, because due to the temperature difference between liquid LNG and water, regasification becomes more intense, causing feeding of the flames. In accordance with the safety data sheets for natural gas, water is used for fires of this source EXCLUSIVELY for protection of gas tanks from thermal radiation. It is not appropriate to apply compact streams of water directly on spilled liquid [6].

In the event of gas ignition, extinguishing attempts should not be made until effective inhibition of the leak. The combustion process should merely be controlled in order to prevent explosion and impact of thermal radiation on nearby infrastructure. In accordance with the Material Safety Data Sheet, the preferred extinguishing media to be used in case of a LNG/CNG fire are: extinguishing powders, carbon dioxide.

Considering inability to use carbon dioxide in an environment with people not equipped with gas masks - the recommended extinguishing agents for putting out gas fires in a bus engine bay are extinguishing powders [7].

Taking into account the above-discussed examples of fires of LNG / CNG powered buses, we note that there usually occurs extinguishing of the bus structure rather that direct extinguishing of LNG. In this connection application of water or its derivatives is possible.

When it comes to fires of electric or hybrid vehicles, we have to expect putting out fires of batteries. If we are extinguishing a NiMH battery, we must use a large amount of water in view application of sodium / potassium hydroxide as the electrolyte, which readily dissolves in water producing large amounts of heat and a highly caustic lye.

A different procedure is required in extinguishing of a lithium ion battery. The electrolyte of this battery is an organic combustible material. When a lithium ion battery fire occurs, extinguishing is time consuming. It is recommended to let the battery burn down completely. Contact of water with the battery leads to liberation of hydrogen peroxide, which under the influence of temperature decomposes into water and oxygen. The above reaction is exothermic [8].

Some fire safety tests were performed, which were designed to assess the course of fire and effective methods of fighting it. Batteries were set on fire. Increasing pressure caused opening of safety valves which led to small explosions. Extinguishing efficacy was established on the basis of testing this characteristic among universal extinguishing media: water, extinguishing foam and

extinguishing powder. Although effective, water proved not to be the best solution because of high consumption of this medium for total extinguishing of the fire [9].

This is also confirmed by tests carried out by the US organization National Fire Protection Association - NFPA. NFPA reports that it may take as much as 5-10 thousand liters of water to extinguish a hybrid car fire. The key fact is that putting out the fire does not solve the problem, because in the case of commonly used batteries fire will break out again with fresh intensity until the temperature of the batteries is reduced. Extinguishing with water therefore aims to cool down the batteries to a temperature of several dozen degrees Centigrade [10]. For economic reasons, fighting electric and hybrid car fires with water is not advisable. Due to the design of the batteries, it is preferred to use extinguishing POWDERS which exhibit inhibitive properties [11, 12].

6. Final Opinion

On the basis of literature analysis [1-12] performed by specialists of the Extinguishing Devices and Media Team, we note that although water is the most widespread extinguishing medium, in the event of LNG / CNG gas fires and hybrid and electric vehicle fires water is not preferred.

The effectiveness of a given medium is determined in extinguishing tests. An important issue, critical for the effectiveness of the selected medium, is the configuration of a fire-extinguishing system, whose task is to promptly deliver the extinguishing medium as close as possible to the potential fire location. Performing extinguishing efficacy tests of a medium in correlation with a system for different fire scenarios is the basis for issue of final assessment of relevance of use of a given fire safety system in engine bays of buses powered with alternative fuels.

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Józefów, ... 2017.

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