A Hybrid Water/Nitrogen Mist Extinguishing Technology Used for Fire-Fighting Bomb Development

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Abstract

Hybrid media is a combination of an inert gas, typically nitrogen, and atomized water that creates very small droplets. This results in better heat absorption due to a much larger evaporation surface which increases the extinguishing efficiency. Water mist fights fire in three ways; cooling effect, high velocity wetting and oxygen displacement. These beneficial water mist attributes were used for Fire-Fighting Bomb (FFB) development. To retard the wildland fires, fire-retarding material is typically dropped from aircrafts into the advancing fire. The conventional Firefighting dropping is performed from 60 m altitude which is extremely difficult and dangerous. The FFB, however, is dropped from any appropriate altitude and activated at the most effective distance above the fire. The basic Fire Fighting Bomb structure is similar to the conventional one. The explosive fill is replaced by Sodium-azide that generates nitrogen and a bulk of water. The heavy high fragmentation steel body is replaced by a biodegradable material or an aluminum shell. The hybrid water/nitrogen mist technology used in the FFB has an eightfold increase in the extinguishing intensity and effectiveness compared to present methods.

Keywords: hybrid water mist, water mist technology, fire-fighting bomb, aerial firefighting dropping.

Introduction

Hybrid media is a combination of an inert gas, typically nitrogen, and atomized water creating an atmosphere that does not support combustion. By using inert gases, some of the hybrid systems produce droplets of the order of 10 µm. The diameter of classic water mist droplets is on average 10 times larger. This results in better heat absorption, due to a much larger evaporation surface, which increases the extinguishing efficiency. The superior fire suppression capability of water mist is based on evaporation. When tiny water mist droplets turn into vapor, a great amount of energy is absorbed from the fire. Water mist fights fire in three ways; the cooling effect, high velocity wetting and oxygen displacement. The cooling effect of water mist takes place when the water mist droplets absorb the heat radiation from the fire. Nozzles discharge fine water mist at high velocity wetting the fuel and the area around the fire. The pressure employed in the water mist fire protection system is a key aspect in the fire extinguishing quality of water mist. Oxygen displacement happens at the heart of the fire when the water mist droplets turn into vapor and take oxygen from the fire. These beneficial water mist attributes are used for the Fire-Fighting Bomb (FFB) development.

The combination of climate change and the expanding human development in the wildland-urban interface create devastating fires that are burning and spreading more quickly than they did 30 years ago. To retard these fires, fire-retarding material is typically dropped into, or in front of the advancing fire from aircraft such as helicopters or airplanes. To be effective, the conventional Aerial Firefighting dropping must be performed from an altitude no higher than 60 m above the treetops. But such low flights are extremely difficult and dangerous, particularly at night. Most of the aviation-related wild-land firefighting fatalities result from failure to maintain clearance from terrain, water, or objects. The FFB can be dropped from any appropriate altitude and can be activated at the most effective distance above the fire.

The idea of 'bombing' a fire from the air isn't entirely new. After the end of World War II the U.S. Army Air Force developed modified drop tanks filled with water to blow them open right above the fire by means of TNT charge [1]. Russian Bazalt Factory designers have developed the ASP-500 Fire-extinguishing Air System intended for extinguishing forest fires [2].

The basic Fire Fighting Bomb structure is similar to the conventional aerial bomb. The explosive fill is replaced by a solid propellant (Sodium-azide) and a bulk of water. The heavy high fragmentation steel body is replaced by a biodegradable material or an aluminum shell. Once the requisite threshold is reached or exceeded, the FFB fuse activates the detonator resulting in gas bursts into the water tank, forcing the bomb shell to open. The opened FFB releases a huge fire-retarding aerosol cone precisely at an optimal level above the fire, resulting in effective rapid extinguishing, while using significantly less water as compared to conventional methods.

Hybrid Fire Extinguishing Systems (HFES)

General description

Hybrid media is a combination of inert gas, typically nitrogen, and atomized water that creates an atmosphere that inhibits combustion [3]. The inert gas is used to atomize the water into small, 250 µm (10 µinch) droplets. The atomized water droplets provide a large available surface area for heat absorption, and are easily converted to steam to provide cooling and oxygen dilution.

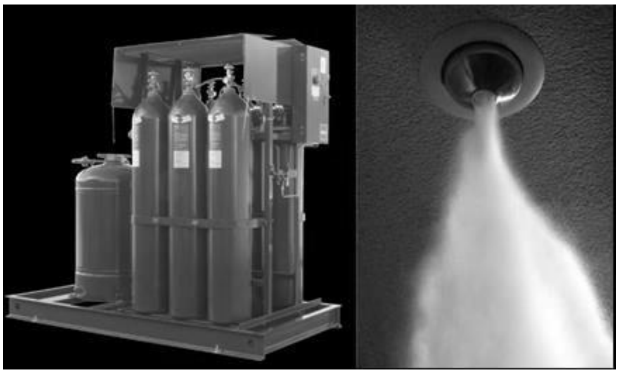

Fig. 1 Hybrid fire extinguishing system

The hybrid media discharge is regulated by nozzles operating at a given nitrogen pressure that controls the discharge rate. Water is delivered to each nozzle at a controlled flow rate, mixed with the nitrogen, and atomized into small droplets (see Fig. 1).

The longer suspension time, and the nitrogen, make Hybrid Fire Extinguishing Systems more effective on concealed or shielded fires. Such fires cannot be reached by larger droplets that tend to fall directly to the ground in many instances. The cooling effect of water mist takes place when the water mist droplets absorb the heat radiation from the fire. Nozzles discharge fine water mist at high velocity, wetting the fuel and the area around the fire. The pressure employed in the water mist fire protection system is a key aspect in the fire extinguishing quality of water mist. Oxygen displacement happens at the heart of the fire when the water mist droplets turn into vapor and take oxygen away from the fire.

The recent application areas of water mist system are surveyed for class A-F fires involving combustible solid materials such as wood, paper and textiles; flammable liquids such as petrol, oils, lubricants, paints and waxes; flammable gasses such as natural gas and liquefied petroleum gas; fires involving electrical equipment such as computers and information technology facilities; and flammable cooking oils and fats. In practical use the Water Mist Systems improve the traditional water sprinkler systems by consuming 50 to 90 percent less water, while resulting in little to no collateral damage. Water mist systems may be connected to a building's water supply for continuous fire-fighting capability, or to a tank or reservoir in remote locations.

The nitrogen is stored in high pressure canisters (see Fig. 1) but can be also generated by a Sodium-azide reaction. Sodium-azide is the gas-forming (nitrogen) component in many car airbag systems. Once the requisite threshold is reached, or exceeded, the airbag control unit triggers the ignition of a gas generator propellant to rapidly inflate a fabric bag.

Hybrid water mist research

Although the beginnings of research related to hybrid systems took place over 20 years ago, due to its high firefighting capabilities, more interest has only occurred in the recent years.

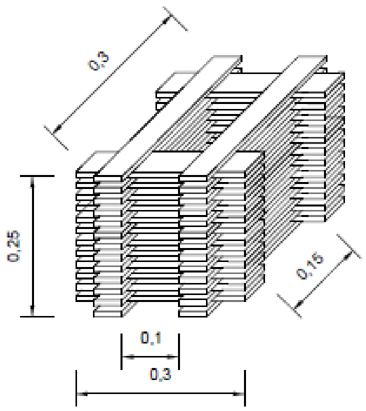

Fig. 2 A pile of coniferous boards

Extinguishing system tests were carried out by Gałaj et al. at the Main School of Fire Service in Warsaw [4]. They conducted a research the objective of which was the analysis of the impact of the flow rate of nitrogen-powered water mist in a specially designed and constructed hybrid system on the variability of temperature in a closed room during a wood fire. The research was aimed at determining the time of effective extinguishing of flames and comparing the extinguishing efficiency. For each test, a pile of wood was created consisting of 50 coniferous boards which were placed in the corner of the test room (see Fig. 2).

Gałaj and his team concluded that: "The most effective extinguishing system turned out to be a hybrid system using a nitrogen-powered water mist fed with a flow rate of 3 L/min. In this case, only about 10 L of water was consumed during the entire extinguishing, which is significantly less than in the case of conventional sprinkler systems and even standard mist systems, which also significantly reduces fire losses".

Another, different, test was carried out at the School of Civil Engineering, Central South University, Changsha, China [5]. The influence of gas-liquid ratio, injection angles, volume flow rate of foam liquid and driving pressure on the fire-extinguishing efficiency of protein foam (PF) in diesel pool fire was investigated by a self-built foam extinguishing system (see Fig.3). (Foam is a vital part of aerial suppression operations based on significantly increased efficiency when compared to ordinary water.)

The results show that PF with a gas-liquid ratio of 20 possesses the shortest extinguishing time and lowest extinguishing agent dosage among the samples. The fire-extinguishing efficiency of PF in diesel pool fire varies with spray angles, and is highest at 90° (vertical injection). Besides, fire-extinguishing efficiency of PF can be improved with an increase of the liquid flow rate and driving pressure.

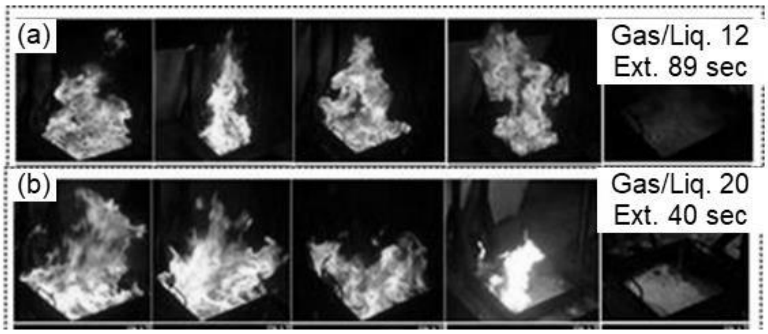

Fig. 3 The extinguishing process with a different gas-liquid ratio

Figure 3 presents two extinguishing tests with a different gas-liquid ratio; (a) represents a gas-liquid ratio of 12 and 89 sec extinguishing time, (b) represents a gas-liquid ratio of 20 and 40 sec extinguishing time. Another test with a gas-liquid ratio of 24 ended in 48 seconds.

Another, important test was carried out by Li and Wang at the University of Science and Technology of China, Hefei, China [6]. Explosion energy is used to push and disperse water into water mist to extinguish fire. Characteristic parameters of explosive water mist were calculated, and the interaction mechanism between the fires was analyzed.

Experimental equipment was consisted of a tap water plastic bag with TNT charge inside, and a fuel pan beneath the water bag (see Fig. 4 and 5). Temperature variations during the interaction were obtained by thermocouples and an infrared radiation thermometer, and photos were taken by a DV Digital Video.

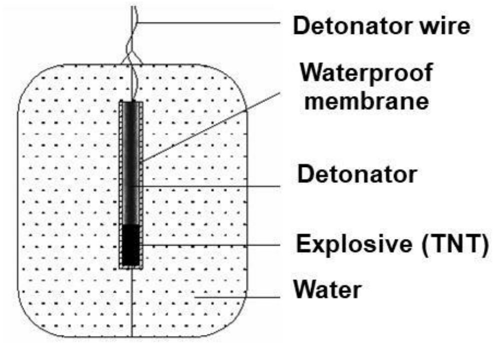

Fig. 4 Plastic water bag structure

A blast wave that is produced by an explosion always travels supersonically faster than the speed of sound. These waves affect and increase the fire before explosive water mist because the former propagate much faster than the latter.

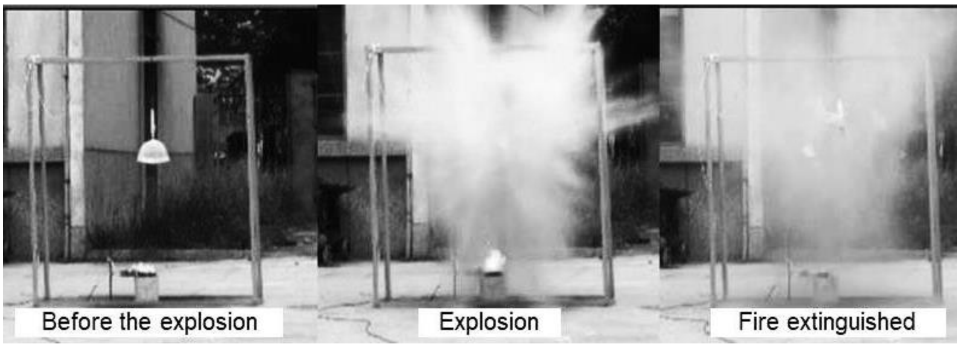

Fig. 5 A sample set of experiment images

Figure 5 depicts a typical set of experiment images. Fire is low and steady before the explosion (left). Both shock waves and explosive water mist are generated by the explosion but, as the shock waves propagate faster, the fire increases (middle). After the explosive water mist reaches the flame, the fire is put out (right).

Li and Wang's main conclusions were: "Explosive water mist suppresses and suffocates fires by mechanism of lowering the temperature and insulating oxygen. Besides, explosive water mist has comparatively large momentum, which enables it pass through smoke and flames to act on the surface of fuel".

The Fire Fighting Bomb (FFB)

General description

The idea of 'bombing' a fire from the air isn’t entirely new. After the end of World War II, the U.S. Air Forces began to fully investigate the feasibility of this idea and developed various dedicated aerial forest firefighting weapons. The first of these were modified drop tanks filled with water (see Fig. 6) and equipped with special 'variable time' radar proximity fuses to blow them open right above the fire [1]. Unfortunately, tests showed that the explosion itself was enough to ignite blazes. Accuracy remained the limiting factor and the United States ultimately abandoned the project.

Fig. 6 Water-filled drop tank on US P-47 fighter plane

Russian Bazalt Factory designers have developed the ASP-500 Fire-extinguishing Air System intended for extinguishing and localizing forest fires [2]. The ASP-500 system is filled with the fire-extinguishing mixture and an explosive dispersing charge (see Fig. 7).

Fig. 7 Russian ASP-500 Fire-extinguishing Air System

On impacting the ground surface ASP-500's dispersing charge is actuated, instantly forming a water-mist radial stream that 'sweeps' around the fire zone (Bazalt officials say). The ASP-500 bomb is dropped by a military aircraft as a 'first-strike' measure to suppress intense burning area, providing more time for ground-firefighters to move in an organized way. As the bomb comprises an explosive charge, it probably ignites blazes, exactly as the above U.S. Air Forces 'Water bomb' does.

All of the above innovations assume to provide firefighting methods and fire retardant delivery systems that make aerial firefighting safer and more effective, but none of them come close to high effective Hybrid Fire Extinguishing technology that is in use with the proposed Fire Fighting Bomb.

Fire Fighting Bomb (FFB) structure

Li and Wang's water plastic bag with TNT charge inside [6] can function as a Fire Fighting Bomb to be used instead of aerial fire suppressant drops. The TNT charge that generates the fire increasing blast wave is replaced by Sodium azide that generates nitrogen in a non-propulsive way. Sodium-azide is the gas-forming (nitrogen) component in many car airbag systems. Once the requisite threshold is reached or exceeded, the airbag control unit triggers the ignition of a gas generator propellant to rapidly inflate a fabric bag. One kilogram of Sodium azide generates three hundred liters of nitrogen.

The basic Fire Fighting Bomb (FFB) structure is presented in figure 8.

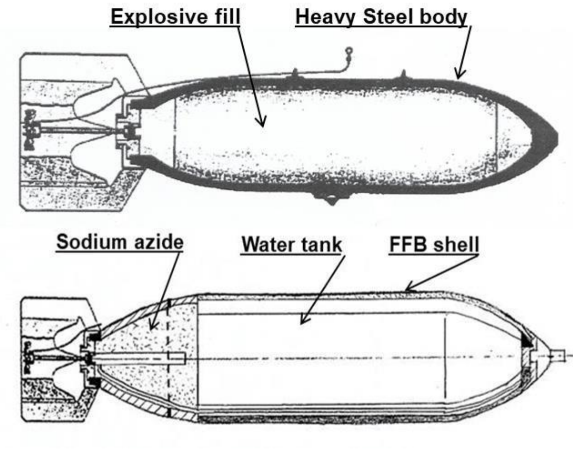

Fig. 8 The Fire Fighting Bomb basic structure

The basic Fire Fighting Bomb structure is similar to the conventional air bombs that are currently in use. The explosive fill is replaced by the Sodium-azide propellant and a bulk of water. The heavy high fragmentation steel body is replaced by biodegradable or aluminum parts. Once the required gas pressure is exceeded, the FFB case disintegrates, creating an ultra-fine water mist similar to the HFES nozzle (see Fig. 1). Exactly as the Hybrid Fire Extinguishing technology, this water mist covers an enlarged surface area as compared to the conventional aerial firefighting resulting in effective rapid extinguishing, using significantly less water as compared to existing methods.

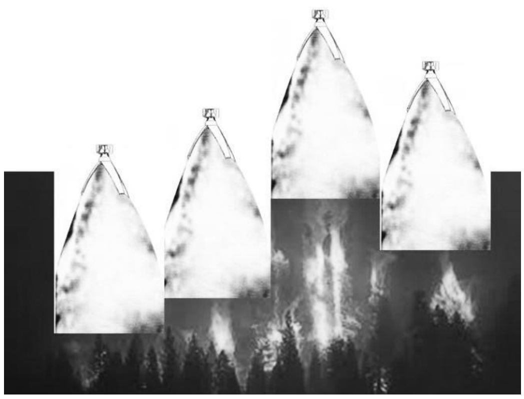

Fig. 9 FFBs opens on an optimal level above the fire

The FFB can be dropped from any appropriate altitude and can be activated at the most effective distance above the fire (see Fig. 9). This eliminates aerosol losses completely, and increases the fire extinguishing safety and efficiency.

The FFB fire extinguishing efficiency is compared to that of the Erickson S-64 Air-Crane fire-fighting helicopter to demonstrate its advantage. The Air-crane can be fitted with a 10,000 L (2,650-gallon) retardant material tank to assist in the control of bush and forest fires. 200 L (66 gallon) FF bomb provides a good example. The estimated weight of the external body and the propellant are approximately 50 kg (110 lb.), so the total weight is 250 kg (551 lb.). The Erickson S-64 Air-Crane helicopter can carry 40 such bombs at a 10,000 kg (22,050 lb.) total weight. The FFB efficiency is similar to that of the Hybrid Water Mist Systems (ten times higher), but to be on the safe side, let assume a lower value of eight. The outcome of this assumption is that the fire-fighting capability of a 200 L FF bomb is equal to 1600 L of the conventional water dropping. If we multiply this water volume by the FFB number (40), we get 64000 L, which is similar to the water carrying capacity of the 747-400 Supertanker.

This means that a medium category, low cost, firefighting aircraft can virtually be converted into a super heavy category aircraft, which is very expensive and difficult to operate.

The firefighting bombs will be clustered in vertical position into a special container, and dropped by helicopter. The FFB vertical position enables a very accurate target impact due to helicopter's ability to hover exactly above the targeted point of fire.

Conclusions

Water has always been the mainstay for fire suppression. The big question has always been, "How do we make water last longer and do a better job"? The use of Hybrid Fire Extinguishing technology helps to accomplish this purpose.

The development of the Fire Fighting Bombs (FFB) yields many beneficial results:

- The use of Fire Fighting Bombs dropping will be the most efficient approach to wildland fires suppression.
- The Hybrid Fire Extinguishing water mist covers an enlarged surface area as compared to the conventional aerial firefighting resulting in effective rapid extinguishing, using significantly less water as compared to existing methods.
- The FFB can be dropped from any appropriate altitude, and can be activated at the most effective distance above the fire. This eliminates aerosol losses completely and increases fire extinguishing safety and efficiency.
- The FFB vertical dropping yields a very accurate target impact.

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