PROPELLED EXTINGUISHING AGENT TECHNOLOGIES (PEAT)

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INTRODUCTION

According to the Montreal Protocol and international legislation, halon production ended (officially) in Jan 1994; however, the search for the "ideal halon replacement" is ongoing worldwide. In fact, there is a lot of confusion in the fire protection market as to what should be used as fire extinguishing agents for the unique applications where halon was the only solution. A large number of candidate replacement agents have been evaluated; some of them have been commercialized, yet all of them have serious tradeoffs regarding the four major criteria defining the ideal halon replacement: (1) low global environment impact (low ODP, GWP and atmospheric lifetime); (2) acceptable (low) toxicity; **(3)** cleanliness/volatility; and (4) fire extinguishing effectiveness. It is a complicated task to find a candidate that meets all four criteria and serves **as** a "drop-in" replacement. During the past decade various international and national research institutes, military and civilian laboratories, federal agencies and industries have evaluated several hundred materials.

One of the proposed halon alternative technologies is the powdered aerosols, which are produced by the reaction of an oxidizing agent and a solid fuel, which, when ignited, produce a fine solid particulate aerosol (powdered aerosol) providing extinguishment similar to that of dry chemical agents. The small particle size appears to increase efficiency, decrease deposits, and increase the space filling capability (multidimensionality) relative to normal dry chemical agents. Some have termed this type of technology "pyrotechnically generated **aerosol."**

Several formulations and system concepts have been commercialized worldwide. "SFE" technology (Powdered Aerosol **A on** the EPA SNAP List or EMAA [Encapsulated Micron Aerosol Agents] by the USAF) was one of the first such systems. The **SFE** (Spectrex Fire Extinguishing) agents are cast in solid form and are contained in modular units (generators) of various sizes containing from 100 grams to 5 kg net weight **"SFE,"** some of which include cooling. The approximate design factor is 50 g/m^3 for direct material activation in enclosed areas and 100 to 120 g/m^3 when discharged from cooled generators, where a safety factor of 20% is included. Typical system configuration includes several modular units connected in a loop to a control box/display panel, activated electrically by a signal from a separate detection system or by a self-contained detection element incorporated in the modular unit.

As particle size decreases, the particulate surface on which heterogeneous recombination of combustion chain propagators can occur increases. Moreover, as particulate size decreases, the sublimation rate increases, enhancing homogenous gas-phase inhibition mechanisms. In addition to improving dispersion, the small particle sizes inherent in particulate aerosols gives these materials greater weight effectiveness than standard dry chemical agents, thus decreasing the problems due to residue. Both heterogeneous (particulate surface) and homogenous (gas-phase) inhibition appear to contribute to flame inhibition by particulate aerosols. Heat absorption by decomposition reactions and phase changes may also contribute.

Although highly effective in protecting closed spaces (total-flood extinguishing method), the powdered aerosol technology has limited effectiveness in open area fire extinguishing, caused mainly by environmental conditions (airflows and winds, turbulent weather, high temperatures). The highly buoyant aerosol particles easily flow out of the fire zone, blown out by the fire heat and environmental airflows. To solve this problem, other methods of delivering aerosol powders and other pulverized materials have been considered and will be discussed in the present paper.

The effectiveness of dry powders and water droplets **as** fire suppression agents is well established and the only limitation so far has been their efficient delivery mode to the fire source to provide complete extinguishments and prevention of reignition. Delivering extinguishing materials into a fire zone, dispersing them in homogeneous clouds that penetrate the fire flame front and stop it causing immediate fire suppression (in less than a second), while at the same time employing rather small quantities of fire extinguishing agent for complete extinguishment, is a challenging task. The most common delivery methods for standard fire suppression agents rely on pressurized systems (cylinders, bottles, pipes, and nozzles) that propel the extinguishing agent by mere impulse discharge caused by pressure differential between the system and the fire zone. These propelling forces are, however, limited by the gas pressure and the cylinder volume thus limiting the covering range of the extinguishing agents to several meters.

A new approach was suggested in the former Soviet Union (by Prof. Zachmatov), whereby the discharge and pulverization of extinguishing agents can he performed by employing minute charges that create a strong linearly oriented pressure impulse that propels the agents to long distances.

TECHNICAL BACKGROUND

As mentioned earlier one of the most critical tasks is to develop a compact, mobile, and remotely controlled fire suppression system for effective operation in hard-to-reach areas, such as storage tank farms, pump stations, hangars, mining and underground cellars, high rise buildings, cable ducts, high density bush and forest areas, etc. **A** standard streaming fire extinguishing system has several limitations, e.g., relative heavy weight, large size, limited extinguishing material capacity and short operation range, and it is cumbersome and difficult to operate in remote areas. The low fire extinguishing efficiency of standard extinguishers can be explained by the large consumption of extinguishing agents, the long duration and low intensity of the ejection jet, the limited surface area of the extinguishing agent jet, and the low kinetic energy responsible for the short range coverage of the extinguisher.

The proposed technology is based on the " Impulse" provided by the use of small pyrotechnical charges (employed in barrel guns, smoke and fireworks, etc.) that form directional waves (impulse jet) that spread across porous materials. This impulse torrent has a vortex structure and high kinetic energy, providing a flat front wave flight trajectory. These waves penetrate into the mass of the fire extinguishing agent increasing its volume, surface area and dispersion range, creating directional suppression jets that enter the fire zone and provide enhanced extinguishing capabilities.

The directional gas/particulate streams contain a high concentration of finely dispersed fire extinguishing substances, which can be in the form of fine water droplets, powdered aerosols, or any other pulverized agent. These finely dispersed agents carried by the jet force are discharged simultaneously into the combustion zone of the burning material, practically "cutting-off' the flame from the fire source (fuel), thus eliminating one of the fire pyramid parameters (fuel, heat, oxygen, chemical chain reactions). Other mechanical and physical mechanisms include the following.' large surface area heat absorption and dispersion, destruction of flame front, disturbance of fuel surface (in class B fires), forced mixing of extinguishing particles/droplets with fuel vapors, and separation between oxygen/air and fuel molecules.

Impulse systems based on pneumatic pressure type, such as the German IFEX, the Russian IGLO or Ukrainian TAJFUN, are limited by their delivery rate (100 l/sec), maximum range (80 m) and large dimensions. These systems contain high-pressure air cylinders (300 bars), providing typical impulses at 25 bars operation pressure with pulse duration of 200 msec for each shot. The recharge time is 6 sec, requiring large capacity vessels and pumps. Larger systems that create a water jet with a range of up to 200 m, a delivery rate of up to 100 l/sec, and power of up to **2500** kW are required to expel the water from a 20 m^3 storage tank. A high pressure of 40 kg/m^2 is required for this task. The smaller, portable pneumatic systems pose also a safety problem to the operators. The high-pressure hose carrying a jet of 16-25 bars can cause serious personal injury to the fireman, should there be a malfunction or hose self-disconnection.

The proposed impulse system eliminates the requirement of pressurized vessels, pumps, and hoses, by simply creating the impulse torrent from the activation of a small powder charge in a standard cartridge and discharging it through a tubular (barrel) of predetermined caliber. Additional devices in spherical, hemispherical, disc, and cone designs have been tested. The main parameters influencing the extinguishing effectiveness are the size or caliber of the discharge device, the amount of extinguishing material, and the number of devices activated in each "firing volley." Preliminary tests, performed **on** barrel type prototype systems, related the impulse torrent range with the effective extinguishing area and volume for various barrel calibers and the number of barrels in each volley. Table 1 presents some of these typical experimental test results.

TABLE 1. TYPICAL PARAMETERS OF IMPULSE SYSTEMS.

Barrel Caliber (mm)	Number of Barrels in a Volley	Amount of Extinguishing Substance (kg)	Impulse Torrent Range (m)	Effective Extinguishing Scale	
				Area (m^2)	Volume (m^3)
25	1	0.35	3	3	2
	3	1	5	10	8
100	1	5	15	10	15
	2	10	18	15	20
	3	15	29	25	150
	4	20	28	35	70
120	1	7.5	21	12	20
	2	15	24	25	45
	3	22.5	27.5	40	60
	4	40	40	58	80
150	1	10	28	15	35
	2	20	30	35	60
	3	30	38	50	100
	4	40	45	70	I20
200	1	20	32	30	70
	2	40	40	70	120
	3	60	45	110	180
	4	80	50	150	220
	10	300 (30x10)	120	500	1800

As seen from the test results, employing several systems simultaneously provides unprecedented fire extinguishing over large **areas.** Whereas a small, personal impulse extinguisher operated by a fireman, containing 0.35 kg extinguishing agent provides maximum delivery range of **3** m (max volume of *2* m^3), a 100 mm caliber barrel can deliver a 5 kg extinguishing mass with **an** impulse torrent range of 15 m, to cover an area of 10 m^2 and a volume of 15 m^3. Employing several barrels in one volley, for example 4 barrels (each with a caliber of 100 mm), each one pushing and pulverizing a 5 kg extinguishing agent charge, can extinguish effectively an area of 35 m^2 and a volume of 70 m^3.

Devices designed in different shapes and sizes, the amount of extinguishing materials delivered by them and their extinguishing effectiveness in terms of range, area, and volume coverage are detailed in Table **2.** The shaped devices were suspended above the protected area on high poles or from the ceiling (in closed volumes). Some experiments were carried from airborne units (helicopters or drones) that activated the shaped device over the fire source, in actual forest fire scenarios.

A comparison between the traditional fixed and mobile type extinguishing systems and the impulse systems for various **types** of Class A, **B,** C fires was conducted experimentally, and the results are presented (Figures 1 and **2;** Tables 3, 4, *5).* Conventional fire extinguishing systems (including pneumatic impulses)

TABLE 2. EXTINGUISHING EFFECTIVENESS OF SHAPED IMPULSE DEVICES.

Type of Device	Amount of Extinguishing Substance (kg)	Impulse Torrent Range (m)	Effective Extinguishing Scale	
			Area (m^2)	Volume (m^3)
Spherical	10	2.5	10	100
	20	3.5	20	200
Hemispher-ical	10	3	20	100
	20	4.5	40	200
Disc	10	3	50	100
	20	4	100	200
Cone	10	4	40	100
	20	5	80	200
	50	a	200	500
	100	9	400	1000
	150	10	600	1500
	200	12	800	2000

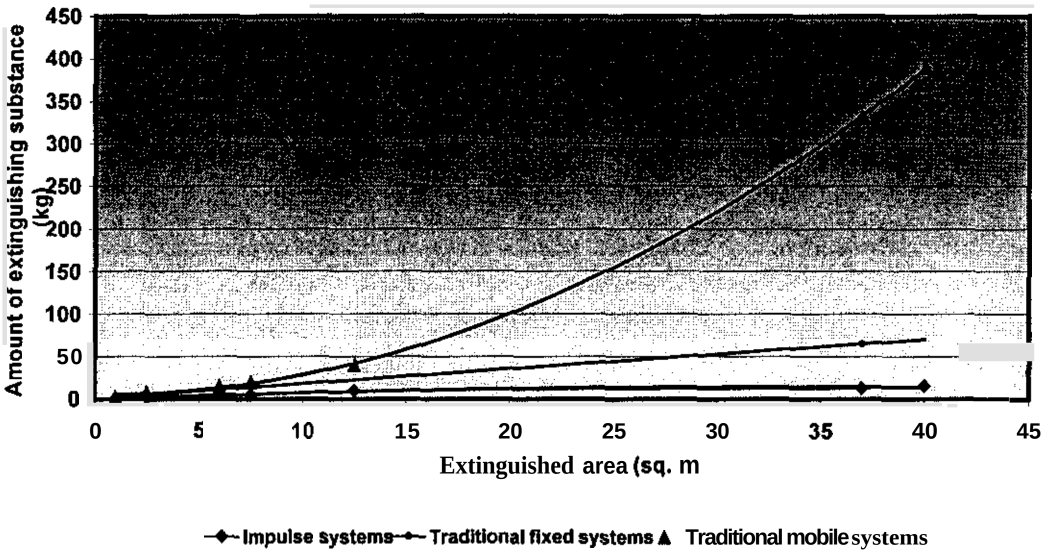

Figure 1. Effective extinguished area—comparison of traditional impulse systems.

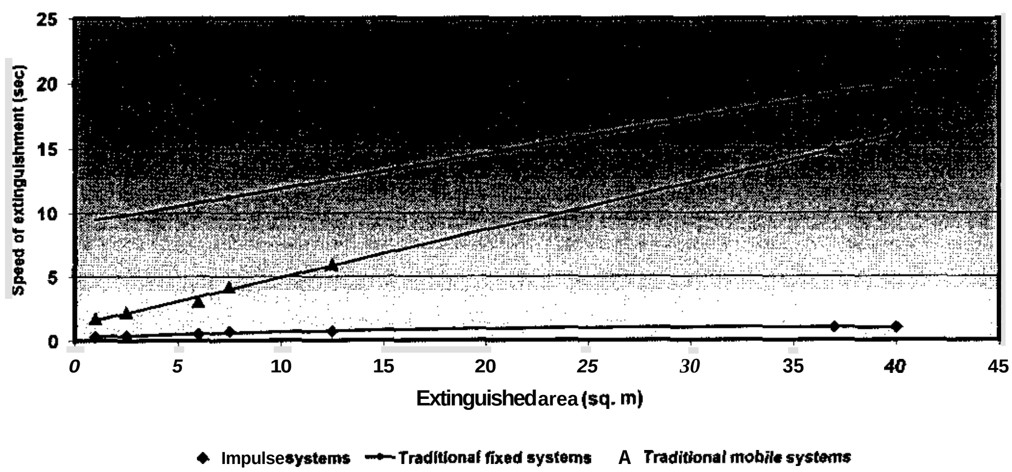

Figure 2. Speed of extinguishment - comparison of traditional and impulse systems.

TABLE 3. COMPARISON OF IMPULSE AND TRADITIONAL FIREFIGHTING SYSTEMS **CLASS** A FIRE (SOLIDS).

Fuel Type	Fire Size	Extinguishing Method	Range (m)	Extinguishing Time (sec)	**Mass *of*** Extinguishing Substance (kg)
Wood stack	15 x 6 x 3.5 m^3	Traditional	10-20	300-400	80000 water (4 fire engines)
		Impulse	30-60	< 15	1000 water (multibarrel system)
Forest fire	2000 m^2	Traditional	5-15	700-800	12000 water (4 fire engines)
		Impulse	10-60	<100	1500 water (multibarrel system)
Forest local fire at mts., Crimea	appx. 2500 m^2	Traditional (helicopter + 3 tons water tank)	30	3x600	9000 water (3 flights)
		Impulse (with 1 suspended powder system)	20	2	200 powder (multibarrel system)

TABLE 4. COMPARISON OF IMPULSE AND TRADITIONAL FIREFIGHTING SYSTEMS CLASS **B** FIRE (LIQUIDS).

Fuel Type	Fire Size	Extinguishing Method	Range (m)	Extinguishing Time (sec)	Mass of Extinguishing Substance (kg)
Kerosene	Square 140 m^2	Traditional	10-20	60-100	3000 water with foam
			10-20	30-40	1000 powder
		Impulse	30-60	< 10	120 powder
	Square 200 m^2	Traditional	10-20	100-200	5000 water with foam
			10-20	40-60	1500-2000 powder
		Impulse	30-60	<2	300 powder
	Square 400 m^2	Traditional	10-20	200-300	8000-10,000 water with foam
			10-20	80-120	4000-5000 powder
		Impulse	30-60	<5	600 powder
	Square 800 m^2	Traditional	10-20	350-500	18000 water with foam
			10-20	60-100	8000 powder
			30-60		
		Impulse	30-60	<10	1200 powder
	Numerous Local Fires 2000 m^2	Traditional	10-20	600-700	24.000 water with foam
			10-20	200-300	10,000 powder
		Impulse	30-80	<60	3000 powder

employing large amounts of extinguishing materials cover only a limited area, whereas the novel impulse systems provide effective enhanced area coverage with very small amounts of extinguishing materials (Figure 1). Also, the experimental results show better performance and area coverage with lower amounts of extinguishing materials for fixed systems when compared to mobile systems.

Figure 2 shows the linear relationship between the time (speed) **of** extinguishment and the extinguished (covered) area. As can be seen, for traditional fixed and mobile systems to cover larger areas, longer times are required for complete fire extinguishment. For the impulse method, the speed of extinguishment is almost constant, the area coverage **is** increased, **i.e.,** larger areas are covered very fast.

SUMMARY OF TEST RESULTS

The preliminary tests showed the following advantages of the impulse systems:

1. High extinguishing efficiency when using small quantities of various extinguishing compounds, including natural materials like water, sand, or soil.
2. Substantial improvement in the safety of operators due to the increased range of extinguishing coverage distance and area.

TABLE 5. COMPARISON OF IMPULSE AND TRADITIONAL FIREFIGHTING SYSTEMS CLASS C FIRE (GAS).

Fuel Type	Fire Size	Extinguishing Method	Range (m)	Extinguishing Time (sec)	Mass of Extinguishing Substance(kg)
Gas jets	Gas well-3jets P=150 atm. Flow= 10^6 m^3 per 24 hr.	Traditional	10-20	650	1 10,000 water (4 fire engine) + 5000 powder
		Impulse	40-50	<2	300 powder (multibarrel system)
	G ll –1 jet P=150 atm. Flow= 1.5×10^6 m^3 per 24 hr.	Traditional	10 –20	700-750	150,000 water (6 fi ines)
			10-20	200	10000 powder
		Impulse	25	<1	300 powder
			50	<2	300 powder
			100	<2.5	600 powder
	Offshore platform, 12 gas – oil wells p=250 atm. Flow=$5 \times 10^6 m^3$ per 24 hr.	Traditional fire ship	40-60	600	12,000,000 water
		Impulse fire ship with multibarrel installation	60	3	1200 powder

3. Small weight of extinguisher, including agent charge module.
4. No need of pressurized systems (no air cylinders required).
5. Simple design, maintenance, and reloading operations, no need for special preparations before activation.
6. Simple and fast agent module reloading for the same impulse system.
7. Fast discharge of fine spray of particles/droplets in a directional cloud form.
8. Optimal range, area, and volume coverage by impulse "cloud" dispersion.
9. Optional remote control of the multi-barrel systems.
10. Simple design incorporates standard components (including the impulse cartridge).

The proposed PEAT (Propelled Extinguishing Agent Technologies) system contains three main parts: (1) tube/Barrel of various calibers; (2) extinguishing agent module; and (3) activation (cartridge) module. The larger systems that incorporate several barrels can be mounted on a mobile robot or a dedicated fire extinguishing vehicle or an airborne target drone or helicopter. Typical automotive systems include multibarrel (up to 50) scanning (directional) extinguishing module installed on a tank, truck, or trailer chassis. Airborne modular systems, including suspended multi-bombs that propel the fire extinguishing agents in conical oriented impulses.

Fast response volume coverage (total flood) is achieved through dispersal of the modules, which provides a fine powder cloud. Various particles sizes floating non-homogeneously, fill the entire protected area according to the temperature, size, and momentum/impulse. The extinguishing agent module can contain traditional fire suppression agents (water, foam, powders) or advanced novel halon replacements (FM-200, FE–36 and others) and halon alternatives (powdered aerosol).

Another approach for the agent module is that of a hybrid system delivering premixed granulated SFE agents with powder into the fire zone. The granulated SFE is activated by the heat emitted by the fire producing fine particulate aerosol that is held in suspension with the larger powder particles. This highly effective fire suppression cloud is created in situ in the fire zone, thus acting on the fire both physically and chemically and providing complete extinguishment and preventing fire reignition.

APPLICATIONS

Propelling fire suppression agents faster to longer distances and covering larger areas has always been the ultimate goal of the fire brigades. Accessing difficult areas (congested industrial sites or highly obstructed storage areas) and providing safe and effective fire detection and suppression has been a challenging task for fire protection experts worldwide.

PEAT (Propelled Extinguishing Technologies) provides a large variety of modular, fixed, and mobile systems for many applications in military, industrial, commercial, and household markets.

Some typical applications for each market are listed below:

1. Military Market:
   Aircraft hangars and airfields
   Ammunition Storage areas
   Armored vehicles (engine compartment)
   Navy ships (large engine rooms)
   Remotely activated fire extinguishing grenade
   Portable fire extinguishing launcher

2. Industrial Market:
   Oil & Gas production & storage facilities
   Tank storage farms
   Chemical and Petrochemical production and storage facilities
   Large warehouses
   Paint spray applications
   Mining industry

3. Commercial Market:
   Generators/Transformers/Pumps rooms
   Boiler rooms
   Automotive (LPG /LNG)
   Cable tunnels
   High rise buildings
   Fire brigades

4. Household Market
   Portable mini-extinguisher
   Electrical boards and cabinets
   Elevator pier
   Kitchen mini-extinguisher

CONCLUSIONS

The versatility and simplicity of the impulse technology provides the fire extinguishing market in general and the halon alternatives market is particular with cost-effective systems that deliver the fire suppression agents to the fire zone faster, safer, and to longer distances than traditional systems.