ENHANCEMENT OF FIRE SURVIVABILITY BY EMPLOYING PYROTECHNICALLY GENERATED OR PROPELLED AGENTS

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ABSTRACT

The search for environment friendly and effective Halon Alternatives has led to substantial technological developments that enhance the fire survivability for both military and commercial applications. The current and future battlefield with its new and unique tasks and fire scenarios associated with the armored vehicles, especially the light vehicles operational arena, require in addition to the improved fire protection for their engine and crew compartments, protection for the outer skin and tire sections.

New developments in pyrotechnically generated powdered aerosols and their special delivery systems, as well as, an emerging variety of propelling devices for fire extinguishing agents are now available for applications ranging from light armored vehicles to electrical cabinets. The need to employ a combination of two or more complimenting agents for a difficult fire scenario (for example burning tires) will require systems that can propel various fire extinguishing agents such as: foam, gas, dry powder, water, etc. The present paper describes a new generation of automated fire extinguishing powdered aerosol delivery systems and propelling devices including several fire suppression variations and their possible configurations.

INTRODUCTION

According to the Montreal Protocol and International legislation, Halon production ended (officially) in Jan '94; 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 trade-offs 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.
(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.

BACKGROUND

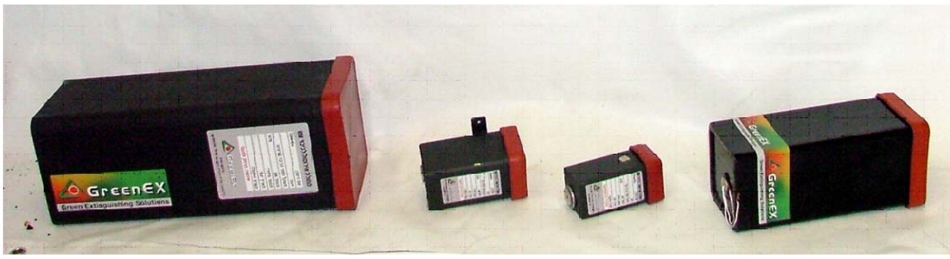
The effectiveness of dry powders and water droplets as fire suppression agents is well established but limited by the delivery mode to the fire source to provide complete extinguishment and prevent re-ignition. Delivering optimum quantities of extinguishing materials into a fire zone and dispersing them in homogeneous clouds that penetrate the fire flame front to cause immediate fire suppression (in less than a second), is a challenging task. The most common delivery methods for standard fire suppression agents rely on nitrogen 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, determined by gas pressure and cylinder volume, thus limiting the coverage of the extinguishing agents to several meters.

A standard streaming fire extinguishing system has several limitations, such as: relative heavy weight, large size, limited extinguishing material capacity and short operation range, 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, the low kinetic energy that is responsible for the short range coverage of the extinguisher.

POWDERED AEROSOL A (SFE)

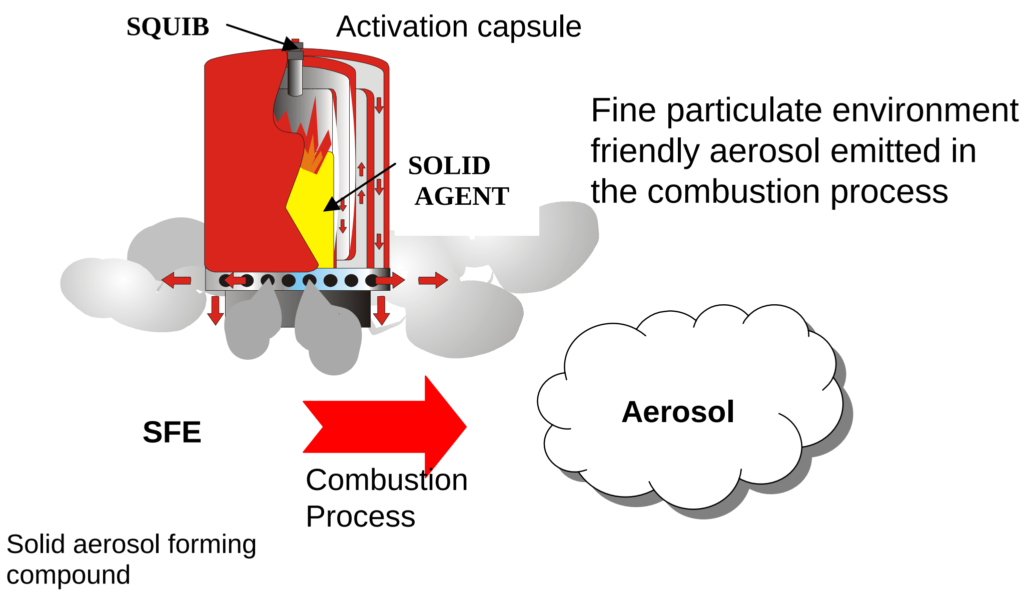
One of the proposed Halon Alternative Technologies is the Powdered Aerosol produced by the reaction of an intermixed oxidizing agent and a solid fuel. When the solid agent is pyrotechnically ignited, it produces a fine particulate (1-2 micron diameter) aerosol extinguishment. The small particle size increases efficiency, decreases precipitated deposits, and allows the agent to flood cluttered areas rapidly and completely relative to normal dry chemical agents. It has been shown to be six times more effective than Halon 1301 per unit mass and is shown to be non-corrosive. Some have termed this type of technology "pyrotechnically generated aerosol".

Powdered Aerosol A, listed per EPA SNAP List, also known as EMAA (Encapsulated Micron Aerosol Agents) by the USAF, was one of the original powdered aerosol technologies developed. The extinguishing agents are cast in solid form and are contained in modular units (generators) of various sizes containing from 20 grams to 5 kilograms net weight. 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 30% is included. Various shapes and sizes of generators are available. 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. The technology is licensed to leading fire suppression systems manufacturers and is marketed under the trade names Micro–K (Ansul), SFE (Spectrex), GreenSol (GreenEX).



Powdered Aerosol Generators (Box Type)

The highly efficient aerosol contains up to 40 % solid particles and 60 % gaseous molecules. The small particle size (1-2 micron) allows for increased surface area of the particulate and, therefore, increases the heterogeneous recombination of combustion chain propagators. Moreover, as particulate size decreases, the sublimation rate increases, enhancing homogenous gas-phase inhibition mechanisms. In addition to improving dispersion, the small particle size gives these materials greater weight effectiveness than standard dry chemical agents and significantly less residue. Both heterogeneous (particulate surface) and homogenous (gas phase) inhibition contribute to flame inhibition by particulate aerosols. Heat absorption by decomposition reactions and phase changes also contribute. The Aerosol is non-toxic as shown by the U.S. Navy Tox-Lab (NMRI/TD) in 50-80 g/m^3 concentrations, and no ODP and GWP are generated.



Powdered Aerosol Generator (Cartridge Type)

Several formulations and system concepts have been commercialized worldwide and international standard organizations are establishing powdered aerosol standards: NFPA 2010 (USA), CEN/TC191/WG6/TG2 (Europe), IMO FP44/ WP.7 –SOLAS 74 (Maritime Standard), ISO/TC21 (International Standard Organization).

Some applications for the powdered aerosol generators (PAG) are:

- electrical cabinets
- telecommunications facilities, computer rooms
- flammable liquid and gas storage facilities
- engine and compressor rooms, control rooms (sub-floor, above-ceiling)

Although highly effective in protecting closed spaces (total flood extinguishing), the powdered aerosol technology has limited effectiveness in open areas caused by environmental conditions (airflows and winds, turbulent weather). The highly buoyant aerosol particles easily flow out of the fire zone, blown out by the fire heat and environmental airflows. In order 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.

Performance Test Report on GreenSol Aerosol units (Electrical Cabinet Simulation):

During 2005 a series of fire extinguishing tests were performed with various GreenSol powder aerosol generators. The tests were performed with the test chamber in two positions, horizontal and vertical to mimic electrical cabinets of various configurations. Several fire sources included n-heptane canisters as well as electrical wires and plastic/rubber cables at various locations in the test chamber.

<u>Test Setup 1a: Test Chamber in Vertical Position</u> - Extinguishing tests in a 0.65 cubic meter test chamber (height 1.3 m x floor area 0.5 m x 1 m)

Test no	Extinguishing material (grams)	Number of fire sources extinguished	Comments
1	50	3/3	The n-heptane canisters were located at low, mid and upper positions, gas generator located a t lower position
2	50	3/3	same as (1)
3	50	3/3	same as (1)
4	50	3/3	same as (1)
5	50	3/3	same as (1)
6	50	1/1	Fire source included n-heptane and electrical cables located on the test chamber floor, in the center.
7	50	4/4	3 n-heptane canisters located at low, medium and high positions and a cables tray in the test chamber center – a total of four fire sources
8	50	4/4	same as (7) with the aerosol generator located in the upper section of the test chamber.
9	50	4/4	same as (7) with the aerosol generator located in the upper section of the test chamber.

Test Setup 1b: Test Chamber Horizontal Position – Extinguishing tests in a .65 cubic meter chamber (length 1.3 m x height 0.5 m x width 1 m)

Test no	Extinguishing material (grams)	Number of fire sources extinguished	Comments
1	50	3/3	The n-heptane canisters were located at low, mid and upper positions, gas generator located a t lower position
2	50	3/3	same as (1)
3	50	3/3	same as (1)
4	50	4/4	3 n-heptane canisters located at low, medium and high positions and a cables tray in the test chamber center – a total of four fire sources

Test Setup 2a: Test Chamber Vertical Position – Extinguishing tests in a 2.65 cubic meter chamber (height 2 m x floor area 1.15 m x 1.15 m)

Test no	Extinguishing material (grams)	Number of fire sources extinguished	Comments
1	200	4/4	The n-heptane canisters located at low, mid and upper positions up to 1.95 m, gas generator located at lower position
2	200	4/4	same as (1)
3	200	**3/4	same as (1)
4	200	4/4	same as (1)
5	250	4/4	same as (1)
6	250	1/1	Fire source included n-heptane and electrical cables located on the test chamber floor, in the center
7	250	5/5	3 n-heptane canisters located at low, medium and high positions and a tray with electrical wires/cables in the test chamber center – a total of four fire sources
8	250	5/5	same as (7) with the aerosol generator located in the upper section of the test chamber
9	250	5/5	same as (7) with the aerosol generator located in the upper section of the test chamber

** Fire at the lower location not extinguished due to crack-open door section. The problem was fixed in further tests.

Test Setup 2b: Test Chamber Horizontal Position – Extinguishing tests in a 2.65 cubic meter chamber (height 2 m x floor area 1.15 m x 1.15 m)

Test no	Extinguishing material (grams)	Number of fire sources extinguished	Comments
1	250	4/4	3 n-heptane canisters located at low, medium and high positions and a tray with electrical wires/cables in the test chamber center – a total of four fire sources
2	250	4/4	same as (1)
3	250	4/4	same as (1)
4	250	5/5	wood pieces instead of electrical wires/cables

Test Chamber Temperature measurements
Temperature in the test chambers before fire ignition was 40ºC. Temperature in the test chamber after fire suppression by aerosol was 63.5 ºC to 66.9ºC

Corrosion Test Results on GreenSol Aerosol Material:

Independent laboratory tests were performed for the aerosol material in the GreenSol generators in 1999. Various metallic and plastic materials were tested to conditions of aerosol exposure, cleaning or lack of cleaning after aerosol exposure, water exposure after aerosol exposure, and control samples with no exposure to aerosol or water. Results indicate that the aerosol will not cause corrosion on materials which are not susceptible to corrosion by normal humidity.

Specimens submitted for testing were separated into four groups as follows:
- Group 1 specimens were not cleaned after exposure to aerosol.
- Group 2 specimens were cleaned with compressed air after exposure to aerosol.
- Group 3 specimens were cleaned with water after exposure to aerosol.
- Group 4 specimens were not exposed to aerosol.

Item	Material	*Results
1	Copper 110	exhibited varying degrees of tarnish on all specimens except that which was cleaned with water after exposure to aerosol (Group 3)
2	Steel 1010	isolated areas of corrosion consisting of at least 10 rust spots were present on all specimens except Group 3 specimen, which had only one rust area. The worst condition was present on group 4 specimen
3	SS 303	no visible corrosion on any specimen
4	Brass 360	Group 1 and 2 specimens exhibited tarnish. No visible corrosion on Group 3 or 4 specimens.
5	Bronze 905	a greenish tarnish was noticeable on the top edge of Group 1 and 2 specimens. Group 3 had no visible corrosion and Group 4 had only slight discoloration on one edge.
6	Aluminum 6061	no visible corrosion on any specimen
7	Galvanized Steel	slight oxidation was visible on all specimens
8	PC Board (epoxy)	no visible corrosion on any specimen
9	Nylon 616	no visible corrosion on any specimen
10	PVC	no visible corrosion on any specimen
11	Relay Contact	slight corrosion of one contact visible in Group 3. No visible corrosion on any other specimen
12	Terminal (tin plated)	slight residue or corrosion was present on Group 1 and 2 specimens. No corrosion evident on Group 3 or 4 specimens

*Note: None of the specimens exhibited corrosion worse than that encountered in Group 4. There were slight differences in the amount of tarnish between the exposed and the Group 4 Brass 360 specimens, as well as, slight differences in corrosion or residue between the exposed and the Group 4 relay contacts and terminals.

PROPELLED EXTINGUISHING SYSTEMS (TYPE 1)

One of the most critical tasks is to develop a compact, static or mobile, remotely controlled fire suppression system for effective operation in hard-to-reach areas, such as: storage tank farms, pump stations, aircraft hangars, engine compartments of military vehicles, aircraft dry bays, engine rooms in naval ships, mining & heavy duty vehicles, underground mine shafts and cellars, high rise buildings (elevators piers and cable ducts), high density bushes & forest areas, etc.

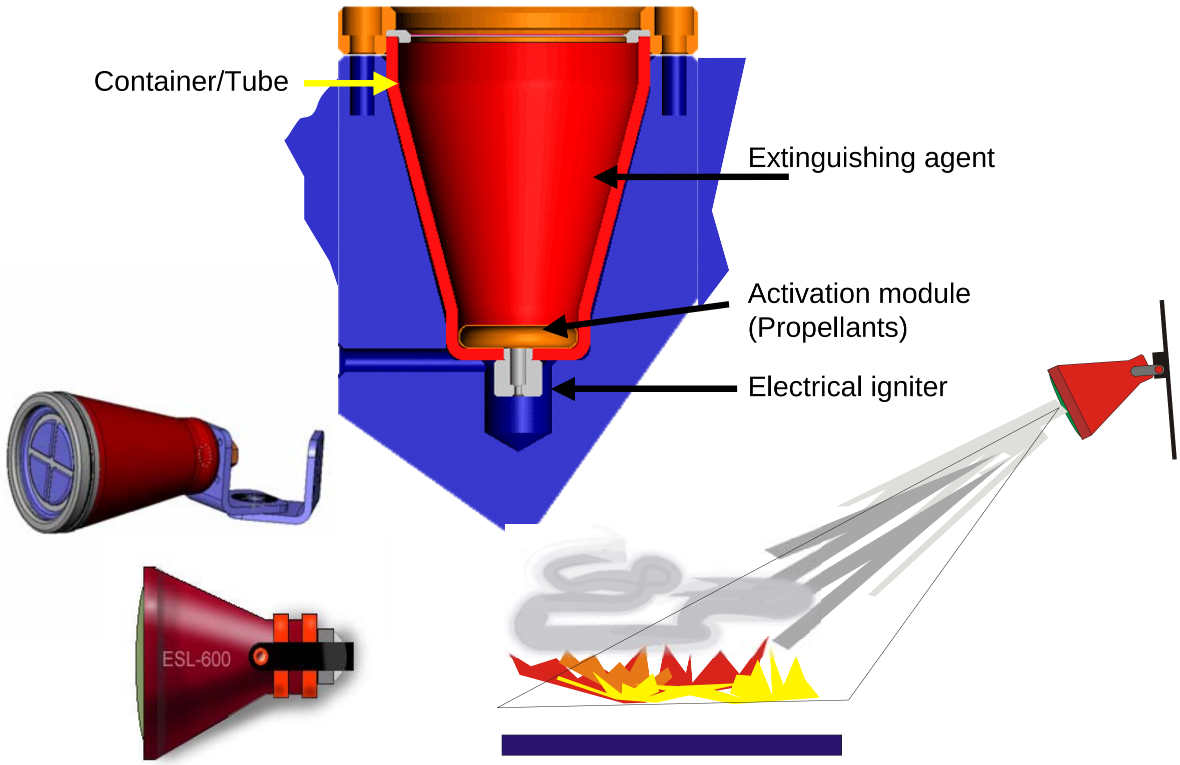
A new approach to discharge and pulverize the extinguishing agent is performed by employing an impulse that creates a strong linear pressure to propel the fire suppression agent to long distances. The propelled energy penetrates into the mass of the fire extinguishing substance within a specifically designed container, pulverizing and dispersing the material into the protected area, thus increasing the original material's volume and surface area to obtain fast and reliable fire suppression.

The proposed technology is based on the "Impulse" provided by the use of a small pyrotechnical charge (employed in barrel guns, smoke & fire works, etc) that forms a directional wave (impulse jet) and spreads 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 new PL (Propelled Launcher) developed by GreenEx eliminates the requirement of pressurized vessels, pumps and hoses, by simply creating the impulse torrent from the activation of a small powder charge (squib) in a standard cartridge and discharging it through a bell-shaped device or a tubular (barrel) of predetermined caliber . 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 simultaneously.

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, "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: 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, separation between oxygen/air and fuel molecules.

PROPELLED EXTINGUISHING AGENT LAUNCHER



A typical propelled extinguishing system contains:

- Container of various shape and/or caliber
- Extinguishing agent
- Propellant
- Electrical ignitor (squib)
- Mount assembly

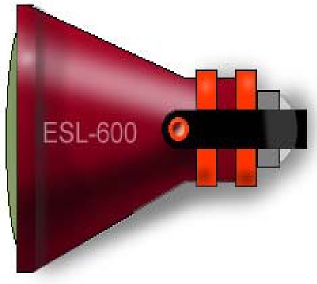
The Propelled Extinguishing Agent Technologies (PEAT) advantages are:

1. Smaller quantity use of conventional and environmentally friendly fire extinguishing agents (water, foam, powder, etc.) than their usual requirement.
2. No need for pressurized cylinders and piping.
3. Flexibility in system design.
4. Increased effectiveness on a weight/volume basis.
5. Discharge range is increased over that of the conventional systems.
6. Rapid discharge and suppression time (less than 0.1 sec to 1 sec).
7. Inertization capability.
8. Large volume - rapid area coverage.
9. Cost effective (low cost of ownership and life cost cycle).
10. Simple installation and minimal maintenance required.
11. High efficiency operation at extreme temperatures (down to – 40 C).
12. Long shelf-life (greater than 10 years).

One type of Propelled Launcher (Propelled Mini Launcher, PML) contains a net weight of 300g dry extinguishing powder (Potassium Bicarbonate, Sodium Bicarbonate, Purple-K, Ammonium Phosphate, Monnex, or any other commercial extinguishing agent). It can extinguish a class A, B, C fire of 1 cubic meter volume, or on a surface area of up to 2 square meters, within 100 msec when the powder is propelled from a distance of up to 3 meters.

Main Features:

Extinguishing agent: Standard Dry Powder **
Agent net weight: 300gr
Total weight: 770 gr
Extinguishing Class A, B, C fires
Coverage volume: 1 m^3
Coverage Area: 2 m^2
Extinguishing time: 0.1-0.2 sec
Dimension (cm): Width (4.9), Length (22)
Activation method: Electrical
Activation current: 2 Amp
Toxicity: None
Environment Friendly: No GWP, No ODP



**Note: The extinguishing agent module can also contain traditional fire suppression agents (water, foam, dry powders) or advanced novel Halon Replacements (FM-200, FE-227ea, FE 36 and other Halocarbon liquids) and Halon Alternatives (powdered aerosol).

PROPELLED EXTINGUISHING SYSTEMS (TYPE 2)

A proposed variation of the Propelled Extinguishing Agent Technologies (PEAT) combines the Powdered Aerosols (SFE) and Propelled Launching (PL) technologies with the solid propellant know-how to provide versatile solutions for special fire protection needs created by modern battlefield threats to engine compartments, tire compartments, external vehicle areas, crew cabs, etc.

Concepts of typical fire extinguishing systems for APC engine compartment and tire zone are shown in Figures 1 and 2.

Figure 1. Engine Compartment

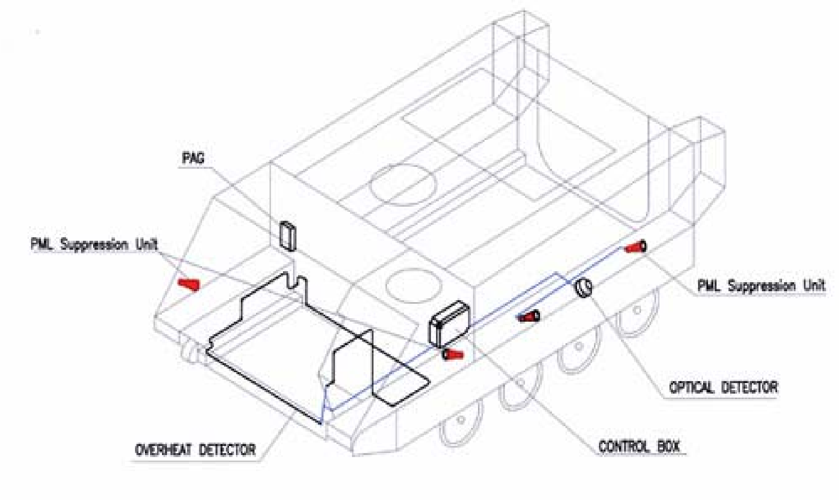
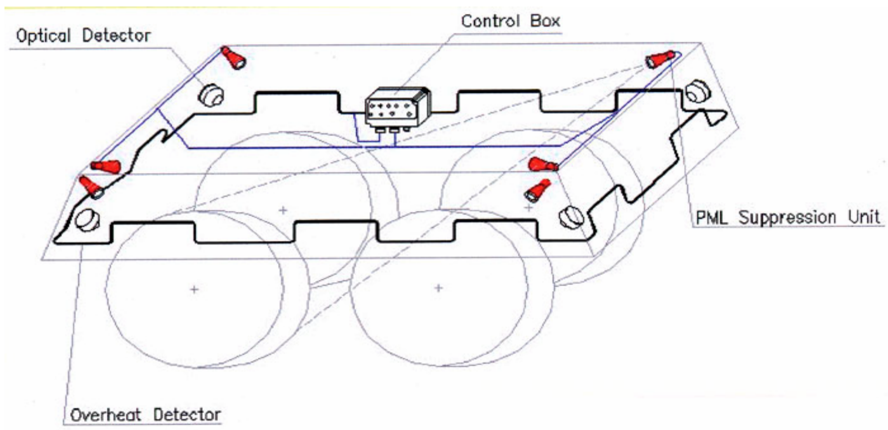


Figure 2. Tire Zone



The combination of aerosol, dry powder agents or other halon alternatives can provide both directional coverage (streaming), as well as, flooding of a highly cluttered fire zone area for complete extinguishment and prevention of re-ignition .

SUMMARY: PYROTECHNICALLY GENERATED FIRE SUPPRESSION SYSTEMS

Two lines of products, **Powdered Aerosol Generators (GreenSol)** and **Propelled Launchers (GreenPulse)** are available from GreenEx**.** The protected volume configuration, fire scenarios and internal compartment structure determine the number of units of each type.

1. **Powdered Aerosol Generator –** The powdered aerosol extinguishing is created “in-situ” from a non-pressurized container, delivering small particles (1-5 microns) floating in inert gases. This agent is considered an approved Halon Alternative for non-occupied spaces and is listed on the EPA-SNAP list as Powdered Aerosol A. Several prototype models, varying in content and size are available.

2. **Propelled Launchers Type 1** - The extinguishing dry powders are propelled from special devices that discharge a mass of 20-500 grams powder in less than 0.1 sec, creating a fine particulate cloud (20-50 micron particle diameter) over a large area. The powder stream is directional in a “cloud” form that propagates very fast in the protected volume, penetrating the fire zone and preventing fire propagation.

3. **Propelled Launchers Type 2** - Another approach for the agent module is that of a hybrid system delivering granulated SFE (powered aerosol) agents and dry powdered suppressant into the fire zone. The granulated SFE is activated by the heat emitted by the fire, producing the 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 providing complete extinguishment and preventing fire re-ignition.