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SPECTREX AUTOMATIC FIRE DETECTION & SUPPRESSION

ARMORED AND TACTICAL VEHICLES SURVIVABILITY

By Jerry A. Brown

Mr. Jerry A. Brown, Consultant to Spectrex Inc. has over 30 years experience in the US Government Research and Development and Acquisition System, in providing both active and passive fire protection solutions for military applications such as combat and tactical vehicles, ships, aircraft and fixed ground installations. He has worked on various US Government development programs such as the M60 Tank Series, Abrams Tank Series, Bradley Fighting Vehicle Series, M88A2 Improved Recovery Vehicle, Halon Alternative Automatic Fire Extinguishing System, USMC AAV Alternate Propulsion System Program, USMC AAV Auxiliary Power Unit, USMC Light Armored Vehicle Hydraulic System Upgrade, US Navy Arresting Gear Program, US Army Ground Base Radar, and US Army High Mobility Engineer Excavator System, and many other programs. Mr. Brown has a Master of Science Management degree from the Florida Institute of Technology, and is a graduate of the US Army War College and several management programs from other Defense organizations. Since retiring from the US Government over 15 years ago, Mr. Brown has represented numerous domestic and foreign companies with marketing, proposal writing, program management, ILS, and contract administration functions.

INTRODUCTION

As a result of the US experience in Iraq, over the past four years, the military forces found out that the army was not ideally structured, prepared, or conditioned for the challenges posed by enemies employing irregular warfare tactics which included: Improvised Explosive Devices (IED), Molotov cocktails and other ways to ignite fuel fires, Incendiary hand-grenade charges and Concealed explosive/incendiary packages.

New generations of significantly improved RPG's and Anti-tank missiles with enhanced penetration capability and extended firing range are operated by infantry or small groups of soldiers from concealed shelters or remotely by radio communications. Sophisticated explosives and sticky incendiary materials coupled with conventional propellant and explosives mixtures, create more hazardous and lethal weapons that not only penetrate the armored vehicle causing havoc and secondary fires in the crew





or engine compartments, but also stick to its surface igniting the vehicle's external equipment and wheel bays and preventing the rescue of the trapped soldiers from the vehicle.

A reexamination of US strategy has yielded a myriad of changes aimed at developing the capabilities required to succeed in small wars or wars fought in the midst of civilian population. The Army is in the midst of its most radical reorganization since World War II. By converting from a division-based structure to one centered on a brigade-sized unit of action that possesses organic combat, combat support, and sustaining capabilities, thus being able to deploy more rapidly and fight upon arrival. Light tactical and fast-deployed vehicles, special trucks and tractors, logistics and engineering vehicles are part of the modern units arsenal engaging the enemy in its territory.

The enemy's use of guerrilla warfare tactics coupled with the heavy traffic of large numbers of tactical wheeled vehicles that provide logistics, security, and command and control in danger areas, led the Army to recognize the importance of force protection and establish multiple programs for upgrading and enhancing the

various vehicles fire protection systems. These systems are designed to provide suitable detection and extinguishing capabilities that addresses the individual threats and extinguishing challenges to save human life, prevent skin burns and, enable soldier to save themselves or be rescued from disabled vehicle, enhance vehicle survivability and continued operation on the battle field.

The multiple threats posed by fires developing on and under the external surface of military vehicles require special fire detection and suppression measures. In many cases fuel tanks sustain direct hits from missiles, RPG's or hidden explosives, spraying fuel all over the vehicle's surface engulfing it in flames. The fuel spill under the vehicle may further ignite and spread to the wheel-bay and tire area causing a major fire and even potentially an explosion. Even if the fuel tank remains intact, the impact of the modern and improvised incendiary weapons and missiles on the vehicle external surface may ignite flammable equipment stored on the vehicle's outer compartments causing a major fire that if not detected and suppressed in time could destroy the entire vehicle.

An in-depth testing and evaluation program conducted by the US army included exposing the vehicles to various expected threats and selecting the optimal detection and suppression means as well as their optimal configuration within the vehicle.

Recently, the US Army has reviewed and refined its requirements for fire detection and suppression systems for the Up-Armored HMMWV (M1114) vehicle according to the present battlefield threats. These vehicles until the Iraq war were not protected by any AFES system, are currently being upgraded with crew and cargo compartment AFES systems to protect them from intentionally caused and rapidly developing fuel fires.

The armored personnel wheeled vehicles family (like the Stryker and LAV) in past editions were originally outfitted with only a basic manual engine fire protection system, however due to their vulnerability because of their new operational missions, they are currently upgraded with modern AFES systems. Both Stryker and the LAV variants are being equipped with automatic fire suppressions systems for both crew and engine compartments.

An accelerated procurement process has been implemented to equip the fleet of several thousands vehicles.

SURVIVABILITY ON THE MODERN BATTLEFIELD

When a kinetic or a chemical energy (HEAT) ammunition round penetrates a vehicle, a fuel oil or other hydrocarbon spray in the vehicle will be ignited by the high intensity of heat and will cause the creation of an inferno inside the crew or engine compartments. It is the uncontrolled growth of explosion and resulting fire that causes the most damage, injury, and death in combat vehicles, often resulting in catastrophic destruction.

Today's weapons used against military vehicles are not limited to tra-

ditional missiles like guided missiles (ATGM), shoulder fired anti-tank rockets, recoilless rifles, mortars and artillery since the recent world conflicts, terrorist activities have created new threats and challenges that need to be addressed.

The guerrilla – type of war has added to their tool bag fire threats of a rapidly approaching fire that hits the vehicle, fuel tank causing a pool fire. Some of the weapons used by the enemy are Improvised Explosive Devices (IED), Molotov cocktails, Incendiary hand-grenade charges and Concealed explosive/incendiary packages.

These threats may ignite a fire or fuel explosion in or on one or more of the vehicle's areas:

- Crew compartment - generated internally from a hit or penetrate through open windows
- Engine or fuel tank direct hit
- Air-intake ports
- External walls (body) of the vehicle
- Under the vehicle – pool fire (fuel; hydraulic, engine, steering and braking lubricants)
- Wheel-bay area (Tire Fires)

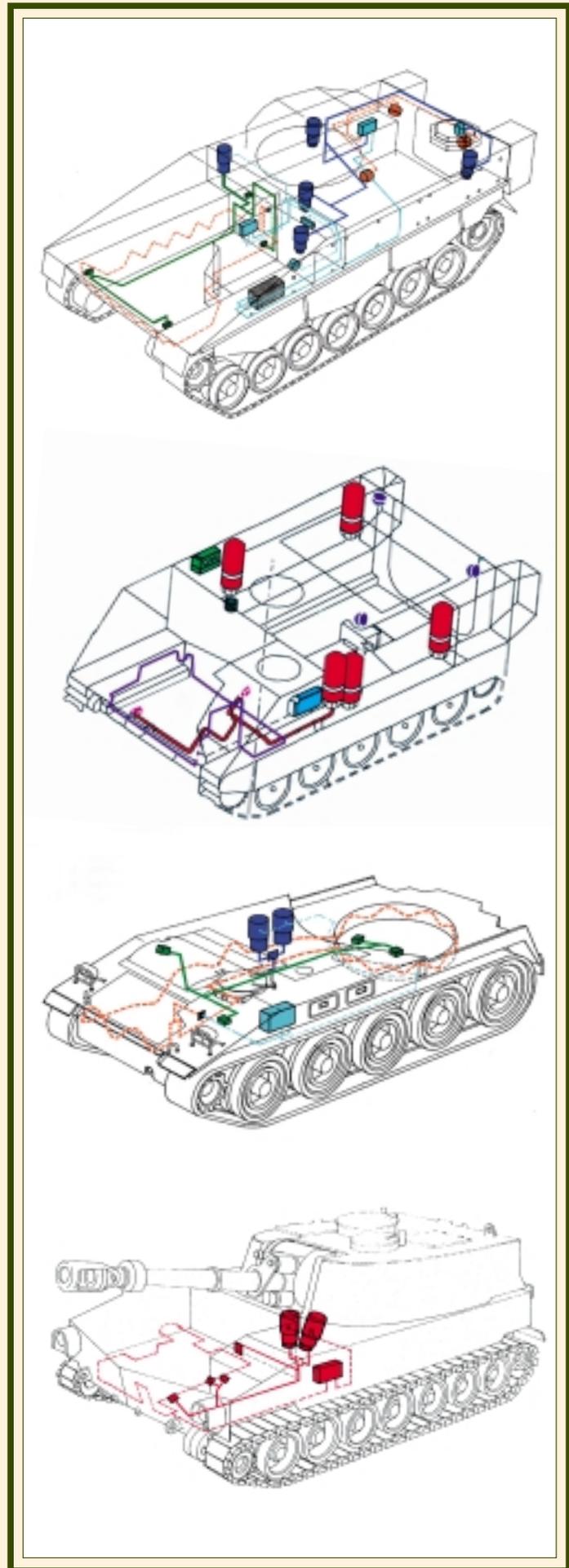
Detecting the approaching fire or penetration by optical means, detecting the pool or flash fire in the engine and crew compartments, tire wheel-bays or on the vehicle surface by optical, heat or hybrid detectors are just some of the fast detection capabilities available. However, detecting the fire before it becomes a major threat to the vehicle and its occupants is just one facet of the solution – suppressing the fire in time to prevent skin burns to the personnel and at the same time save the vehicle and allow its continued operation is the KEY to survivability on the battlefield.

To the research and development engineers, survivability means providing special design and hardware that addresses these performance requirements as well as many other vehicle and operational considerations. For the logistician, it means reducing the loss of equipment. For the user – the soldier on the battlefield, it means life or death.

MILITARY FIRE EXTINGUISHING SYSTEMS

The US Army Tank-Automotive Command worked with the US Army Surgeon General to establish the guidelines shown in Table I as the minimum acceptable requirements of Automatic Fire Extinguishing Systems (AFES) for occupied vehicle compartments. These parameters have been set at levels that do not result in incapacitation of the crewmen from the fire and its extinguishing process, allow them to take corrective action and potentially to continue their mission.

The standards established by the Army Surgeon General clearly state that time is the enemy of a fire extinguishing system. Once a fireball begins to grow inside of the crew compartment, if not extinguished fast (<250 ms),



it takes more extinguishing agent to suppress the fire; there is greater potential for the production of toxic gasses; there is less oxygen; exposed skin can be injured, and higher overpressures. In simple terms, the faster the AFES extinguishes the fire, the higher the probability that the crew will not be injured.

A typical fire and explosion detection and suppression system is comprised of modular components designed to fit into any type of armored vehicle. The AFES incorporates explosion/ fire detection and fast suppression technologies. Special systems are designed for the crew compartments (where several soldiers occupy the area) and different systems for the engine compartment (which is usually much smaller in volume).

Crew compartment systems are based on High Speed Optical UV/IR or IR/IR Flame Detectors, free of false alarms that respond to fire in under 5 milliseconds, communicating with a reliable control system with normal and combat modes and activating extinguishing cylinders with high speed valves opening within 5 milliseconds and rapidly-dispersing the extinguishing agent and allowing for a second shot capability.

Engine compartment systems are based on optical or linear heat detection and fast suppression technologies. The fast and reliable system is designed to fit the unique engine compartment configuration for both air and water-cooled engines.

Another major consideration of combat vehicle AFES and key element in the system design is the false alarm rate. Automatic fire extinguishing system should have minimal or no false alarms. If a soldier loses confidence in an AFES because its detectors are providing false alarms resulting in activation and release of agent, the soldier will soon find a way to circumvent the system.

If the AFES is unreliable, breaks down often, is difficult to diagnose

Armored vehicles protected by AFES systems		
US Army	ABRAMS BRADLEY FAASV LAV STRYKER HMMWV	MBT AFV Artillery Ammo. Support Vehicle APC APC Tactical
Canada	Leopard 1	MBT
France	Leclerc VBCI EBG	MBT APC Engineering Tank
Poland	T72	MBT
Austria	M60A3 Kurtasier M109 Pandur	MBT Tank SP-Artillery APC
Taiwan	M60/M48	MBT
South Africa	G6	SP-Artillery
Italy	Centauro Ariete	APC MBT
Germany	Leopard2 Marder	MBT AFV
Slovenia	T55	MBT
Spain	AMX30 Pizarro BMR M113 M109	MBT AFV APC APC SP-Artillery
China	T59, T69 Type80, Type90	MBT MBT
India	T72	MBT

and repair, the logistics burden becomes an enemy of the AFES. Yet another challenge is finding an extinguishing agent that will efficiently fill all space, effectively extinguish fires, be friendly to both humans and the environment.

CONVENTIONAL AFES SYSTEMS

The Detection Subsystem in laymen terms either sees or feels the fire event. If it is in an occupied compartment such as the crew compartment, an electro-optical sensor is the quickest means to identify a fire. It acts like an eye. Since the eye can see light at the speed of light, it is almost instantaneous. A special UV/IR, dual IR or triple IR combination provides greater sensitivity and higher speed of response while pro-

viding a high immunity to false alarms.

Engine Compartment System provides complete detection coverage by means of overheat wire detector and a uniquely designed nozzles for extremely effective fire extinguishing.

The sensors in the engine compartment act like our skin in that a wire sensor (thermistors) senses the changes in temperature and at pre-designated temperature points gives an alarm or activates the extinguisher.

The wire detectors are not as fast, but are preferred because they are very reliable in dirty and hard to get to areas such as under the engine, under batteries, under the auxiliary power unit, under turret floor areas,



etc. Only the optical detector can meet the speed requirement for occupied spaces. The optical detector can certainly identify slow grow accidental fires effectively, but if in areas that make it difficult to clean the windows of the optical detector, it is not practical.

The Controls Subsystem acts like the brains. It receives input from sensors, verifies it is a real fire and then sends a signal to the extinguishers to release agent. Just like our brains, it constantly monitors the health of the whole system. In other words, it has a built-in-test (BIT) that monitors the whole system to determine if all components are operational. For example, if a detector is inoperable, the control will identify that there is a problem with the detection and automatically look for information from the other detectors as back up; or if a cylinder malfunctioned and did not release agent, the control, in less than four milliseconds, will tell another cylinder to release the agent. The controls provide redundancy and back-up to components that malfunction or are damaged. The control subsystem can be easily adjusted to provide additional functions the customer desires, such as audible alarms, continuing to monitor for fire after the master, switch is turned

off, or shutting down exhaust fans or engines if a fire is detected.

The Fire Extinguishing Subsystem consists of an agent, shatterproof pressurized cylinder or by a gas generator, high speed valve, wiring harnesses, nozzles, and piping. For decades, Halon 1301 was the agent of choice for military ap-

plications, but with the approval of the Montreal Protocol, Halons were banned from production and the military community worldwide conducted a wide search to find the "silver bullet" that would be a "drop-in" replacement of Halon 1301. Although after an exhaustive search, they did not find the "silver bullet", they did find several acceptable replacements.

A published report written by Mr. Steve McCormick, Fire Research Team Leader, US Army TARDEC and Mr. David Koehler, Manager, Army ODC Elimination Program, state the following concerning their search for a Halon Replacement:

"Performance equivalent to Halon 1301 can be achieved with available agents and delivery system technologies. Crew survivability criteria have been satisfied against ballistic fires with HFC-227ea concentrations well below accepted exposure limits. Adding small amounts of sodium bicarbonate powder to the HFC reduces acid gas formation by half. Water mist with potassium acetate salt also proved to be very

System Considerations

Crew System Considerations:

Vehicle operational requirements

- Access to ammo storage and other stored items
- No interference with weapon systems and other vehicle systems
- No interference when entering/exiting vehicle
- Withstand vehicle operating environment – vibration, shock
- Vehicle maintenance routine

Agent discharge and dispersion

- Discharge will not cause threat to crew – design appropriate valve outlet
- Secure homogenous and effective dispersion throughout the protected volume

Crew safety

- Appropriate anti-recoil device
- Divert discharge from direct impact on crew

Engine System Considerations:

- Protect dispersion nozzles from dirt
- Locate extinguisher beyond engine compartment bulkhead
- Consider airflow, sources of fire hazards
- Consider airflow and need for engine shut down before agent discharge

effective with no concern of hazardous byproducts and simple cleanup. Hybrid gas generators offer a smaller overall envelope for the same agent weight, pressure on demand, and a more consistent agent discharge. Wet mains allow the agent to be pre-positioned for very rapid agent dispersion and offer the flexibility of nozzle locations.

Other agents can be used in the engine compartment such as sodium bicarbonate based dry powder used in the Abrams M-1 Series Tank. HFC-227ea will be used in vehicles that shut the engine off prior to agent discharge (including the M2/M3 Bradley Fighting Vehicle) because of its ease of retrofit.

The AFES for combat vehicles certainly works well. However, there is always room for improvement. The US Air Force Research Laboratory in cooperation with the US Army has developed an Ultra High Speed Water Deluge System that is able to extinguish fires in less than 30 ms. Water is the agent and this system protects individuals working next to explosive materials as they are being manufactured.

Future combat systems will definitely have need of an AFES; however, weight and space are critical design parameters. Therefore, FCS will be used to drive AFES to smaller and lighter packages. The challenges for the AFES are changing as technology looks at using hybrid electric propulsion, Electro-Magnetic or Electro-Thermal guns, capacitors, and fuel cells. These power and propulsion systems offer new types of threats that the AFES of the future will need to address. Mr. Steve McCormick stated, "These fire threats may require completely new survivability strategies with respect to detection, suppression/ mitigation, and/or post event safety."

The next generation system will be governed by an integrated micro-processor based Control Electronics Unit (CEU).

The CEU will acquire analog and



digital signals from the system detectors, manual activation devices and external status switches; process the inputs; activate the fire extinguishers according to the system logic including selection of properly charged and connected cylinders and enabling backup extinguisher activation; control indication and annunciation devices (audiovisual); and enable performance of system maintenance and trouble shooting according to diagnostic information continuously gathered from the system components.

The CEU will provide all system component status, faults, alarms and extinguishing signals to the vehicle electronics by means of RS 485 or Ethernet serial data communication. The CEU will have dedicated independent software that governs all operational, maintenance and diagnostics tasks. The CEU will have a built-in maintenance program that issues recommended corrective actions.

The CEU can be either an independent stand-alone box or be integrated into a vehicle common interface electronic box that will govern sev-

eral vehicle subsystems.

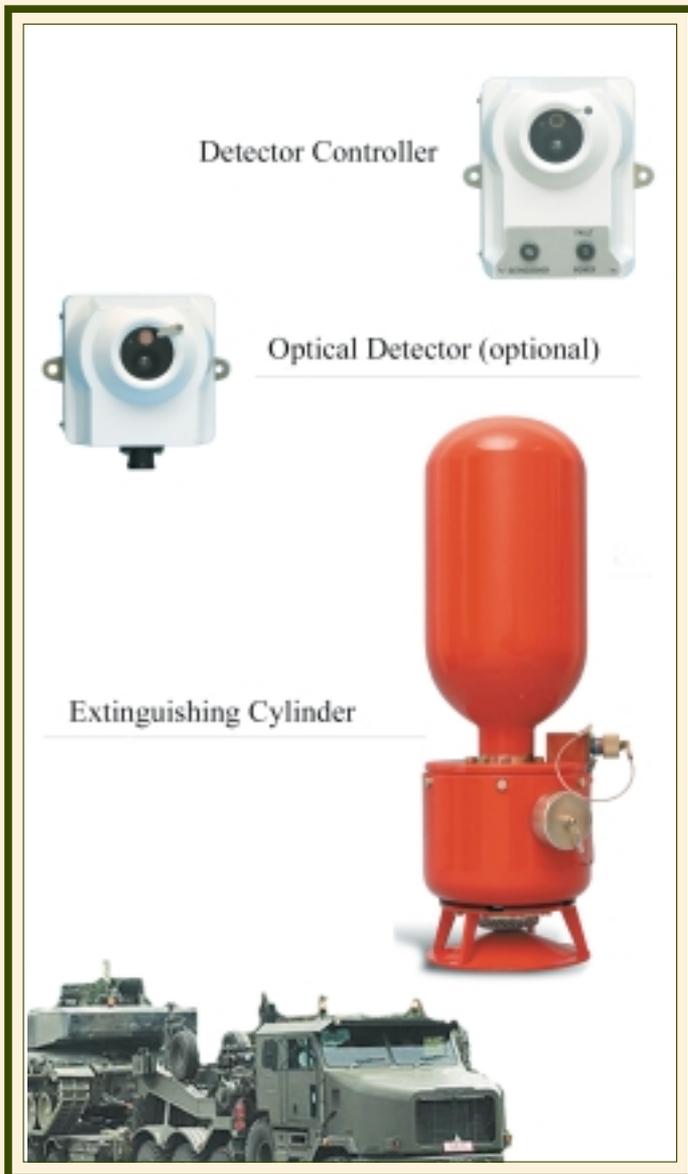
In either case, the system will provide all information to a control and display panel or to designated crew member panel/s. Such panel/s will include operation capability switches and enable the operator to perform troubleshooting, receive diagnostics and prognostics information.

KEY FEATURES OF MODERN AFES SYSTEMS

Various technologies are currently evaluated for external vehicle fire protection, whether it's for protecting the vehicle's surface or its "soft belly" before they are engulfed in flames that may cause irreparable damage. Improvements to conventional crew and engine compartments have been introduced to meet the new critical design parameters for the Future Combat Vehicle (FCS) and other new armored and tactical vehicles.

Key features of these modern AFES systems include:

- 1.** Valve and dispersion special design that provide for:
 - a. Rapid efficient and homogeneous dispersion of the extin-



guishing agent throughout the protected volume (ensuring suppression in less than 250 milliseconds)

- b.* Dispersion mechanism (deflector) that ensures rapid drop in pressure at a short distance from the valve outlet and substantially increased safety to personnel during cylinder discharge, compared to the previously used high pressure pointed discharge nozzle
2. Sensitivity of the optical detectors that ensures optimal detection coverage of the protected volume including detection of penetration in less than 3 milliseconds as well as detection of small and slow growth fires (size of 8 in. pan fire located anywhere in the crew compartment), all combined with increased detector immunity to false alarm
3. Preferably a double shot system providing a second shot suppression to address the high likelihood of a vehicle being hit twice once acquired as a target by the enemy in the battle field
4. Embedded diagnostics that detect and isolate all

essential system critical performance functions of each one of the optical flame detectors, extinguisher valves and the system control unit

5. Embedded prognostics that enhances the availability of the system and its components and reduces support costs by predicting critical performance failures in advance of their occurrence
6. Microprocessor based control units providing for:
 - a.* Visual alarm, fault, status indications and operational switches on panel or detailed indication by LCD display (as an option)
 - b.* RS-485/422 serial communication port connects to external control system for test, maintenance, diagnostics and troubleshooting
 - c.* TCP/IP Ethernet port interfaces with LAN for integration into vehicle communication infrastructure (option)
 - d.* Built-in event recorder (option)

Novel environment friendly fire extinguishing agents and new methods of dispersion are considered for the modern AFES. Fire suppression solutions may include:

- Small particles or dry powder “shot” directly at the incoming fire threat to counter/diminish the fire ball that may hit the vehicle’s surface
- Dry powder in direct stream or through piping and nozzles discharge. The powder dispersion in cloud form or surface area coverage to protect the vehicle surface
- Surface-acting wetting agents (chemical agents) such as foam or fuel and rubber decomposing material by itself or in combination with dry powder for the wheels compartment
- Total flooding and streaming agents discharged from hybrid systems

The mechanisms by which these fire suppression agents extinguish the fire are complicated and usually more than one mechanism applies for fast and successful fire suppression. Some of the most effective fire extinguishing mechanisms identified so far include:

- Dry powders (various particles sizes) that act chemically and physically on the fire propagating species in the gaseous phase, disrupting the flame front and causing fire suppression
- Wetting agents/foams that act chemically on the burning surface to prevent further burning
- Water-based agents with additives (loaded streaming agents) that act chemically and physically to suppress the fire and cool-down the fuel surface

As technology changes, leading companies with their aggressive research and development programs are up to the challenge that will provide innovative fire protection strategies and products for the modern battlefield.

