Information Paper on

Next Generation Water Enhancer for Fire Protection and Suppression in Wildland and Structural Applications

In cooperation with

TetraKO, LLC

manufacturer of

TetraKO™

Water Enhancer

All testing was performed at the TEEX Product Development Center.

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Table of Contents

Overview

The history of the fire service is a fascinating study in the advancement and application of science. Fire suppression effectiveness has improved through technology, computerization, communication, organization, administration, equipment, protective gear, breathing apparatus, engineered detection and suppression systems, training and education and breadth of specialization and skills. While these advances over the past 100 plus years have dramatically and positively impacted the fire service in how and how well service is delivered, one key component has not changed – the dependence on water as the predominant suppression agent for firefighting.

In addition to improved engineered solutions for water delivery (including fixed systems), various chemicals, inert gas-based agents, additives that improve the effectiveness of water, and even technology such as sound waves have been evaluated and introduced, all with varying levels of success. These agents each have their specialized role, but consequent concerns about the hazards and toxicity associated with these agents have increasingly limited the scope and uses of these applications in both structural and wildland firefighting operations. Specifically, while they may have served to increase the options available for protection and suppression and/or the effectiveness of water, it has often been at the cost of resultant hazards including toxicity to plants, fish and amphibians, and mammals (including humans); harmful environmental impact (such as ozone depletion); and corrosion to key equipment, machinery, and exposures. Quite often decisions for deployment of these agents have boiled down to a "lesser of two evils" between the damage caused by fire and that caused by the agents, including the costs and logistics associated with capturing and treating/disposing of runoff. And with an ever-increasing focus on environmental issues– including fire service operations – these alternative and supplemental agents will face even greater scrutiny and justification.

Recently, a major step was made on both fronts with the introduction of a technology that substantially improves operational effectiveness, *while* being environmentally friendly. The product – a water enhancer – is a self-wetting powder that actually transforms the physical nature of water resulting in exponentially improved suppression while remaining non-toxic, non-corrosive, and biodegradable. Thus, "the lesser of two evils" becomes "a win-win." This important new technology is known as TetraKO™ and has been developed by the EarthClean Corporation (EarthClean).

On October 13 – 14, 2011 members of the International Association of Fire Chiefs (IAFC) Technology Committee and Wildland Policy Council attended two-days of TetraKO™ testing at the Texas Engineering Extension Service (TEEX) Brayton Fire Training Field. Day one consisted of aerial drops for the TetraKO™ technology, simulating aerial operations in a wildland fire. Day two consisted of pod burns simulating a typical single room and content structure fire. In all the simulations, the TetraKO™ technology significantly performed more effectively as a suppression agent than water alone and water mixed with Class A foam concentrate. This white paper will analyze the potential for this new technology as a water enhancer for fire protection and suppression in wildland and structural applications.

Scope of the Problem

As an extinguishing agent, water is effective in that it:

- has a high thermal inertia and high latent heat of vaporization, which means it can absorb more heat per mass than virtually any other substance,
- is generally readily available wherever humans exist, and
- it can be moved by pumping.[1]

However, due to its high surface tension, water tends to not penetrate many materials such as upholstery, thus limiting the ability to extinguish fire, with an actual efficiency of only five to ten percent of water used in extinguishment. In addition, water cannot provide a protective coating on surfaces or effectively suppress vapor production.[2] The introduction of various "wetting" agents to increase the effectiveness of water culminated in the development and widespread introduction of Class A foams in the 1980s and 1990s. As a "synthetic detergent hydrocarbon surfactant (surface active agent)," Class A foams serve to reduce the surface tension of water by two-thirds, and substantially improve heat absorption and water penetration of organic materials (e.g. vegetation).[3] When delivered through a compressed air foam system (CAFS), the rate of steam conversion, and thus absorption, of heat is further substantially increased.[4] As such, in both structural and wildland fires, these systems have been proven to reduce the amount of water used, reduce number of rekindles, and improve firefighter safety. However, these benefits come at a price to the budget, environment, equipment, and exposure.

Cost

Budgets continue to face scrutiny and reductions. The cost of the foam alone can be substantial. While it is true that there are tradeoffs in operational effectiveness and efficiencies that offset these direct costs, they are often difficult to measure, and in the charged political nature of today's budgeting process, it can often be hard to justify the purchase. A five gallon container of Class A foam averages over $70. When you factor in the cost of a CAFS to a piece of apparatus, the cost can well exceed $20,000 for a basic, no-frills unit. Finally, CAFS increase maintenance costs even when properly flushed and maintained. A lack of oversight, regular maintenance, and proper use can dramatically increase these costs.[5]

Toxicity to Fish

For many years, most fire-retardant chemicals used in wildland firefighting – including both Class A foams and long-term fire retardant chemicals – were assumed to have relative minimal toxicity to fish and other aquatic life; however, there are numerous documented cases of fish kills involving trout, fathead minnows, and chinook salmon in circumstances where these chemicals have been accidently released into surface waters both directly and indirectly through runoff. Today, the wildland fire community realizes that there is a moderate to high chance of toxicity to fish and aquatic life. Even when properly applied (thus avoiding unintentional spills and

overspray), these chemicals can reach aquatic environment through stormwater runoff, oftentimes made worse by the loss of vegetation in the watershed as a result of the wildfire itself. Lab studies show that the toxicity is worsened significantly when exposed to UV radiation such as sunlight. As the level of toxicity remains above threshold limits for at least 45 days, there remains the potential for substantial fish kills long after operational use, even with the best-use practice of application.[6]

Toxicity to Mammals and Birds

Studies indicate that while the lethality to mammals and birds from exposure to these chemicals does not correlate to similar exposures to fish and aquatic life, there is an impact at a lesser sub-lethal level, nonetheless. For birds, the results included "lethargy and loss of equilibrium," primarily from dietary, rather than direct, exposure. As to mammals, across various ecosystems there were no "measurable effects" on populations or growth; however, species diversity did "depress."[7] These impacts, while less lethal, are yet statistically significant enough to warrant risk-benefit analysis for the use of such fire retardant and suppression chemical agents.

Toxicity to plants

As with mammals and birds, the impact to plants in both lab and ecosystem evaluation studies indicate a lesser lethality impact than to fish; the impact was significant, nonetheless. While aquatic plant life was not impacted to a discernible degree, the same was not true for vegetative (land) species. In one study, the number of plant species "declined significantly" after the application of these agents, but recovered in relatively short order (eleven weeks). In another, there was an actual increase in the biomass of non-native species at the expense of the mass and diversity of native grasses.[8] Again, this demonstrates the need for a careful analysis and evaluation of risk-benefit in the use of such agents in wildland firefighting operations.

Corrosive Nature

Due to their chemical make-up, these agents can be corrosive. Studies show that carbon-based steel – similar to that used in apparatus and most firefighting equipment – is susceptible to "pitting and crevice corrosion" when exposed to these chemicals.[9] Aluminum tanks used in air tankers are also susceptible to similar corrosion upon exposure. The sad irony is that the chemicals typically added to reduce the corrosive nature of the agents serve in some conditions to significantly increase the toxicity of the agents, with results like those summarized earlier.[10]

Together, these inherent downsides to these firefighting agents mean that, at a minimum, caution should and must be used when applying them in both wildland and structural firefighting operations. The environmental risk, and risk to equipment and exposures must be incorporated into the risk-analysis portion of operational planning to avoid long-term negative consequences at the expense of short-term benefits. Quite simply, in certain conditions, it may boil down to a somewhat "lesser of two evils" analysis.

Technology Solution

In early 2003, EarthClean Corporation acquired the rights to some promising intellectual property for a new fire suppression agent. With this foundational knowledge and experience, EarthClean continued research and development, resulting in the commercialization of a new water enhancing technology – TetraKO™ – that not only incorporates but improves on the benefits inherent in additive suppression agents and fire retardants, and does so while being environmentally friendly and non-corrosive.

TetraKO™ is a patented powder-based technology designed to be batch mixed with water or injected through a proprietary eductor system with the pump in circulation. It does not require any specialized equipment or nozzles for use, and can be pumped through standard fire equipment. Using "sheer thinning technology," the product is converted into a free-flowing liquid when pumped under pressure (as with firefighting operations), and reverts back into a gel once it leaves the nozzle and impacts a surface. As a gel, it has "stick and stay" characteristics that allow for excellent extended protection and suppression characteristics. It has proven to be effective in both wildland and structural applications, and via application from units ranging from small portable pumps all the way up to aerial tankers. Cleanup leaves no residue and is simple, requiring only rinsing and system flushing with water.

As our society continues to look to and demand environmentally friendly solutions, the fire service will certainly need to consider solutions that protect the environment as well. This was reinforced when, in 2010, a federal judge in Montana ruled that the U.S. Forest Service "violated the Endangered Species Act by failing to put any real limits on firefighters from calling in retardant drops."[11] This new technology addresses these concerns. Through testing by independent labs, using EPA and internationally recognized Organization for Economic Co-operation and Development (OECD) standards, TetraKO™ is certified non-toxic to water, fish, plants and mammals and "ready biodegradable," and is the first water additive agent that uses no super absorbent polymers (with their associated non-biodegradable environmental impact).

Established through the efforts of an experienced firefighter, a retired 3M engineer, and chemical engineers from H.B. Fuller, EarthClean Corporation is a Minnesota-based start-up company whose stated mission is "to develop and introduce environmentally friendly and innovative technologies to help firefighters perform at a higher level." As a result of its efforts, EarthClean was the Grand Prize recipient of the 2010 Minnesota Cup competition as "Minnesota's Top Breakthrough Business Idea" and, more recently, the top prize winner in the Cleantech Open (known as "the Academy Awards of green-technology business") North Central region competition, finishing third nationally.

Benefits

The benefits of TetraKO™ over water alone and other water-based suppressant and retardant additives currently available to the fire service, include:

- increased fire protection and suppression qualities,
- non-toxic and non-corrosive,
- improved firefighter safety and effectiveness,

- less product to water ratio resulting in greater cost efficiency,
- lower potential for product and water damage during structure protection,
- safer product for firefighter and public who may be exposed during operations, and
- performs better under pressures associated with fire streams.

Formal independent testing, case history, and firsthand firefighter testimonies all support the improved fire protection and suppression qualities of TetraKO™ . Early testing involving initial assessment of air tanker operations using TetraKO™ , demonstrated highly successful applications in various stages and operational simulations. Three separate trials representing three levels of coverage drops utilizing TetraKO™ were performed utilizing a Fire Boss aircraft tanker (approximately 675 gallon effective load). Even in difficult conditions with a 90-degree crosswind, the distribution and coverage results were positive across the grass and small shrub target zone. The positive results formed a foundation for more formal testing.

As follow-up to the aircraft tanker drop testing, EFI Global – a recognized full-service engineering and fire investigation service – tested TetraKO™ for its operational effectiveness and efficiency in structural firefighting, specifically knockdown and suppression performance, and its ability to preserve the forensic evidence of a fire scene. The product was evaluated in comparison with water and Class A foam. EarthClean advocated that unique proprietary properties of TetraKO™ means that it "sticks and stays" where it is applied and, when heated by fire, it becomes even thicker and releases dense steam. As such, fire suppression is greatly enhanced verses water alone or water laced with foam (verified from our Tech Fire Incident Sheet). Tests involved using various sizes and types of structures, all with positive results. For example, in one test using a 10x10 meter wood-frame and sheetrock pod designed and constructed to represent a typical "room and contents" fire, 1,700 liters (approx. 449 gallons) of water and 1059 liters (approx. 280 gallons) of Class A foam were required to extinguish the pod, while only 151 liters (approx. 40 gallons) of TetraKO™ solution was needed, with extinguishment in just under eight seconds. This test demonstrated that TetraKO™ yielded a nearly 91% efficiency increase over water alone, and an 86% increase over foam. In addition, samples in the area of origin of another test that used an accelerant and was extinguished using TetraKO™ , showed a subsequent positive reading for gasoline, supporting the TetraKO™ attribute that it does not negatively impact forensic samples.

Case histories serve to substantiate these more formal tests. Following are some of those case histories:

- *TetraKO™ was used by the Spring Lake Park–Blaine–Mounds View (MN) Fire Department to extinguish a fire that had vented through the roof at a local community church. The church building and much of its contents were saved, with minimal water damage, and the fire was controlled in 15 minutes.*
- *TetraKO™ was used by the Oakdale (WI) Area Fire Department to help contain a 10-plus acre wildfire. Approximately 175 gallons of solution was able to control one-third of the perimeter of the fire,*

accomplishing what typically would be required of a much larger vehicle and water load, all without any evidence of rekindle.

- *TetraKO™ was used by the Wayzata (MN) Fire Department to suppress a residential fire with major involvement and extension throughout 50% of the structure. The initial crew was able to knock down and suppress the exterior flames, protect the garage exterior, and quickly extinguish the fire while a second crew extinguished the fire that had extended to the attic, all with very minimal collateral water damage. A total of approximately 40 gallons of solution was used for the initial knockdown and control.*
- *TetraKO™ was used by the Spring Lake Park-Blaine-Mounds View (MN) Fire Department to extinguish a fully involved residential garage fire with exposures including a car and two snowmobiles. The initial crews used two 1 ¾-inch pre-connected lines and approximately 500 gallons of solution to completely extinguish the fire and limit collateral damage to the home and exposures.*
- *TetraKO™ was used by the Santo (TX) Fire Department and several other mutual aid companies in the 2011 Possum Kingdom complex fires involving over 148,000 acres and over 600 threatened homes. Consensus feedback indicated that firefighters found TetraKO™ substantially more effective than Class A foam for structural protection, mop-up and pretreatment.*

Though not measurable or statistically significant, collectively, these case histories provide a more qualitative view that, in total, show a consistent and comparable meaure of effectiveness of TetraKO™ in supporting protection and suppression activities in both wildland and structural operations.

Non-Toxic and Non-Corrosive

Extensive independent accredited laboratory testing has proven TetraKO™ to be compliant with all applicable EPA, OECD, NFPA, ASTM guidelines and standards for:

- biodegradability,
- mammalian toxicity,
- aquatic toxicity, and
- uniform (metals) corrosion

What this means from an operational standpoint is that incident commanders can make the best tactical application of TetraKO™ solution in protection and suppression actions, in both wildland and structural applications, without concern for subsequent negative impacts to the environment, personnel, and equipment – for both the short and long term. This allows a total focus on those approaches that best assure firefighter safety and effectiveness.

Similarly, budgets are positively impacted; the upfront purchase price of TetraKO™ typically runs 1/2 to 2/3 that of Class A foam, and subsequent exposure-related costs are eliminated, including costs associated with:

- activities and materials needed to provide for exposure and equipment protection,
- any follow-up environmental or other impact testing, and
- any necessary clean-up planning and activity, including environmental, apparatus, equipment, and personnel.

Firefighter Safety and Effectiveness

The proven effectiveness of TetraKO™ over water alone and other suppressant and retardant additives also positively impacts firefighter safety and effectiveness as:

- the direct exposure to fire and related phenomenon (e.g. flashover) is reduced as the time to suppression is significantly reduced,
- the "stick and stay" protective properties of the solution means fewer fire events, thus fewer responses and exposures to firefighters,
- TetraKO™ does not exhibit the "slick" nature of other gel-based systems, meaning a reduced risk of slips / falls,
- the incidence of rekindles are virtually eliminated, thus reducing or removing related follow-on exposures and risks,
- fires – both wildland and structural – are more effectively contained with reduced quantity of applied product,
- water damage to structures and exposures is minimized as less product, and thus less water, is needed to effectively extinguish fire, and
- TetraKO™ reduces the temperature of the upper thermal layer in a typical single room and content fire by 37% in 3 seconds after application of the fire stream, compared to a temperature reduction of only 21.6% with water alone, thereby more effectively reducing the potential for extreme fire behavior.

Limitations

The only limitation to integrating TetraKO™ into protection and suppression operations is the direct cost of the product, when compared to using no additives in firefighting water supply. The direct costs of using TetraKO™ (as noted earlier), while comparable pound per pound to those of other water additives, however, are actually 1/2 to 1/3 that of foam when comparing amounts necessary for effective application (i.e. efficiency). When factoring in CAFS equipment and maintenance costs, comparison costs of TetraKO™ are substantially lower. Because TetraKO™ needs no specialized technology or equipment to be introduced and applied, and no specialized cleanup is required, it is the more cost-effective solution in the long run.

To become integrated operationally, minimal training is needed (primarily focused on that of mix rate) as applications are the same as that for other gels and foams used in protection and suppression operations. Similarly, cleanup necessary to put equipment back into service is relatively simple and routine, involving only rinsing and flushing, so no additional specialized techniques, training, or equipment is needed.

Conclusion

The negative impact to the environment, equipment, and exposures from the application of current water additives for protection and suppression, has been scientifically verified; as a result, their use is receiving ever-increasing scrutiny. A trend towards limiting their use through public pressure – including litigation, regulation, and legislation – has been increasing more successful. At a minimum, Incident Commanders are faced with considering a risk-assessed evaluation of the tradeoff of their benefits (i.e. more effective and efficient operations, and higher levels of safety for firefighters and the public) verses this scrutiny and accountability. Consequently, increasingly (and becoming more the norm) the benefits of increased firefighter safety that are inherent by virtue of their application are being denied.

What is needed is an additive that, at a minimum, provides the same level of protection and suppression benefits as currently available additives in an environmentally safe and responsible way. TetraKO™ meets these needs; it does so by being even more operationally effective and more cost-effective, while being totally biodegradable and non-corrosive. In summary, benefits for using TetraKO™ include:

- Greater safety to firefighters as a result of faster knockdown and suppression
- Faster knockdown
- Effective suppression
- Reduces rekindling
- Reduces water consumption and damage since less extinguishing agent is required
- Earth friendly
- Easy to use
- Easy cleanup
- Effective in wildland fires

TetraKO™ has the potential of not only increasing the effectiveness of both wildland and structural firefighting, but doing so in a more environmentally friendly manner – a true "win-win" for the fire service. And in this era of decreasing resources and increasing scrutiny, it makes good business sense as well. TetraKO™ makes firefighters – whether metro or rural, paid or volunteer, wildland or structural, and perhaps especially firefighters facing a wildland-urban interface firefight – more effective, while better providing for their safety.

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Test Results Summary

Upper Thermal Layer Comparison

	Gallons Used	% Increase Over TetraKO	High Temp Upper Layer	Time to Initial Knockdown	Upper layer Temp at 3 Seconds	% Drop at 3 Seconds	Temp at 15 Seconds Post Knockdown	% Drop At 15 Seconds	Temp at 30 Seconds Post Knockdown	% Drop At 30 Seconds	Upper Layer Temp At 2-Minutes	Time to Reach 600 F
TetraKO	3.75	0	1035 C/1894 F	2.5 Sec	642 C/ 1188F	37%	495 C/923 F	51.30%	412 C/773 F	59.20%	178 C/352 F	0:57
Water	7.65	104%	1044 C/1911 F	5.1 Sec	819 C/ 1506 F	21.60%	617 C/1142F	40.20%	502C /936F	51.00%	204 C/400 F	1:10
Class-A Foam	4.65	19.40%	1041 C/1905 F	3.1	1029 C/ 1884 F	1.00%	720 C/1328 F	30.20%	542 C/ 1007 F	47.10%	207 C/ 405F	1:12

Mid Thermal Layer Comparison

	Gallons Used	Gallons Used	High Temp Mid- Layer	Time to Initial Knockdown	Mid-layer Temp at 3 Seconds	Temp Reduction In First 3 Seconds	Temp at 15 Seconds Post Knockdown	% Drop At 15 Seconds	Temp at 30 Seconds Post Knockdown	% Drop At 30 Seconds	Upper Layer Temp At 2-Minutes	Time to Reach 600 F
TetraKO	3.75	0	881 C/1618 F	2.9 Sec	573 C/ 1063 F	34%	391 C/735 F	54.60%	271 C/519 F	68.00%	75 C/ 167F	0:23
Water	7.65	104%	837 C/1537 F	5.1 Sec	610 C/ 1130 F	26%	399 C/750F	51.20%	328C /622F	59.00%	96 C / 205 F	0:33
Class-A Foam	4.65	19.40%	961 C/1762 F	3.1	912 C/ 1674F	4%	552 C/1025 F	41.80%	408 C/ 766 F	56.50%	107 C/ 225 F	0:45

Notes:
For each knockdown the same size hose and same nozzle was used
For each knockdown the water pressure was 150 PSI
For each knockdown the nozzle was set at 90 GPM
For each knockdown the nozzle was set for a 30 degree Fog
Gallons used was calculated at 1.5 Gallons per second based on 90 GPM

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