RELATIONSHIPS OF WATER, WET WATER, AND FOAM TO WILDLAND-URBAN INTERFACE FIRE SUPPRESSION

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ABSTRACT: Consequences of recent fires demand more effective means of fighting wildland-urban interface fires. Fire suppression properties of water, wet water, and foam are examined as they influence application guidelines. Modern water attack requires high flow rates. Wildland foams combine the best attributes of water, wet water, and other foams. Indirect water attack on structures may have practical applications for wildland foam in the interface. Water should not be used to fight fire without a surfactant.

INTRODUCTION

The wildfires in California and Oregon during the late summer of 1987 were devastating reminders of the conflicts created by homes in the wildland.

Nine lives, over 60 structures, and at least 850,000 acres of timber were lost in California alone (Rios, 1987). The large number and size of the fires quickly depleted resources. Suppression strategies necessarily shifted to human and structure protection at the expense of timberlands. The increased need for property protection and efficient resource use attracted much attention to wildland fire foams.

To understand the merits of wildland foams as a tool for fire suppression in the wildland-urban interface, an examination of the development and use of foam for firefighting is appropriate. The relationships of plain water and its foam additives are shown in table 1.

Current wildland and structure fire suppression efforts in the United States rely almost entirely on plain water. The most common water additives include aerial retardants for wildland fires, and vapor suppressant foams for industrial and crash fires. Wet water is used sparingly for mop-up by wildland and urban fire forces. Foam for wildland fires has a small and growing following.

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WATER

Water has been recognized as a means of suppressing fire since rain was first observed extinguishing the warming fires of early man. Water is transportable. It is neither corrosive, toxic, nor reactive. Water has one of the highest cooling capacities; requiring the absorption of 9330 btu per gallon as it boils and then becomes steam. Layman (1955) found the conversion of water to steam to be 90 percent efficient with high pressure and low water flow. Layman's rapid, low water flow tactics which did not include structure entry, may have applications for the wildland-urban firefighter. The water droplets he projected into superheated spaces expanded 1600 times to steam forcing heat and oxygen out of the building.

With the advent of breathing apparatus in the 1960's, Grady (1987) notes that structure fires have been attacked from inside and out. Moving personnel inside necessarily changed water flow tactics to prevent injury from superheated steam. Water streams were applied directly to the fire, requiring more applications, and more water than before. The Iowa formula is the current water flow guide for interior structure attack:

$$\text{gallons per minute} = \frac{\text{cubic feet of largest room}}{100}.$$

The molecular structure of water influences its vaporization and effectiveness as a fire suppressant. Each molecule has two hydrogen atoms bonded asymetrically to one oxygen atom. The resulting polarity gives the molecules a strong mutual attraction manifested in a high surface tension of 73 dynes/cm at 20°C. Strong surface tension forms water into beads or drops rather than films. Because of water's surface tension, utilization of water droplets to make steam and cool fire is rarely complete. Haessler (1974) notes that a solid stream of water is 5-10 percent efficient at actual extinguishment. The Iowa Formula has a built-in effectiveness factor of 40 percent (Grady, 1987).

Another gauge of water effectiveness is the water flow rate required by the Insurance Services Office (1980). For a 1-2 family dwelling not exceeding two stories in height and at least 100 feet from other dwellings, the Office states that 500 gallons per minute must be available to protect this house.

Table 1--Relationships of water, wet water, and detergent-based foams.

	WATER						
Add	Nothing	Surface Active Agent					
Agitation?		No Agitation	Agitation				
Result	WATER	WET WATER	MECHANICAL FOAM				
			Common Features				
Type of Foam			Wet Water Foam	Detergent Foam	Wildland Foam	High and Medium Exp. Foam	Aqueous Film-forming Foam
Date Introduced		1950's	1950's	1930's	1980's	1950's	1960-70's
Surface Tension (dynes/cm)	73	25-33					16-19
Mix Ratio (%)		0.05-0.1	1,3,6	1,6	0.2-0.7	1,3	3,6
Major Use: Fuel Class and Applications	A: -Extinguishment -Mop-up	A: -Mop-up: wet charred fuels and textiles	A & B: -Bulk Fuel fires -Rapid knockdown	A & B: -Combination use for departments with variety of fuels	A & B: -Wet charred, uncharred, dead, living fuels -Exposure insulation -Rapid knockdown -Mop-up	A & B: -Confined space fires -Exposure insulation	A &/or B: -Aircraft crash control -Rapid knockdown -Diked fuel spills -Polar solvents

The specific gravity and heat transparency of water also affect its use. Because most hydrocarbons have a lower specific gravity, they float on water. Therefore, water has no resistance to reignition and flashback. Since water is a poor reflective barrier to radiant heat, continuous, high volume water flows are necessary for exposure protection.

SURFACTANTS

To improve the wetting, penetrating, and durability characteristics of water, man has been adding surface active agents for over fifty years (Ratzer, 1956). The surface active agent, or surfactant, reduces the surface tension of water to 17-30 dynes/cm, allowing elasticity of water surfaces and greater mobility of water molecules. Surfactants have been developed for specific functions on certain fuels. A surfactant made to adhere as foam to plastics, for example, will differ from one made to create a film seal over petroleum products.

Surfactants for firefighting can be roughly grouped as either wetting agents or foaming agents. Wetting agents increase the spreading ability of water and usually are not designed for use as foam. Surfactant foaming agents have wetting agent properties and permit the formation of clinging bubbles. These products are detergent-based.

Foam can also be made with bubble stabilizers derived from protein matter. These include chemical, protein, and flouro-protein foams. These foams have great bubble stability but do not share the wetting and penetrating characteristics of surfactant foams.

Wet Water

The basic form of surfactant-treated water for improved extinguishing efficiency is wet water. Wet water is defined as water to which a wetting agent has been added (NFPA 18). Wet water products first became available after the Second World War (Bryan, 1982). Wetting agent wet waters are approved by the United States Forest Service for use on decaying and charred Class A fuels only. Some wet waters will create a frothy wet water foam when mechanically agitated with air. These foams have rapid drain times and are used on bulk fuel fires. The National Fire Protection Association (1962) explained and demonstrated how wet water and wet water foams are more effective for fire suppression than plain water. Davis (1951) shows a wetting agent to be three times more effective than plain water on wood-burning fires.

The words "wet" and "wetting" are loosely used to mean penetrating and spreading. Wet water surfactants spread water by reducing surface tension. Textiles and other water porous materials can be wetted by this filming action of wet water. Detergent-based foaming agents not only spread the water, but also use a solvent to promote penetration through water-resistant plant surfaces.

Mechanical Foam

The largest type of treated water for fire suppression, mechanical foam, was first made in 1904. Detergent-based foaming agents for mechanical foams appeared in the 1930's (Bryan, 1982). Mechanical foams require a device to mix air with foam solution and allow for desired bubble expansion. Apparatus that provide these features include: 1) an aspirating nozzle with expansion tube, 2) an air compressor, pipe tee and length of hose or mixing chamber, and 3) turbo jet or water-agitating nozzle. Aspirating nozzles are almost universal. These nozzles use a venturi to pull air into the solution as the stream is being atomized into an expansion chamber. Foaming agent is usually mixed by eduction. Large water flow through these nozzles require large concentrate flow at the eductor. A deterrent, therefore, to most foam use is the large space required on an engine to carry sufficient agent for its task.

The compressed air foam system (Schlobohm and Rochna 1987) brings air and water together at equal pressures near the pump and compressor. With air in the hoselay, water flow is one-third less than without. Wildland foam agents are made at high concentration, and mix ratios are 1/10 - 1/20 of other foams, making agent storage space practical.

Recommended expansion ratios for mechanical foams range from 8 and 10 to 1 for wildland foams to 200 and 1000 to 1 for high and medium expansion foams. However, detergent, high and medium expansion, and wildland foams show very similar expansion characteristics for a given apparatus (Hubert). At a mix ratio of 0.3 percent, 1 gallon of wildland foaming agent can turn 300 gallons of water into 3000 gallons of foam.

Wildland Foam--As a relative newcomer to the mechanical foam group, wildland foam combines some of the best attributes of its cousins. Wildland foam retains the heat absorption of water and the spreading characteristics of a wetting agent. Like other detergent-based foams, wildland foam penetrates all Class A fuels. Its ability to cling to surfaces enables penetration, reflection of radiant heat, and suppression of oxygen. With other foams, wildland foam shares vapor suppressant and rapid flame knockdown capability. What wildland foams do not share with any other medium is performance per gallon of water. This is mainly because of the compressed air foam system (CAFS) attempted by Peterson and Tuve (1956), and revived by Ebarb (1978). Unlike aspirating nozzles, compressed air systems convert 90 percent of the water to foam. Systems of 40 cfm provide instant knockdown from 90 feet with 35 gallons per minute of water as foam.

Wildland Foam and the Compressed Air Foam System--With the compressed air foam system, wildland foams become a valuable tool for fighting fires in the wildland-urban interface. Water conservation is a key feature. A limited water supply cannot only be expanded, but because of the expansion, the water also becomes more effective. There are applications for both the firefighter who must drive to a distant water source, and the woodland homeowner who may have a finite water supply in a pond or pool. High agent concentrations and low mix ratios (3 gallons/1000) permit adequate on-board storage without reducing engine water capacity. Hoses, filled with foam, are light and maneuverable.

The clinging, wetting, and reflecting properties of wildland foam make exposure protection perhaps its most important application. Compressed air provides the discharge distance to reach and the agitation to cling to walls, eaves, roofs, and trees. Small, portable pumping systems can give the homeowner a method of on site structure protection.

Compressed air wildland foam may have applications for protection of residential fuel tanks. These foams have also been shown to be effective extinguishing small liquid fuel spill fires.

Another application for wildland foam with the compressed air system in the interface may be structure attack. Layman (1955) developed the indirect attack for structures using rapid, low water flows into superheated spaces and watched fires go out without entering buildings. On urban training fires over the past two years, the compressed air foam system has duplicated this feat.

CONCLUSION

Utilization of water for fire suppression has not changed over the centuries, with few exceptions. The fact is that use of any additive with water is the exception. AFFF and related film-forming foams occupy a small niche of specific duties on liquid fuel fires. Thickeners, such as retardants, are accepted for aerial use on wildfires large enough to justify expense, but development of new technologies, such as residential sprinklers, continues to be water oriented. Wildland and structure fires are primarily fought with plain water. And, although structure fire personnel rely on documented formulas for water use, wildland firefighters do not have a guide for water use.

Acceptance of water additives to improve efficiency will not occur overnight. The advocacy of surfactants in the literature for over 50 years and their continued limited use indicates a strong tradition of water use. This same advocacy would seem to necessitate justification of plain water, not surfactant. The integration of strategies and technologies of wildland and urban fire services may present the forum necessary for the social, political, and economic change from water to wet water and foam. Regardless of application or apparatus efficiency, water should never be used to fight fire without a surfactant.

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