forest management note

Note No. 9 Northern Forest Research Centre Edmonton, Alberta

PERFORMANCE GUIDELINES FOR WATER-THICKENING COMPOUNDS USED IN FOREST FIRE CONTROL

Water-gelling agents have been in use in forest fire control since the early 1960s. Several water additives ranging from swelling clays to organic and synthetic polymers have been developed and marketed as short-term forest fire retardants. These products have the ability to increase the viscosity of water so that, when applied to forest fuels, it absorbs more heat energy and the fuels are sealed off from the supply of oxygen. In this manner viscous water is more effective than plain or untreated water as a retardant. Improved deliverability is another important attribute of thickened water. Short-term retardants, however, do not chemically alter combustion reactions as do long-term retardants, their chemical counterparts, and therefore are effective only in the wet state as applied.

In Canada, viscous water has been most commonly applied by amphibious or water-skimming air tankers. The thickening agent is generally stored in a hopper on board the aircraft and is injected into the tank compartments at a predetermined mixing ratio during the short, 10- to 14-second water pickup time. Hydration takes place in the tank during the flight between the water source and the fire. The duration of this flight must be equal to or greater than the hydration time of a given thickening agent for it to reach its optimum viscosity prior to release over the fire.

Thickened water has been most commonly applied as a suppressant directly at the fire's edge, with little emphasis given to its retardant characteristics. These products have been used with land-based air tankers and ground tankers on a very limited basis; therefore, this note only considers the role of viscous water in aerial fire control using water-skimming air tankers.

The use of viscous water as a short-term retardant/suppressant has certain advantages as well as disadvantages compared to the use of plain water.

Advantages:

- reduced water loss due to evaporation during the load descent phase and following contact with the fuel complex, which becomes particularly important as air tanker turnaround times increase;
- improved resistance to load breakup so there is reduced drift or deflection, greater drop accuracy, and more-efficient distribution on the ground, particularly as drop height, drop speed, and/or wind velocity increase(s);
- extended drip-and-run and canopy penetration through improved rheological (elastic) properties, an attribute of some thickening agents; and
- enhanced load penetration through fire plumes when fire-induced wind conditions prevail.

Disadvantages:

- reduced fuel surface wetting characteristics and greater water volume retention in the vertical fuels (canopy) depending upon the rheological properties of the thickening agent;
- steadily rising costs of viscous agents, while water is free;
- development, installation, and maintenance costs of specialized injection equipment on board each air tanker;
- constraints and costs associated with storage, handling, logistics, and parasitic weight; and
- consistent monitoring of injection equipment performance and quality of the mixed product.

In consideration of the preceding comments on the presently known performance characteristics of viscous water, the following guidelines have been developed to aid in the future use and development of short-term retardants/suppressants.

Product performance guidelines for use in the development and selection of water-thickening compounds

Priority	Parameter	Desired characteristics
1	Toxicity and other health and environmental hazards	Product must comply with all federal and provincial health, occupational, and environmental hazard regulations. Where applicable, all packages shall be labeled with warning or precautionary instructions concerning safe handling procedures or the use of protective devices.
2	Rheological properties	Product should hold the water load together during release, deformation, and breakup stages as well as during free-fall descent, thereby reducing erosion, evaporation, and drift. Mixed product should resist evaporation under ambient and fire-induced temperature, moisture, and wind conditions relative to the amount of liquid retained on the fuel surfaces. Product elasticity should contribute to enlarged droplet sizes to enhance canopy penetration and drip-and-run effect.
3	Cost-effectiveness	Product should exhibit a benefit-cost ratio of greater than one, and benefits should be attributed to a combination of rheological properties and fire retardant or suppression characteristics.
4	Preparation and logistics	Product-to-water mixing ratio required to develop desired viscosity should be as low as possible. Product should readily mix with water to produce a uniform mixture. Product can be in powder or liquid form and should be of low density to minimize parasitic weight when carried on board skimmer aircraft. Associated mixing system should also be lightweight and compact. The desired quantity of product should flow readily through an induction, gravity, or pressurized feed system in less than 12 seconds during water pickup. Foam buildup during mixing should be minimal and should not cause displacement of any portion of the total mixed load. The rate of hydration of the product should be rapid, so that at least 85% of the maximum level of hydration is achieved within 3-5 minutes.
5	Water hardness, pH, and temperature	Neither rheological nor effectiveness properties should be affected by water quality. Following preparation at the optimum mixing ratio in medium hard water (61-120 ppm $CaCO_3$), a water-thickening agent should yield an apparent viscosity of at least 70% of the value obtained when prepared using distilled water. Water pH of 6 to 8 and water temperatures between 1°C and 30°C should have no effect on the mix characteristics.

Product performance guidelines, continued

Priority	Parameter	Desired characteristics
6	Packaging and storage	Product should be packaged in moistureproof and puncture-resistant containers that will resist breakage during normal handling procedures. Containers should be readily handled, stored, emptied, disposed of, or returned to distributor. Each container should be identified by lot number, date of manufacture, weight of contents, handling precautions, and name and address of manufacturer. Product should have a shelf life of not less than 2 years when stored in protected cold storage and should not show any evidence of physical or chemical deterioration. When mixed, the product should remain viable for a minimum period of 1 h without the addition of stabilizing agents.
7	Corrosion and/or abrasion	Product should not cause or aggravate corrosion and/or abrasion of mixing, loading, and delivery systems, nor should the product cause or intensify deterioration of loading pads, taxiways, and runways. Corrosion and/or abrasion should not exceed that caused by the use of normal water supplies. Where corrosion is anticipated, the manufacturer should inhibit the product accordingly. Routine equipment maintenance and housekeeping procedures are assumed to be the responsibility of the user or his agents.
8	Color	If color is a desired feature, the hue, saturation, and brilliance of the mixed product should be such that it is readily visible for at least 0.5 h from a height of at least 500 m above the forest canopy.

None of the water-thickening compounds marketed or evaluated to date would meet all of the preceding criteria. Some of their major limitations have resulted from their sensitivity to water hardness conditions, their mixing characteristics, and logistical constraints.

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