

## **Evaporation of a Small Aqueous Suppressing Agent Droplet**

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### **Abstract**

Due to its ozone-depleting potential, halon 1301 (CF<sub>3</sub>Br) has been banned from production under the Montreal Protocol. The research for halon replacement(s) has led to the reconsideration of using water in certain applications. However, under cold storage conditions (below 0 °C) water will freeze, thus posing a limitation in low temperature operations. Certain additives, if selected properly, not only can suppress the freezing point of water but also can improve its fire suppression effectiveness. Some water-based agents have recently been proven to be more effective than pure water when used in the form of mist to suppress a small JP-8 pool fire (Finnerty *et al.*, 1996). Among the thirteen agents they tested, potassium lactate (60% w/w) and potassium acetate (60% w/w) were found to be far superior than pure water and other candidate solutions.

When a fine mist is formed in a nozzle, the majority of the droplets are unlikely to penetrate to the base of the fire because the droplet momentum is small enough that they are deflected away from the rising plume (Downie *et al.*, 1995). The deflected mist droplets subsequently experience a cooler environment outside the hot gas plume, thus resulting in slow droplet evaporation. Some of the slowly vaporizing droplets will impinge upon the enclosure surfaces wherein the fire is located or obstacles within the enclosure. The droplets will eventually be vaporized on the heated surfaces.

The evaporation of suspended droplets containing dissolved solids was first studied by Charlesworth and Marshall (1960). The formation of a solid crust and various appearance changes during the course of evaporation under a wide range of experimental conditions were observed. Three major evaporation stages were identified: (1) evaporation before the formation of the solid phase, (2) progressive formation of the solid phase about the droplet, and (3) evaporation during the solid phase formation. Several studies on droplets with dissolved solids have since been conducted (Nešić and Vodnik, 1991; Kudra *et al.*, 1991). It is the objective of this work to examine the evaporation characteristics of some of these water-based agents and pure water on a heated surface. Previous studies (*e.g.*, Chandra and Avedisian, 1991) have been focused on relatively large drops (above 1 mm in diameter). Droplets with diameters less than 0.5 mm (to simulate mist droplets) are used in the present work.

Figure 1 is a schematic of the experimental apparatus. It consists of a droplet generator, a solution reservoir, a nickel-plated copper block equipped with two small cartridge heaters, a stainless steel surface, a temperature controller, and a CCD camera. The droplet generator has a chamber, a piezoelectric ceramic disc, and a glass nozzle (Yang *et al.*, 1990) and is based on the drop-on-demand ink-jet technique. A small droplet is ejected from the nozzle as a result of the deflection of the piezoelectric ceramic disc upon application of a squared pulse with controlled amplitude and duration to the disc. The use of this droplet generator enables the production of smaller droplets and repeatable operation. The surface on which the droplet is vaporized is made of 5 cm x 3 cm x 0.5 cm polished stainless steel (SS 304). The 5 cm x 3 cm x 1.25 cm nickel-plated copper block is used to heat the surface to the desired temperature (between 50 °C and 150 °C). Surface temperature is maintained within  $\pm 1$  °C by using a temperature controller. The CCD camera is used to record the evaporation histories of the droplets. The evaporation times of the droplets can be determined by using frame-by-frame analysis of the video records. The experimental procedure involves the delivery of a single droplet from

the droplet generator to the heated surface located 6.5 cm below the nozzle tip and the recording of the droplet evaporation processes. No shattering of droplets due to impact on the surface was observed within the range of surface temperatures tested. The Weber number ( $\rho U^2 D / \sigma$ ) of the droplets was less than 80.

Figure 2 is a comparison between the evaporation time of pure water, 5 % (w/w), 10 %, and 20 % potassium acetate droplets as a function of surface temperature. The initial droplet diameter is estimated to be  $360 \mu\text{m} \pm 20 \mu\text{m}$  from the 35 mm single-strobe flash photographs taken near the nozzle tip. Note that the evaporation times for the potassium acetate solutions reported in the figure refer to the times immediately before the formation of solid phase. It is assumed that the amount of water vaporized before solid formation constitutes the bulk of the initial water content. The assumption appears to be reasonable for small droplets (Charlesworth and Marshall, 1960). Addition of potassium acetate does not change the evaporation time significantly (within the experimental uncertainties) at high surface temperatures. Results on other water-based agents will be presented and discussed.

## References

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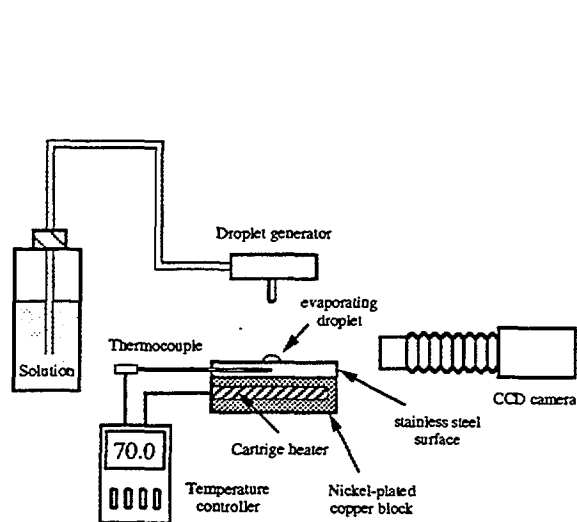


Figure 1. Experimental set-up.

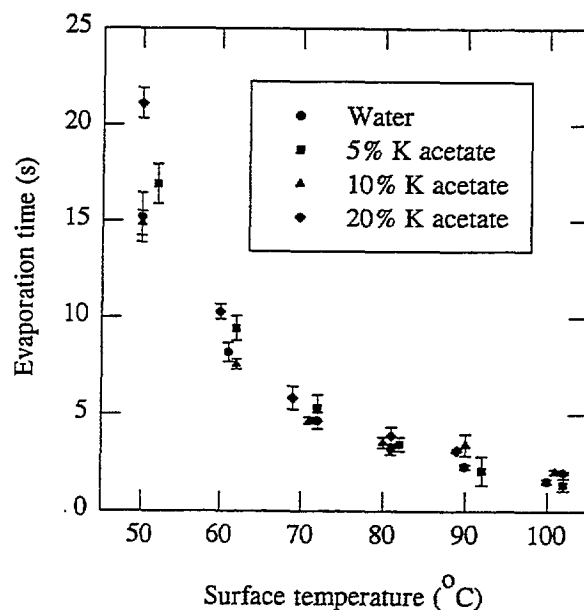


Figure 2. Evaporation time as a function of surface temperature.