Better Use of Water for Fire Suppression

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Introduction: Environmental concerns over the past decade have provided new impetus for expanding and improving the use of water for Navy fire protection. Traditionally, fire suppression in selected Navy shipboard compartments has been provided by Halon 1301 (CF_3Br), whose production has been banned in the United States and other developed countries because of its depletion of stratospheric ozone. Nonbrominated fluorocarbons, while ozone safe, are less effective, carry space and weight penalties for Navy platforms, are significant global warming agents, and produce toxic hydrogen fluoride (HF) gas in extinguishing a fire.

Water is perhaps the oldest firefighting agent, but it can be difficult to implement in many situations; because, unlike Halon, it is a liquid. Droplet size, transport, evaporation rate, and suspension time are all critical parameters in determining the effectiveness of a water-based suppression system against a given fire threat. Although water-based fire suppression has been the subject of empirical tests for many years, the interaction of liquid water droplets with flames has received surprisingly little systematic study in laboratory settings. The identification of the factors important in determining water's effectiveness as a fire extinguishing agent is a prerequisite for better implementation. The Navy Technology Center for Safety and Survivability has a coordinated program, combining fundamental laboratory studies of water/flame interactions with real-scale fire tests, to provide the Navy with implementation particulars for water mist-based fire protection systems.

Water Mist Fire Suppression: Traditionally, water has been used as a firefighting agent in the form of relatively large drops. Typical sprinkler systems produce water drops having diameters on the order of a millimeter. Such droplets are useful at cooling smoldering surfaces, but are relatively ineffective at suppressing combustion of gaseous or liquid fuels. The large size and low surface area/volume ratio means that relatively little of the water evaporates in the length of time the droplet spends near the fire. Thus the cooling provided by the water evaporation and dilution of the oxygen and fuel by the resulting water vapor are not efficiently achieved. For this reason, most water-based fire suppression systems use more water than would be needed if the thermal and dilution effects could be properly utilized.

Fine water mists, having diameters of 200 microns or less, circumvent these difficulties by allowing better droplet vaporization, but they are more difficult to produce. The tradeoffs between efficiency and engineering difficulties in droplet generation and delivery must be determined.

Laboratory Studies: In assessing the applicability of water mist fire suppression systems, one must answer the question "how effective can water be under ideal conditions?" We have investigated water mist inhibition and extinguishment in two types of laboratory flames and find that, under suitable conditions, water mist can be as effective as Halon 1301.

Figure 11 shows data taken in a nonpremixed propane/air counterflow flame, to which suppressants (Halon and water droplets of various sizes) were added to the air stream.[1] Addition of the suppressant to the air stream is the most typical scenario for most fire threats. The extinction strain rate plotted in Fig. 11 is a measure of flame stability. Effective fire suppressants lower the extinction strain rate as shown. Data for water and Halon, plotted on a mass basis, show that over the range of droplet sizes tested (20 to 50 microns), smaller droplets are more effective. Furthermore, water droplets of 14 and 30 micron diameter are considerably more effective than Halon, while droplets of 42-micron diameter are comparable to Halon in extinguishing this particular flame.

The degree of burning velocity reduction is also an indication the effectiveness of a fire suppressant. Figure 12 shows data on the burning velocity of premixed methane/air flames containing submicrometer diameter water droplets.[2,3] These droplets are small enough to completely evaporate during the short residence time (approximately one millisecond) in the flame region. In this type of flame, the effectiveness of the submicron water droplets is comparable to the findings for Halon 1301 in Refs. 2 and 3. Comparison of the water data to measurements with nitrogen and CF_4, two well-studied gaseous agents that are chemically inert and inhibit combustion by cooling and dilution of the available oxygen, indicates that the expected effect of water evaporation is achieved in this environment.

Achieving the maximum effectiveness of water in real fire scenarios is more challenging. The small drops that are most effective in the flame may evaporate before they reach the fire, while larger drops may be too large to be entrained in the air flow and get to the fire, especially for obstructed or cluttered areas. The key issues to understand are mist drop size and distribution in the protected space.

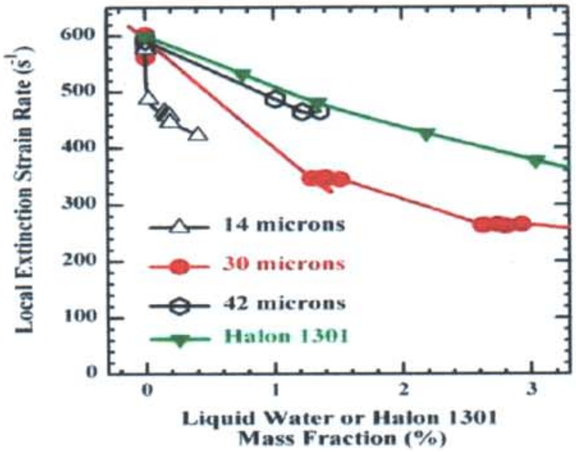

FIGURE 11
Measurements of extinction strain rate in nonpremixed propane/air flames inhibited by Halon 1301 (CF_3Br) and by monodisperse water droplets of various sizes (from Ref. 1).

FIGURE 12
Measurements of burning velocity reduction in a methane/air mixture by addition of nitrogen, CF_4, and submicron water mist. Published measurements for Halon 1301 (CF_3Br) are also shown.

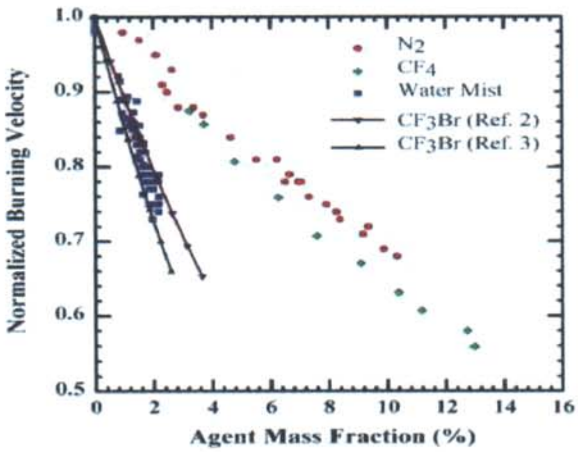

FIGURE 13
Fire test facility at the NRL Chesapeake Bay Detachment. The two enclosures at the rear (285 cubic meters) and the right (27 cubic meters) of the picture are used for testing different sized shipboard compartments.

Toward Implementation: Realistic large-scale tests are currently underway at NRL's Chesapeake Bay Detachment to develop water mist system implementation solutions to protect Navy shipboard flammable liquid storerooms against different fire threat scenarios (Fig. 13). These tests combine a powerful array of instruments to determine droplet sizes, velocities, and number densities at various locations in the test compartment, as well as the in situ measurement of oxygen dilution by the evaporating water mist, for truly understanding suppression by water mist. The detailed suppression mechanisms studies in laboratory flames combined with well instrumented full-scale studies is providing design guidance to the Navy for implementing water mist as an effective and reliable Halon alternative.

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References

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[2] T. Noto, V. Babushok, A. Hamins, and W. Tsang, "Inhibition Effectiveness of Halogenated Compounds," *Combust. Flame* **112**(1-2) 147-160 (1998).

[3] D.J. Parks, N.J. Alvares, and D.G. Beason, "Fundamental Flame-speed Measurements in Combustion Gases Containing CF_3Br," Fire Safety *J.* **2**(4) 237-242 (1980).