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FIRE SUPPRESSION PROPERTIES OF VERY FINE WATER MIST

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Introduction: Water mist is one of the best non-gaseous fire suppression replacement agents for Halon 1301 on a mass basis. In general, small drops are more effective than larger drops, but the highly complex nature of fires defies a simple generalization. Drop size is important but so are drop transport and evaporation behavior. Understanding each of these is critical to the design of water mist fire suppression systems.

Water spray systems like sprinklers in many buildings produce very large drops, generally above a millimeter in diameter. These systems ineffectively deliver much more water than is usually needed. Water mist systems that use low-pressure nozzles typically produce drops between $\sim 200\text{ }\mu\text{m}$ and 1 mm. The production of fine water mist (drops below $200\text{ }\mu\text{m}$) requires high-pressure nozzles. NRL studies in laboratory flames show that drops smaller than $40\text{ }\mu\text{m}$ are more effective than Halon 1301 on a mass basis at extinguishing methane/air and propane/air non-premixed flames.¹ Experimental and computer fire modeling studies indicate that effectiveness continues to increase with decreasing drop size. The case looks especially attractive for very fine water mist with drop diameters less than $10\text{ }\mu\text{m}$.

Mist-generation and Detection: High-pressure mist systems do not typically generate sufficient quantities of very fine water mist. Small drops in high numbers can be produced by piezoelectric nebulization as recently demonstrated.² The misters incorporate an array of individual piezoelectric transducers. NRL, in coordination with Nanomist LLC, is exploring the characteristics of these small water drops in laboratory and real-scale fire suppression applications.

In these studies, mist drop size, number density, and velocities are measured using Phase Doppler Particle Anemometry. The amount of liquid water dispersed as drops is determined from optical density (OD) measurements using a diode laser. Oxygen measurements are obtained using three different instruments. The paramagnetic oxygen analyzer connected to an extractive sampling line typically reads high in the presence of water (both liquid and vapor) since water must be removed from the sampled volume before analysis. The zirconia oxygen analyzer, heated to

approximately $600\text{ }^{\circ}\text{C}$ for proper operation, reads low in the presence of water drops. These two instruments, although impacted adversely by the presence of water drops, provide important upper and lower bounds for the amount of oxygen present. NRL, in collaboration with the University of Heidelberg, developed an in situ oxygen sensor based on tunable diode laser absorption spectroscopy (TDLAS) to provide absolute oxygen number densities in the presence of mist.³ The TDLAS oxygen sensor provides real-time, calibration-free, quantitative oxygen concentrations that are particularly important at times of high mist density.

Fire Suppression Performance and Mist Behavior: The very fine water mist was evaluated in a small corral ($130 \times 85 \times 80\text{ cm}^3$). Mist was brought in at one end of the corral and propelled with a small fan through a dryer vent hose. Mist samples withdrawn at the other end of the corral were sent to the drop size analyzer. A small 10-cm propane test flame was located near the middle of the corral (Fig. 4).

Parameters investigated in the small-scale laboratory tests included mist drop size and concentration as a function of time. Drop lifetime studies evaluated fire protection times possible with very fine water mist. Flame extinction studies show that very fine water mist achieves the theoretical quantitative flame-extinguishing potential for water in this environment (Fig. 5). A key finding in these studies was the time required for flame extinction. Unlike a gas, which quickly disperses and fills the space, very fine water mist requires time to disperse and build to a sufficient concentration to effect flame extinction (Fig. 6).

Mist build-up time is even more important in real scale. The large-scale compartment used for these studies is a $3 \times 3 \times 3\text{ m}^3$ steel-walled compartment with standard Navy hardware designed to simulate a small Navy shipboard flammable liquid storeroom. The compartment contained typical shelving frames, ventilation, and storage accommodations consistent with Navy compartments. A 120-kW heptane pan fire was located in the center of the compartment, 1 ft above the floor.

Information collected as a function of time using an automated data acquisition system included temperature at various locations, concentration of gases including oxygen, and video (visual and IR) to determine fire-out status. The very fine water mist was able to successfully extinguish all pan fires tested. Average extinguishment times were around 5 min, with six mister units each delivering 0.1 liter of water per minute as a very fine mist. Extinguishment times decreased with increasing mist injection rate. The

FIGURE 4

Laboratory scale corral for very fine water mist studies showing drop size characterization using Phase Doppler Particle Anemometry, Optical Density Measurement module, and flame for fire extinction evaluation studies.

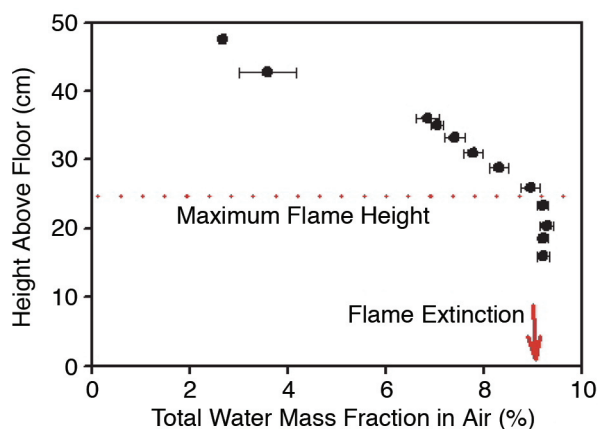
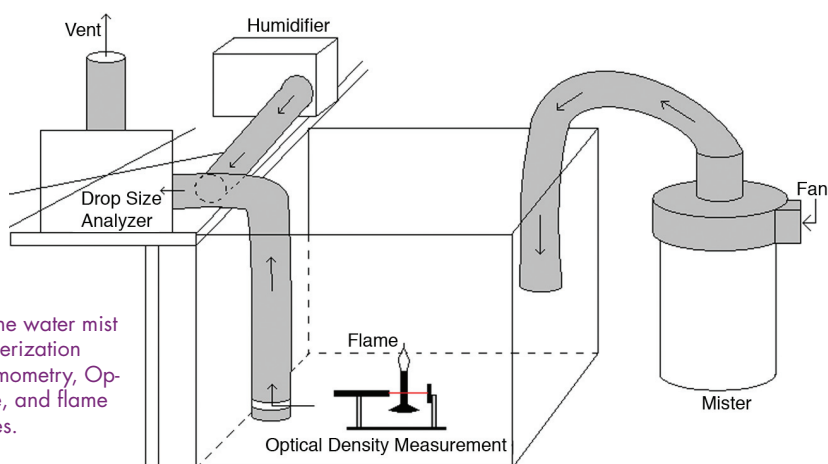


FIGURE 5

Height in corral vs water mass fraction (very fine water mist and vapor). Flame extinction studies show that very fine water mist achieves the theoretical quantitative flame extinguishing potential for water in this environment based on a thermal fire suppression mechanism.

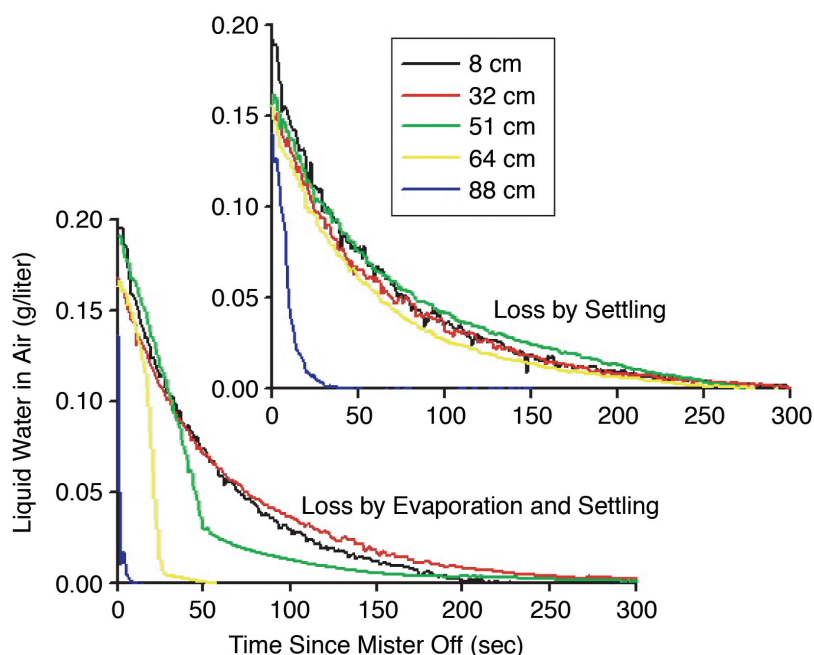


FIGURE 6

Fine water mist drop density decay time as a function of height. At least two competing loss mechanisms occur for the mist: settling and evaporation. The evaporation loss is rapid, until the surrounding environment becomes saturated with water vapor, then the slower settling mechanism dominates.

placement of a simple wall obstruction between mister and fire required more mist output to extinguish the fire in the same suppression time. Visual evidence showed that the mist did not reach all areas of the compartment. These observations highlight the importance of drop transport and fire threat location in the compartment to overall mist effectiveness.

Designing Water Mist Systems: Favorable environmental properties and high potential fire suppression effectiveness keep water mist in strong contention for protecting many Navy spaces formerly protected by Halon 1301. Laboratory and real scale evaluations indicate that very fine water mist has key advantages over mist with larger drop sizes. Very fine water mist drops behave more gas-like than larger drops, but still very differently than gaseous agents. Further understanding of drop size, lifetime, and transport behavior is necessary to provide practical guidance on very fine water mist fire suppression systems. The results presented here contribute to that understanding and provide data necessary for the further development of models to predict water mist suppression in real fire scenarios.

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