An Overview of Water Mist Fire Suppression System Technology

by

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Introduction

Fine water mist has been an active area for research and development, and many commercial systems are available or in development. Fine water mist relies on relatively small (less than 200 μm) droplet sprays to extinguish fires. In theory, the small drops allow the mist to move around obstructions and extinguish fires, characteristics of a total flooding gas. The mechanisms of extinguishment include the following:

- gas phase cooling (like a total flooding "inert"),
- oxygen depletion by steam expansion, and
- wetting of surfaces.

Water mist systems have attracted great interest for a number of reasons. These systems are perceived to have the following advantages:

(1) are inexpensive;

(2) are non-toxic and pose no environmental problems;

(3) suppress flammable liquid pool and spray fires;

(4) utilize water quantities a tenth or lower than sprinklers and hence have little or no collateral damage;

(5) can be made perform functionally in some applications like total flooding gases (i.e., obstructed, enclosed fires) activated by a variety of means;

(6) may be non-electrically conductive; and

(7) may have application as inerting or explosion suppression systems.

Some of the potential perceived benefits have been demonstrated. There are currently at least nine water mist system technologies available or under development using either dual-fluid (N_2/air and water) or single-fluid high-pressure systems.

Table 1 summarizes the current manufacturers of water mist systems for fire suppression use. Some of these manufacturers are still in the R&D phase with their particular hardware.

The efficacy of these and other generic water mist fire suppression systems has been demonstrated in a wide range of applications and by numerous experimental programs. These applications have included Class B spray and pool fires (Papavergos (1991), Butz (1992), Wighus (1991), Cousin (1992)), aircraft cabins (Hill et al. (1991, 1993), Whitfield (1988)), shipboard machinery and engine room spaces (Mawhinney (1992), Turner (1993), Arvindson and Ryderman (1992), Tuomissari (1992), Soja (1990), Gamiero (1993)), shipboard accommodation spaces (Arvindson and Ryderman (1992)), and computer and electronics applications (Hill et al. (1993), Tuomissari (1992)).

Table 1. Water Mist Hardware Manufacturers

Company	Country	Type of System
ADA Technologies	U.S.A.	Dual Fluid
Baumac International	U.S.A.	High Pressure
FSI/Kidde Graviner, Kidde Fenwal	United Kingdom, U.S.A	Dual Fluid
Ginge Kerr (BP)	United Kingdom, Denmark, Norway	Dual Fluid
Semco	USA/Denmark	High Pressure
Marioff Hi-fog	Finland	High Pressure
Microguard-Unifog	Germany	High Pressure
Securiplex (BP)	Canada	Dual Fluid
Spraying Systems	U.S.A.	High Pressure
Bete Fog	U.S.A.	High Pressure
Grinnell	U.S.A.	Low Pressure
GW Sprinkler	Denmark	Low Pressure

To summarize these experimental results, the efficacy of a particular water mist system is strongly dependent on the ability to not only generate sufficiently small droplet sizes but to distribute "critical concentrations" of droplets throughout the compartment (Mawhinney (1993), Cousin (1992), Jackman (1992)). It is worth remarking that a widely accepted "critical concentration" of water droplets required to extinguish a fire is yet to be determined. Factors that contribute to the distribution of this critical concentration of water mist throughout the compartment consist of droplet size, velocity, the spray pattern geometry as well as the momentum and mixing characteristics of the spray jet, and the geometry and other characteristics of the protected area. Hence, water mist must be evaluated in context of a system not just an extinguishing agent.

The major difficulties with water mist systems are those associated with design and engineering. These problems arise from the need to generate, distribute, and maintain an adequate concentration of the proper size drops throughout the compartment while gravity and agent deposition loss on surface deplete the concentration. There is currently no theoretical basis for designing these parameters. System design parameters are being extrapolated from large-scale test data on a case-by-case basis. This poses special problems for standards-making and regulating authorities.

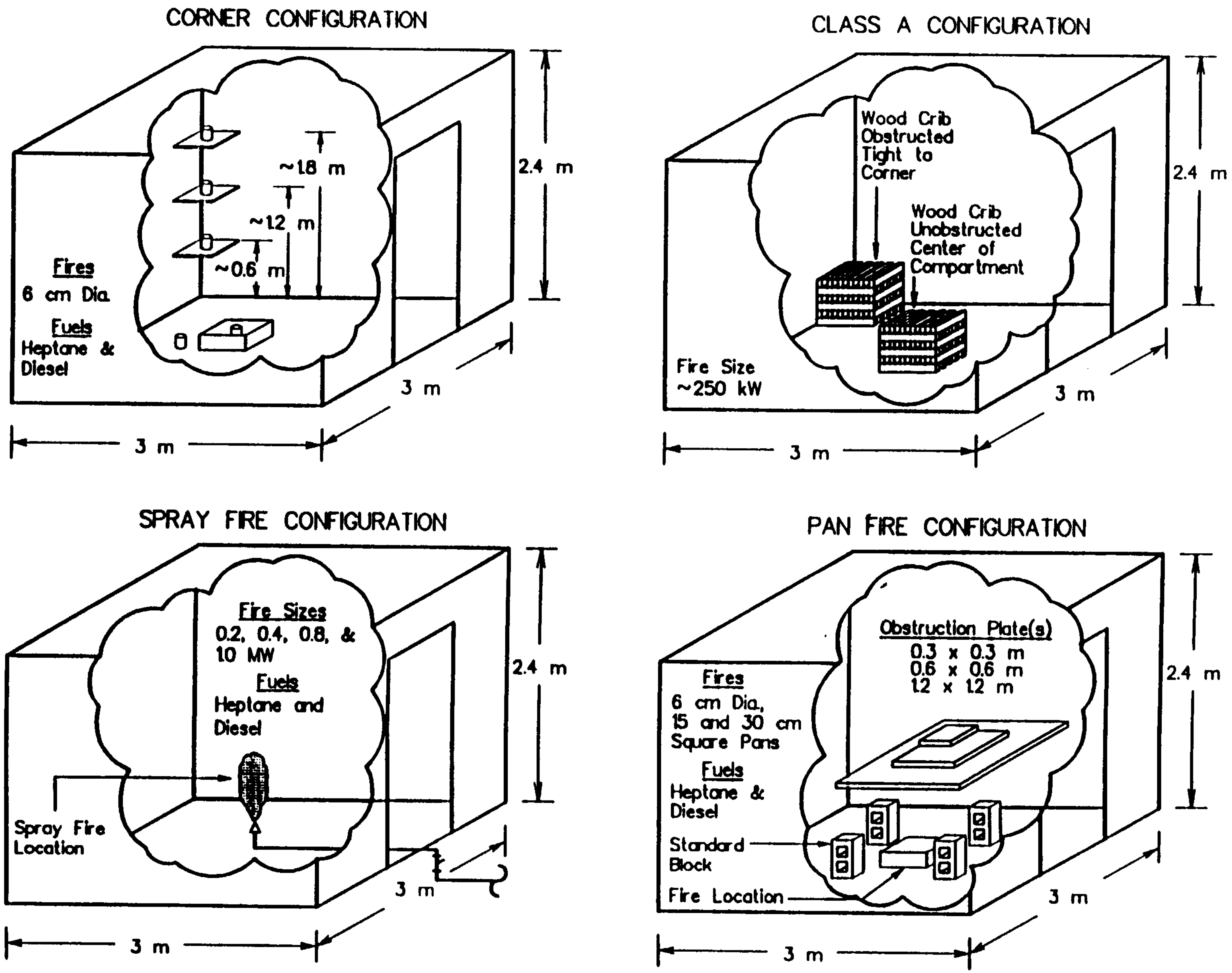
While many of these systems have received some acceptance from overseas approval authorities for limited applications, in the United States, the newly formed NFPA committee, Water Mist Fire Suppression Systems Committee, will not only face the task of developing performance criteria, but will also face the problem of evaluating the systems' adaptability to numerous fire protection applications. The approval testing and standardization effort is just getting underway.

In this paper, the results of an extensive investigation of a number of water mist systems will be reported. The goal of the work is not to evaluate the commercially available systems, but rather to assess the capabilities of the technology and the impact of major design variables.

Experimental Evaluation of Water Mist Systems

Over 500 water mist system tests have been conducted during this evaluation. Many of these tests were part of an ongoing investigation into the use of water mist as a halon alternative in machinery space applications for the U.S. Navy (Leonard (in preparation)). These tests have included both generic systems utilizing modified industrial spray nozzles and commercially-available fire protection misting hardware. The systems tested cover the spectrum of available technologies including dual-fluid fixed orifice, dual-fluid sheet/slit orifice, single-fluid, high-pressure multiple-orifice heads, and single-fluid high-pressure grid/matrix-type systems. It was not the intent of this investigation to judge one system against another, but rather to determine the capabilities and weaknesses of water mist technology.

The systems were evaluated in a 3 x 3 x 2.4 m (10 x 10 x 8 ft) compartment against a variety of fire conditions as shown in Fig. 1. These fire scenarios included both obstructed and unobstructed Class A wood crib fires and Class B spray and pool fires. Obstructions varied from shielded from above using various size plates to shielded on two sides and above. The average localized mist density, based on a combined total flow averaged over the entire compartment floor area, ranged from 0.5-1.5 Lpm/m^2 (0.01-0.03 gpm/ft^2) which corresponds to a volumetric density of 0.2-0.6 Lpm/m^3 (0.0015-0.0045 gpm/ft^2). This mist density is approximately one order of magnitude less than a conventional sprinkler system. Higher flux densities are currently being evaluated.



CORNER CONFIGURATION

CLASS A CONFIGURATION

SPRAY FIRE CONFIGURATION

PAN FIRE CONFIGURATION

Figure 1. Test Fire Scenarios

Each system was evaluated in a variety of configurations to achieve optimum results. The firefighting capabilities of these optimized systems varied only slightly for a given flux density. The results were primarily driven by the similarity in drop size distribution between the systems with the mass mean diameter of drops measured as $D_{V0.5} \sim 75\ \mu m \pm 25\ \mu m$. (The mass mean diameter, $D_{V0.5}$, is defined as the diameter of a drop such that 50% of the total liquid volume/mass is in drops of a smaller diameter.) An overview of the fire performance of the above systems is shown in Table 2.

Table 2. Firefighting Overview of Water Mist Systems – Probability of Success (%) as a Function of Fire Configuration

Test Configuration	System			
	Dual-fluid	Single-fluid High-pressure Type A	Single-fluid High-pressure Type B	Modified Type B
Corner Configuration				
Floor	80	90	95	95
0.6 m	10	10	40	90
1.2 m	10	10	20	60
1.8 m	0	0	10	25
Pan Fires				
Unobstructed	85	90	97	98
Obstructed Plates				
0.3 m	15	25	40	75
0.6 m	0	10	10	40
1.2 m	0	0	0	10
				0
Class A Wood Cribs				
Center	80	80	90	95
Corner	10	10	10	10
Spray Fires	98	95	92	90

Notes: The values in Table 2 represent the percentage of test fires extinguished for a given fire/system configuration. Refer to Figure 1 for a better description of the fire scenarios. Class A wood crib fires were evaluated using a three-minute discharge time.

Some general observations of the firefighting performances of the water mist systems are listed as follows:

- All of the systems evaluated were able to extinguish unobstructed fires on the floor of the compartment with spray flux densities on the order of 1.0 Lpm/m^2;

- Many fires located at higher elevations in the compartment were extinguished with the remaining fires dramatically reduced in size;

- Large fires are easier to extinguish then small fires due to the displacement of oxygen by the expansion of the water mist to steam as well as nd higher plume entrainment rates associated with larger fires;

- The firefighting capabilities of the two-fluid systems were found to increase by substituting nitrogen and other inert gases for air as the second fluid; and

- Obstructed fires become more difficult to extinguish with increased horizontal drop travel distance (i.e., horizontal distance from the higher flux density region near the spray pattern to the fire source). Many fires were extinguished with distances on the order of 0.3 m (1 ft), but were not extinguished for greater distances. It is worthy to note that many of the highly obstructed fires, although not extinguished, were greatly reduced in size by the presence of the water mist.

The dual-fluid and single-fluid Type A systems were practically designed systems consisting of one or two nozzles (coverages similar to conventional systems with dramatically lower flows). These systems were highly effective against all of the unobstructed fires, but lost efficiency with increased fire obstructions. In all cases, the fires were controlled by these two systems. Type B and Mod Type B systems had less practical designs containing high numbers of low flow nozzles. This system most closely approximated a "total flooding" system. The system was capable of effectively extinguishing a majority of the unobstructed fires and demonstrated superior firefighting capabilities (superior than the other systems tested) against the obstructed pan and corner fire scenarios. On a broader view, these extinguishment efficiencies are dramatically less than the gaseous agents' extinguishment efficiencies and would be viewed as a failure in the context of a total flooding system.

Conclusion

Experimentally, water mist systems were observed to function extremely well as highly effective water sprinkler systems. A high percentage of both Class A and B fires were extinguished with these systems with the remaining fires dramatically reduced in size (controlled). Many systems were observed to exhibit characteristics of a total flooding system by extinguishing obstructed fires that a conventional sprinkler system would be incapable of extinguishing. Water mist technology also shows tremendous promise in "local application"-type systems. On the negative side, the ability of water to function completely as a gas in a total flooding application has yet to be demonstrated.

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