An Experimental Evaluation of Water Mist Fire Suppression System Technologies Applied to Flammable Liquid Storeroom Applications

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This report summarizes an investigation into the use of water mist technologies in flammable liquid storeroom applications. The research program was sponsored by the U.S. Army.

The objective of this test series was to evaluate the feasibility of using a water mist total flooding system as a replacement for the currently installed Halon 1301 system used in flammable liquid storerooms. This evaluation focussed primarily on the firefighting capabilities of the "state of the art" water mist technologies as applied to flammable liquid storerooms. **An** assessment of water mist system parameters (i.e., flow rates, pressures, nozzle spacings, etc.) was also conducted to optimize the firefighting capabilities of each system as well as to add robustness to the system's performance. Ultimately, a set of performance criteria and design specifications will be developed.

The tests were conducted in a simulated flammable liquid storeroom. The setup consisted of a 3.0 x 3.0 x **2.4** m (10 x 10 x 8 ft) steel box with a single door ***(56* x 168** cm **(22** x 66 in.)) located in the center of one side. Two additional vents (one high forward and one low aft) were added to provide a known leakage rate in the box, preventing oxygen depletion from becoming a predominant variable in the closed compartment tests. The flammable liquid storeroom was simulated by adding a row of shelves along one wall of the compartment, a metal locker against the opposite wall, and a small table in the back of the space as shown in Figure 1. The space was instrumented for temperature, radiant and total heat flux, optical density, and typical fire gas species (O_2, CO, and CO_2) as shown in Fig. **2.** Oxygen concentration was also measured at the base of the fire. All fires were instrumented for temperature to note extinguishment. Each test was videotaped using both a standard and an infrared video camera.

Five commercially available water mist fire suppression systems and two generic systems produced using off-the-shelf industrial spray nozzles were selected for this evaluation. The systems selected cover the range of available technologies from high and low pressure single-fluid systems to dual-fluid systems. The generic systems were evaluated to identify any variations in performance between the "state of the art" water mist technologies and homemade-type systems with similar drop size distributions and water usage rates. Systems/manufacturers evaluated during this test series include Grinnell AquaMist, Kidde-Fenwal, Semco Marine, Marioff Hi-fog, Securiplex, and Spraying Systems. The commercially available systems were initially evaluated at the manufacturer's recommended design parameters (i.e., pressure, flow rate, nozzle spacing, etc.). When deemed necessary, modifications to the system design were made in order to increase the system's performance.

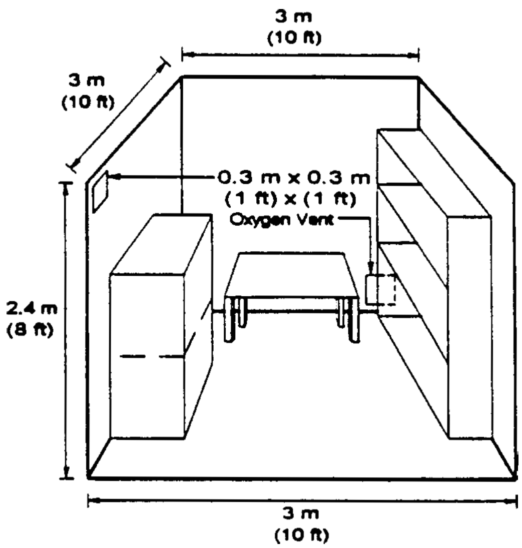

Fig. 1 – Simulated flammable liquid storeroom

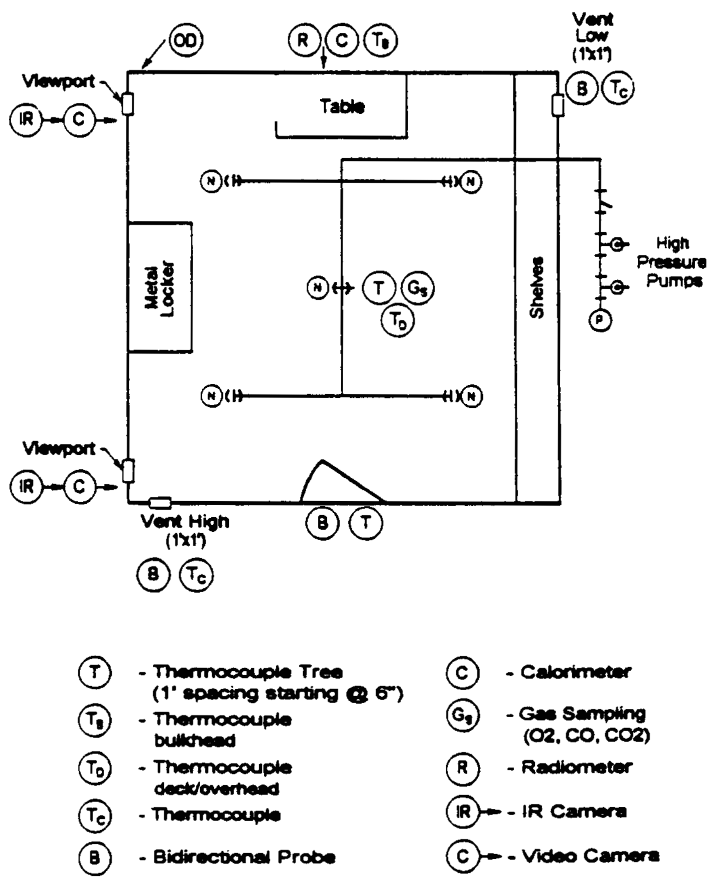

Fig. 2 – Instrumentation and mist system layout

The systems/nozzles were installed in either of two configurations (Fig. **2).** The first configuration consisted of a single nozzle installed in the center of the space, thus producing a nominal nozzle spacing of **3** m (10 ft). The second configuration consisted of four nozzles installed with nominally a 1.5 m *(5* ft) spacing also shown in Fig. *2.* The pipe network was designed to allow an easy transition between the two system configurations.

The systems were initially evaluated against a series of tests containing ten small heptane pan fires referred to as "tell tales." The small pans were positioned at various locations throughout the space (Fig. 3) to evaluate the mixing/distribution characteristics of the systems. These tests were conducted in both open and closed compartments. The "tell tales" measured 5.0 cm **(2.0** in.) in diameter and were fueled with heptane to a depth of **2.54** cm (1.0 in.). This amount of fuel provides a bum duration on the order of 15 minutes. The "tell tales" were ignited and allowed to preburn for one minute prior to mist system activation. The mist system remained activated for a total of ten minutes. The extinguishment times for each "tell tale" were determined based on the temperatures measured directly above/in the fire and on visual observations.

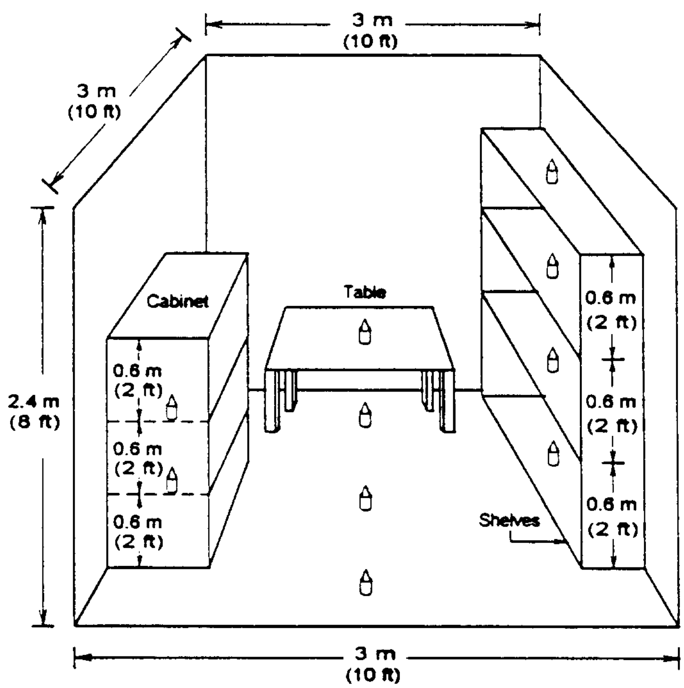

Fig. 3 - **Tell tale fire scenario**

On completion of the tell tale fire tests, the systems were then evaluated against four representative fire scenarios. These fire scenarios were developed to represent the majority of the actual fire threats/hazards associated with flammable liquid storerooms. Two Class **A** fire scenarios (a wood crib and a trash can fire) and two Class B fire scenarios (a large pool and a cascading fuel fire) were selected for this evaluation. The Class **A** fires were conducted to evaluate the capabilities of the mist systems against typical Class **A** threats associated with flammable liquid storerooms (i.e., tarps, rags, trash cans, etc.). The Class B fires are representative of fires involving flammable liquids in open containers as well as a variety of spill type fire scenarios. These fires are shown in Fig. 4.

The system parameters for the eight candidate systems are shown in Table 1. A summary of the results of this test series is found in Table 2. As shown in Table 2, the *two* low pressure, single fluid systems (Systems A and H) exhibited superior results throughout this test series. The superior performance of these systems was attributed to the relatively high water flow rates characteristic of these systems as well as their capabilities against deep seated Class A fires. The low pressure, single fluid systems produce mean drop diameters larger than those of other system types, increasing their capability against deep-seated Class A fires. Unfortunately, the larger drop sizes appear to reduce the system's ability to extinguish shielded/obstructed fires as shown by the lower number of fires extinguished during the tell tale fire tests.

Four of the five high pressure, single fluid systems, two commercially available (Systems B and C) and two generic systems (Systems F and G) also performed quite well during this evaluation. These high pressure, single fluid systems use on the order of a factor of three to four times less water than the two low pressure, single fluid systems. The higher pressure systems usually produce small drops which appear to increase the system's capabilities against shielded/obstructed fires. This is evident by the higher percentage of tell tale fires extinguished with these systems. During the Class A fire tests, the high pressure systems were capable of controlling the fires but, in many cases, were unable to completely extinguish the fires. This was attributed to a lack of momentum and/or mass of the smaller drops. The remaining high pressure and dual fluid systems (Systems D and E) both exhibited varying degrees of success but less than the previously mentioned six systems.

In summary, the water mist systems evaluated during this experimental program demonstrated the capabilities of water mist to replace Halon 1301 in flammable liquid storeroom applications. In a closed space comparison, the firefighting capabilities of the "state-of-the-art" water mist technologies lie somewhere between Halon 1301 and conventional sprinklers (less than Halon 1301 but greater than conventional sprinklers). In open spaces, water mist may even perform better than Halon 1301. The weaknesses of water mist technologies lie both in their inability to completely extinguish deep-seated Class A fires and their limited success against shielded/obstructed fires. In all of the tests conducted during this investigation, when the water mist system was not capable of completely extinguishing the fire, the fire was still dramatically reduced in size (controlled). If the fire is reduced in size such that the fire cannot spread to adjacent items and is maintained at that size until the fire bums out due to fuel consumption, is control synonymous with extinguishment?

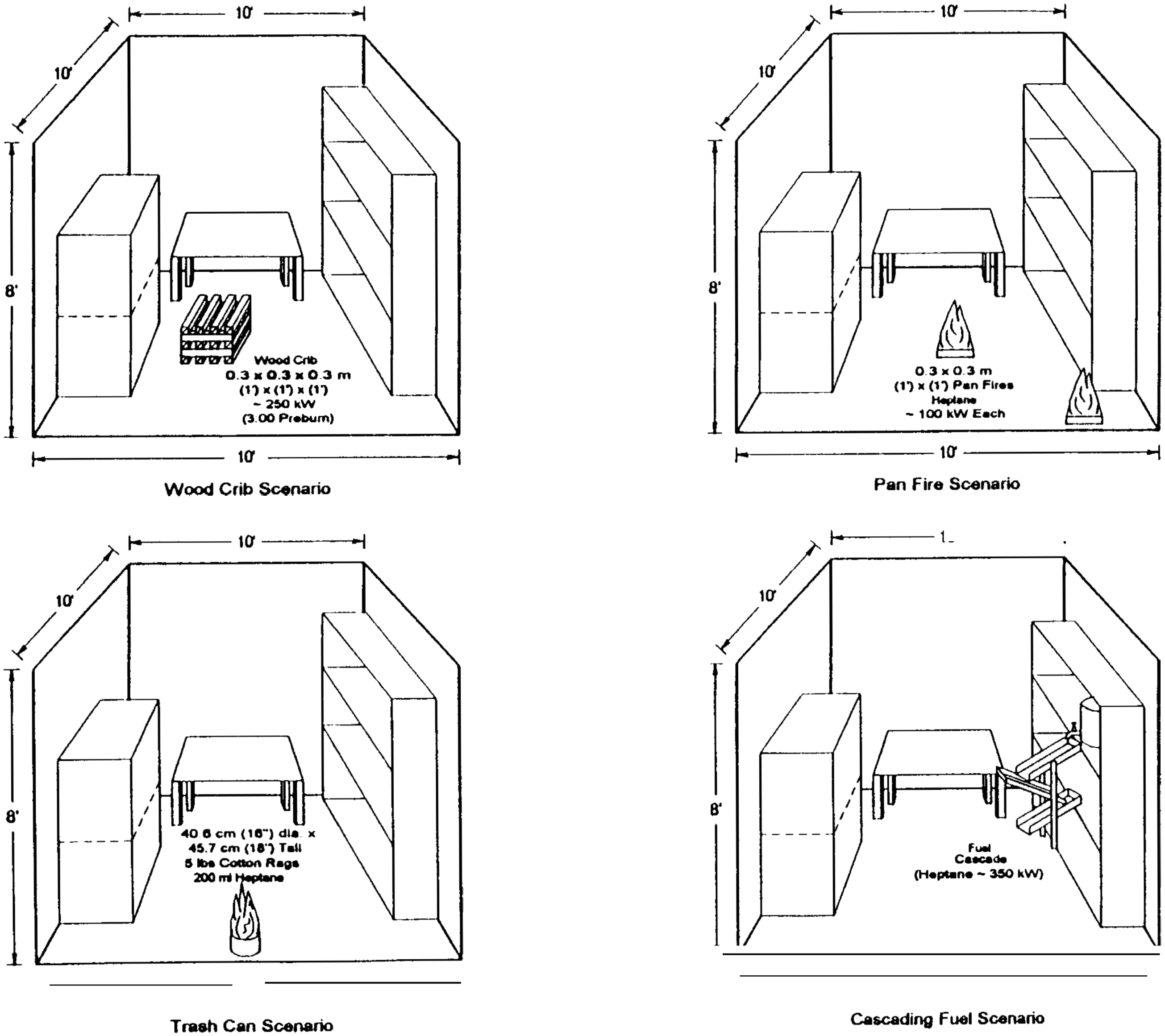

Fig. 4 – Representative fire scenarios

Table 1. Flammable Liquid Storeroom Tests – System Information

System	Number of Nozzles	Pressure (bar (psi))	System Flow Rate (Lpm (gpm))	Application Rate (Lpm/m^2 (gpm/ft^2))
A	4	14.5 (210)	51.9 (13.7)	5.59 (0.137)
B	1	103 (1500)	12.9 (3.4)	1.4 (0.034)
C	1	103 (1500)	9.1 (2.4)	0.98 (0.024)
D	4	69.0 (1000)	15.1 (4.0)	1.6 (0.040)
E	1	4.5/4.5 (65/65)	10.0 (2.65)	1.08 (0.027)
F	4	69.0 (1000)	12.1 (3.2)	1.3 (0.032)
G	1	103 (1500)	9.8 (2.6)	1.1 (0.026)
H	4	12.1 (175)	37.9 (10.0)	4.1 (0.10)

Table 2. Flammable Liquid Storeroom Tests – Summary Table

System	Tell Tale Tests (Percent Fires Extinguished)	Wood Crib Fire Tests	Trash Can Fire Tests with a 2-minute Discharge (Percent Fires Extinguished)	Large Pool Fire Tests	Cascading Fuel Fire Tests
A	65	Extinguished	100	2 of 2	Extinguished
B	80	Controlled	40	2 of 2	Extinguished
C	80	Controlled	30	2 of 2	Extinguished
D	60	Controlled	90	1 of 2	Extinguished
E	65	Controlled	50	1 of 2	Extinguished
F	80	Extinguished	80	1 of 2	Extinguished
G	80	Extinguished	60	1 of 2	Extinguished
H	70	Extinguished	100	2 of 2	Extinguished