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WATER MIST FIRE SUPPRESSION SYSTEMS

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SUMMARY

The imminent lack of availability of halon fire suppressants has sparked worldwide efforts in developing alternative fire fighting agents and delivery systems. Water mist fire suppression systems are potential replacements in many industrial applications as well as in new markets such as commercial passenger aircraft. Interest in water mist technology has heightened over the past two years. There are several manufacturers with developed products on the market, and more entering the market. Two major conferences were held in 1993 on the topic, and the National Fire Protection Association (NFPA) has formed a committee to write an installation standard for water mist systems. The NFPA 750 Committee "Standard for the Installation of Water Mist Fire Suppression Systems," has formed a task group to summarize the data on water mist fire suppression. An international literature search was conducted, and based on the results of the search and input from the main committee, eight topic areas were identified. Each member of the task group assumed responsibility for compiling an executive summary in one topic area. Each summary contains a description of the hazard, a review of the scenarios tested in the literature, a synopsis of what is known and what further research should be conducted in that topic area, as well as an annotated bibliography of key references. This paper presents an overview of the various types of water mist systems and an introduction to the work of the NFPA task group.

1.0 WHAT IS A WATER MIST SYSTEM ? WHY USE ONE ?

A standard definition of what qualifies as a water mist fire suppression system has not been established. These systems however typically produce water droplets with volumetric mean[1] diameters of 30 to 300 μm and have water flow rates an order of magnitude or more less than a conventional sprinkler system. There are three basic types of nozzles used to produce a fine

[1] water mist sprays are commonly defined by the volumetric mean diameter (VMD) denoted D_V. For example, a $D_{V0.5}$ = 200 μm means that 50 percent of the total volume of the spray is contained in droplets with diameters of 200 μm or less. Drop size can also be characterized by the Sauter Mean Diameter (SMD) which is the volume/surface area mean diameter, or by many other means.

water spray: high pressure single orifice nozzles, low pressure single fluid nozzles, and air atomization nozzles. The high pressure nozzles generally operate at pressures of 10 MPa and up, producing droplets whose mean diameters are in the range of 30 to 100 μm. Low pressure single fluid nozzles generally operate at pressures of 0.6 to 1 MPa. These low pressure nozzles produce a larger drop diameter than their high pressure counterparts. Drop diameters for the lower pressure nozzles are in the range of 200 to 300 μm. Air atomization nozzles generate droplets in the range of 100 to 200 μm at low pressures, 0.6 to 1 MPa, but require a separate air supply in addition to the water supply. There are half a dozen or so companies with developed products on the market and about the same number with products in research or development stage.

Why use a water mist system? How do water mist systems compare to gaseous agent systems? How do water mist systems compare to convention sprinkler systems? These are the questions most often asked regarding use of water mist systems. Some advantages of water mist systems over gaseous agent systems include that water is non-toxic, readily available, and lower in cost than most chemicals or patented mixtures. Water-mist may provide more effective fire suppression than new gaseous flooding agents in applications such as deep-seated fires where the cooling capacity and penetration of water droplets may be an advantage. Another application where water mist may be more effective in fire suppression is high temperature equipment surfaces such as found in machinery room fires and turbine enclosures. The water mist spray will provide cooling of the surfaces not provided by the gaseous agents, potentially preventing re-ignition which may occur if a gaseous agent concentration cannot be maintained for a sufficient period of time [1].

Some advantages of water mist systems over conventional sprinkler systems include significantly reduced water flow rates and therefore less water damage to sensitive equipment or occupancies compared to conventional sprays. Low water flow rates also provide a clear advantage in terms of space and weight requirements for the water supply. This is one reason research and testing of water mist systems is ongoing for transportation systems such as in ships and aircraft. Conventional sprinkler sprays may damage high temperature equipment surfaces mentioned above from too rapid cooling due to high water fluxes and large droplet diameters. In addition, flammable liquid spray fires and some other types of flammable liquid fires that cannot be readily controlled with conventional sprinkler sprays due to splashing and spillage of the fuel have been extinguished by misting sprays under certain conditions.

2.0 MIST CONFERENCES

Research and development of water-mist systems is ongoing internationally at many systems suppliers, insurance and approval laboratories, government agencies, and academic organizations. Two major conferences were held in 1993 on the topic of water mist fire suppression systems. The first was a workshop held March 1-2, sponsored by the National Institute of Standards and Technology (NIST). To facilitate the process of commercializing water mist systems, the workshop brought together approximately 100 people from industrial, academic, governmental, and approval organizations to discuss the issues impeding the commercialization of water mist technology. The workshop included representatives from system suppliers, end users, researchers, insurance and approval laboratories. The workshop resulted in uniting the industrial effort by assessing the value of such systems, and identifying areas of concern to all groups. Panel sessions were held in the areas of research needs, end-use criteria, and marketing. Each panel developed a list of issues impacting upon the implementation of water mist fire suppression technology, then each participant voted in order to develop a priority rank order. Issues that were of concern to more than one of the three panels were: water mist and electrical equipment; standards development; drop size/system optimization; additives; confidence in design criteria/system reliability; cost; acceptability by authorities having jurisdiction; and water quantity and/or quality. Complete findings of the workshop are reported in the workshop proceedings available through NIST [2].

A second conference was held November 4-5, 1993 in Boras Sweden, sponsored by the Swedish National Testing and Research Institute. This was an international conference attended by 19 countries. Research findings in the areas of development of standards and test methods for water mist systems, design of water mist fire suppression systems for ship cabins and shipboard enclosures, consideration of equivalency to sprinkler and traditional water spray systems, and full-scale water mist experiments were presented. Proceedings are available through the Swedish National Testing and Research Institute [3].

3.0 NFPA 750 COMMITTEE

In October 1993, the NFPA 750 committee, Standard for the Installation of Water Mist Fire Suppression Systems, held its first meeting at NFPA headquarters in Quincy, MA. The committee is chaired by Jack Mawhinney of the National Research Council, Ottawa, Canada. The goal of the committee is to develop an installation standard for water mist fire suppression systems. The committee intends to have the standard available for voting at the 1996 NFPA annual meeting.

Task Group IV of the NFPA 750 committee - Review of Research Test Results was formed with the intent of providing a synopsis of the state of knowledge for use of water mist fire suppression systems in various applications and/or fire types, and also to summarize knowledge of the basic principles of suppression mechanisms. An international literature search was conducted and based upon the results and input from the main committee, eight topic areas were identified. Each member of the task group assumed responsibility for compiling an executive summary in one topic area. The executive summaries provide a review of research results, highlighting key issues, and an index of materials likely to be useful to the main committee as well as others interested in the use of water mist fire suppression systems. The task group is chaired by Kathy Notarianni of NIST.

Task group IV has not yet completed its review of the research test results presented in the literature; indeed much of the key research is still in progress. Nonetheless, presented below are excerpts from the executive summaries of what is known in some of the above listed areas, the respective authors are indicated. Further information regarding a topic area can be obtained by contacting the respective authors.

4.0 REVIEW OF RESEARCH TEST RESULTS - EXECUTIVE SUMMARY EXCERPTS

Aircraft Cabin Fine Water Spray Systems
C.P. Sarkos, FAA technical center

The U.S. Federal Aviation Administration (FAA) and British Civil Aviation Authority (CAA) have been engaged in a joint program since 1989 to determine the effectiveness and practicability of an onboard aircraft cabin fine water spray system for improving survival during a postcrash fire. Aviation authorities from Canada and other European countries also participated in the program. Full-scale tests were conducted, the main fire scenario was an external fuel fire adjacent to fuselage opening. The degree of flame penetration through the opening was varied. Survival of cabin occupants is dependent on how fast the fire spreads in the cabin and the time to flashover. It should be noted that the fine water spray system is designed to suppress or reduce the burning rate of cabin materials to allow evacuation of the occupants but does not extinguish the intense postcrash cabin fire.

The fine water spray system evaluated consisted of a large array of small agricultural-type nozzles, mounted throughout the cabin ceiling, which discharged a fine water spray for a period of three minutes. The mean droplet diameter was 100 μm. Test results indicated that this system effectively suppressed postcrash fires in both narrow and wide body test articles. In particular, the fine water mist caused large reductions in air temperature and water soluble gas concentrations. By delaying flashover, very significant survival time improvements were achieved. The water mist system was optimized to a zone system which in the narrow body test article involved 2.4 m (8 ft) long zones with 4 spray nozzles per zone. The nozzles were rated at 1.05 ℓpm.

This study also addressed physiological and other human factors such as inhalation of droplets, effect of fine water spray on evacuation time, and a safety benefit analysis to determine the average savings in lives per year. Two of the large aircraft manufacturers conducted a disbenefits study to evaluate the adverse effects of an inadvertent discharge during flight such as protecting key safety of flight systems from water discharge. A cost analysis was commissioned by CAA to cover a range of water spray system configurations and airplane types. The overall findings made it clear that the safety potential of an aircraft fine water spray system is very great; conversely, the cost/benefit is high and the concerns with installation in an airplane persist. Future studies should address cost issues and further evaluate operational feasibility. A summary of this work was presented at the NIST workshop [4].

Crew quarters/light hazard
Russell Fleming, National Fire Sprinkler Association

Several product-oriented test programs have been conducted for mist protection of specific areas typical to passenger cruise vessels. These programs have focused on crew cabins containing bunk beds and arrangements of upholstered furniture as might typically be found in shipboard lounge areas. The test programs have generally attempted to compare the performance of specific mist hardware to the performance of traditional sprinkler protection, which has been accepted for use in passenger cruise vessels.

Tests were conducted with multiple-orifice nozzle high pressure (10 to 18 MPa) mist systems. Other types of known misting hardware are not addressed. Various actuation methods are utilized, ranging from individual heat actuated nozzles to interconnected actuation of multiple nozzles to deluge operation of all nozzles within an area by means of a separate detection system.

The test literature indicates attempts to "prove" the technology by means of demonstrated performance in sample tests scenarios, but there has been no exploration of a worst case scenario for the mist technology. Bill [5] discusses the rapid extinguishment of the ISO wood crib fire using the water mist and notes that while this particular test was devised to provide a challenge for the cooling and fire control abilities of traditional sprinklers, it does not challenge the water mist systems in the same manner. Nevertheless, the tests that have been conducted to date indicate that water mist has a tremendous potential for rapid knockdown and extinguishment of fires in these light hazard occupancies. The limits of effectiveness and system reliability aspects remain to be explored. Several papers on this topic were presented at the water mist conference in Sweden [3].

Electronic Facilities
Kathy Notarianni, NIST

Studies of effectiveness of water mist systems in electronic environments such as computer rooms and telephone central offices are in progress at many laboratories and manufacturers. One concern with water mist systems in electronic facilities is damage to the equipment from the fine water spray. While this effect has not been quantified, due to the low flow rates and small drop sizes, it is believed that it will be of much less concern than with conventional sprinklers. Whether water flows are sufficiently low to allow such sensitive equipment to keep operating during a spray actuation, which is a requirement for some halon 1301 installations, is still a question. Fire Safety International conducted a feasibility study into water mist fire protection in live switch gear. The study was conducted jointly with GTE. Results of the in cabinet suppression tests showed that the high velocity fogs produced by single fluid nozzles at high pressures proved to be the most efficient fire suppressing combination when placed either at the top, bottom or front of the switch. The high velocity fog was able to negotiate obstacles and penetrate to the seat of the fire. Coarse "sprinkler like" sprays were not effective against this fire challenge. These large drop, low thrust sprays were unable to negotiate obstacles and penetrate to the seat of the fire. Room fogging experiments were less successful than the "in cabinet" tests.

Experiments conducted on live switch gear showed that water fog did not damage the electrical equipment contained in the bay. The power was cut-off to the switch gear bays upon the activation of the fog. The switch gear bays became fully operational when dry. A full report of these tests is given in [6]. Studies of water mist fire suppression in electronic facilities are ongoing at many laboratories including Factory Mutual, NIST, and NRC Canada.

Deflagration control
Robert Zalosh, Worcester Polytechnic Institute

Various studies have been conducted to explore the use of water sprays and mists to inert/dilute gas-air mixtures and to reduce flame speeds and associated pressures in gas-air deflagrations and detonations. Flammability limit concentrations are only marginally narrowed by the application of water spray or mist to a gas-air mixture in a confined environment. In an unconfined environment, the use of a high momentum water spray can entrain air into the gas cloud to rapidly dilute it below the lower flammable limit. This dilution effect is difficult to achieve with water mist because the smaller drops do not entrain ambient air as readily as the larger water drops. For deflagration pressure reduction, experiments have demonstrated that the effect of water spray/mist with a characteristic drop size of 50μm and larger depends on the reactivity of the fuel-air mixture and the flame speed at the time the flame front or pressure wave encounters the spray/mist. In the case of a very high flame speed with an accompanying shock wave, the spray/mist can reduce deflagration pressures and possibly extinguish the flame because the shock wave breaks up the drops into a micromist with a characteristic drop size of 0.1 to 1 μm. These tiny drops can evaporate in a sufficiently short time to absorb a significant fraction of the combustion energy released during the deflagration. In the case of deflagrations with slow to moderate flame speeds, the spray/mist usually has a negligible effect. In detonation tests the water sprays have consistently resulted in lower pressures and often in quenching the detonation. The explanation is the shock induced disintegration of the water drops such that a micromist is formed between the shock and the flame front.

Explosion protection publications describe two specific applications of water spray for deflagration control. One application is the use of water spray curtains to dilute flammable vapor clouds produced accidentally. The second application is the use of water spray systems to control methane-air deflagrations and coal dust explosions in mines. The key to the successful use of water spray systems in mines is the triggering of the system by the pressure/shock wave propagating ahead of the flame front in a long mine gallery.

More widespread use of water spray systems for deflagration control will depend on the viability of generating a micromist (drop sizes of 1 μm or less). This will require water mist systems that are different from those being developed commercially for fire suppression applications.

Machinery room fires
Jack Mawhinney, National Research Council, Canada

The reports reviewed in this summary describe tests of water mist fire suppression systems for machinery spaces on ships. Lugar describes a practical system that successfully extinguished diesel and hydraulic fluid fires in submarine compartments [7]. It used commercially available impingement nozzles at 1.7 and 2.8 MPa pressure to produce the mist. The Royal Navy (UK) worked on water mist systems for submarines in the 1980's, the work is described in [8]. The fog nozzles used in these tests produced a relatively coarse mist with a volumetric mean diameter near 300 μm and has a higher discharge capacity than is desirable for low water requirement systems. The tests showed good control over diesel and hydraulic fluid spray fires in closed compartments. The Danish Fire Research Institute also did testing of air-atomizing spray system for a ship machinery compartment. Fires were 6 to 20 MW. In general, large fires were easier to extinguish than smaller fires [9].

J.R. Mawhinnery of the National Fire Laboratory, Canada, describes engineering criteria involved in designing water mist fire suppression systems, based on experiments done in a mock-up of a shipboard machinery space. The importance of locating nozzles strategically to overcome the problems of obstructions, and the need for high momentum sprays in well-ventilated compartments are described [10].

Turbine enclosures
Robert Darwin, U.S. Navy

Fire suppression tests to evaluate the ability of water mist to control fires in gas turbine modules were conducted during 1992-93 at SINTEFF NBL, Norwegian Fire Research Laboratory. The SINTEFF evaluation was carried out in two phases. The scope of Phase I was to identify the extinguishing characteristics of various two fluid nozzles using air and water at approximately 0.5 MPa pressure. The goal was to select the optimum nozzles for Phase II which involved testing in a full-scale mock-up of a gas turbine in an enclosure, with a gross volume of 77.5 m^3. The gas turbine manufacturer performed an analysis of the effect of the water mist on the hot turbine and also provided key data on turbine operation.

Some conclusions were as follows: the most difficult fires to extinguish were small pool fires, especially if hidden beneath spray obstructions, and fires in oil soaked insulation, the minimum water application densities for extinguishing the various fire scenarios in gas turbine enclosures were 0.06 to 0.07 ℓ/m^3 for large fires and 0.4 to 0.6 ℓ/m^3 for small fires; no "cold shock" damage is done to the turbine if the water spray is cycled so no continuous spray application exceeds 10 seconds. An excellent reference on this topic is the full SINTEFF report, "Fine Water Spray System - extinguishing tests in medium and full scale turbine hood" [11].

Two topic areas not presented above are basic knowledge being prepared by Edward Budnick, Hughes Associates Inc. and flammable/combustible liquids being prepared by William Carey, Underwriters Laboratories. The executive summaries will be published in full upon completion. Further information regarding this publication can be obtained by contacting Kathy Notarianni.

5.0 CONCLUSIONS

Water mist systems show much potential as effective and safe fire suppression systems. There is however still much to be learned for proper system design, engineering and reliability. Much of this work is ongoing by manufacturers, research labs, academic institutions, and insurance and approval agencies. The interested parties are communicating through workshops, conferences, and committee work. NFPA has formed a committee to develop an installation standard for water mist systems. The research tests results and the installation standard will take several years to complete and will need continuous upgrades similar to the development of the sprinkler standards.

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