FINDINGS OF EXPERIMENTS USING WATER MIST FOR FIRE SUPPRESSION IN AN ELECTRONIC EQUIPMENT ROOM

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ABSTRACT

This paper presents highlights from a 3 year study conducted at the National Research Council Canada (NRCC), jointly funded by NRCC and National Defense Canada, which investigated performance criteria for a combined "intelligent" fire detection and zoned water mist fire suppression system. The NRCC study identified basic design requirements for a multi-zone water mist suppression system to protect a control room underfloor, individual electronic switchgear cabinets, and arrays of cable trays, using water mist. The experimental program clarified what is feasible for using water mist to suppress fires in electronic equipment cabinets and rooms. The study also investigated the feasibility of designing a fire detection system capable of pin-pointing the location of a fire in a compartment to within I m, and activating one or more specific zones of a water mist system.

The experimental work supports two conclusions about the use of water mist in electronic equipment rooms. The first is that water mist does not perform well when applied in a "total flooding" mode in obstructed compartments. Total-flooding application resulted in locally unpredictable variations in spray velocity and **flux** density distribution, the results of "random splashing". Extinguishment was equally unpredictable. The second conclusion is that the most important factor in determining suppression performance was control over the direction of application, or "directionality" of the water mist. In other words, the designer should devote more attention to the direction of application of the spray, than to drop-size distribution and mass flow rate. It was noted that very fine sprays ($D_{v0.9} < 90$ microns) were not suitable for electronic equipment areas, in that mist drifted throughout the entire room, outside the area of intended application. Coarser sprays, e.g., with $200 < D_{v0.9} < 400$ microns, provided better control over spread of humidity in the facility, as well as better penetration of grouped cables.

The paper describes highlights from the NRCC study into advanced fire detection features of an "intelligent" fire detection system, needed to allow the water mist system to be subdivided into zones within a large volume space.

INTRODUCTION

The telecommunications and utilities industries have avoided the **use** water as a fire suppressant on electronic and electrical equipment, because of concerns about "water damage". For electronic equipment, applying a conductive and possibly corrosive fluid to powered circuit boards may cause short circuits (short term loss of function), or long term damage due to pitting or corrosion of chips and connectors. For more robust electrical equipment, water damage relates to the danger for electrical short circuits as well as corrosion at connectors and in windings. For these reasons, so-called "clean agents", such as Halon 1301, have been the agents of choice for electronic/electrical equipment environments.

That is, until recently. Having been identified as a major ozone-depleting substance, Halon 1301 is being rapidly phased-out of **use.** The National Fire Laboratory (NFL) at the National Research Council

Canada, has been studying the feasibility of using environmentally benign fine water sprays (water mist) as an alternative to Halon to protect facilities involving electronic and electrical equipment. The "Combined Intelligent Fire Detection and Water Mist Fire Suppression System Project", or IntelMist™ Project, has been supported jointly by the Department of National Defence, and National Research Council Canada. An "intelligent" fire detection system is one that **uses** techniques of artificial intelligence to process analog information on fire conditions, which can select and initiate an appropriate response from a set of possible responses.

To date, the NRCC study has identified basic design requirements for a multi-zone water mist suppression system to protect a control room underfloor, individual electronic switchgear cabinets, and arrays of cable trays [1]. The experimental program clarified what is feasible and what is not feasible for using water mist to suppress fires in electronic equipment cabinets and rooms. The study also investigated the feasibility of designing a fire detection system capable of pin-pointing the location of a fire in a compartment to within 1 m, and activating one or more specific zones of a water mist system [2]. This paper reports on the project findings in these areas.

With respect to the matter of water damage, based on a review of National Defence and utility industry telecommunications equipment scenarios, it was concluded that damage potential is equipment-specific. This was supported by a study done for New Zealand Telecom, on the effects of using water sprays on printed circuit boards, which concluded that normal mains water can be used without causing harm in many cases; but demineralized water may be needed in some cases [3]. The appropriateness of using water as a fire suppressant must be decided on the basis of specific information about the internal design, value, replaceability, and intended function of the equipment. Methods for assessing sensitivity to water damage in specific equipment are needed, so that informed decisions can be made as to the benefits or otherwise of using water mist as a fire suppressant.

A review of fire hazards within control rooms, computer and some switchgear rooms revealed the presence of Class **A** fuels, such as waste paper, computer supplies, foam stuffed operator's chairs, and coffee room supplies. The work conducted to develop a water mist system for the electronic and electrical equipment did not address fires in such materials. **A** complete fire protection strategy for a high value facility would have to take such fires into account.

This report summarizes findings on the following elements of the IntelMist project:

a) water mist characteristics needed to extinguish fires in electronic cabinets;

b) water mist characteristics needed for underfloor cable plenums, and overhead cable trays; and

c) characteristics of the detection system needed to allow zoning of the water mist system.

EXTINGUISHING IN-CABINET FIRES

Fire Scenario

Fire statistics reported by Johnson **[4]** indicate that, with the low fire-spread rate typical of fires in electronic equipment, the majority of cabinet fires self-terminate or are suppressed using hand extinguishers or hose reels. There are often large masses of communication cables leading into and out of the electronic cabinets, however. If fire spreads into these cable arrays, it may not self-terminate, particularly if older-generation, non-fire retardant wiring is mixed with more fire-resistive wiring [5,6].

In tests conducted at the Swedish National Testing Laboratory (SP) in Sweden [7, 8], two telephone network frames were ignited and allowed to burn. One cabinet self-extinguished in 10 minutes. The second cabinet "burned" for 70 minutes at less than 10 kW; rose briefly to a peak heat release rate of –38 kW, then reduced to about 20 kW. The tests confirmed that fires in switchgear cabinets and Telecommunications (TC) main frames are small, slow-growing fires, which can usually be extinguished by cutting the electrical power. During the early stages of burning, and even at full-flaming, the potential for spread to adjacent equipment is low because of the low energy of the fire. The most serious threat to property and function is from the spread of corrosive smoke throughout the facility.

The built-in passive features that limit the spread of tire in electronic equipment cabinets bring into question whether an active fire suppression system is needed. After review of several National Defence facilities, with mission-critical equipment on uninterruptible power supplies, and also the circumstance of a public power utility operating remote, unmanned switchgear facilities through micro-wave transmissions, it was concluded that an in-cabinet fire suppression system can be justified under certain circumstances. This study then concentrated on determining how to extinguish an electronic equipment cabinet fire using water mist.

It was established quickly that it was impossible to extinguish a fire inside an electronic cabinet by application of mist to the exterior of the cabinet. The subsequent experimentation was based on application of mist to the interior of each cabinet. Two cabinets were used for fire tests. Cabinet A was 0.86 by 0.80 by 1.69 m (2.8 x 1.6 x 8.6 ft) high, with two magazines ofvertically mounted printed circuit ("PC") boards, and bottom-to-top ventilation from an underfloor opening. Cabinet B was 0.98 by 0.78 m wide by 1.70 m (3.12 x 2.6 x 5.6 ft) high, with horizontally-oriented PC boards, and horizontal air flow from an internal ventilation plenum and fan. Both cabinets were equipped with hinged doors. When the door was closed, ventilation air escaped from the cabinets through grilles in the cabinet doors and top surface. Tests were conducted using different rates of ventilation through the cabinets, ranging from 0, 0.25 to 1.0 m/s (0, 50 to 200 fpm) entrance velocities. Thermocouples were situated in the cabinet to record temperatures during fire tests. A gas sampling probe was installed between the two magazines of PC boards, connected to 3 m (10 ft) long 6 mm (1/4") diameter heated sampling line, so that measurements of O_2 and H_2O (vapor) could be made

A representative fire was created using two 300 by 100 mm (12 x 4 inches) PC boards mounted with the component surfaces facing each other, 32 mm (1.25 inches) apart. An electric stove element was inserted between the two PC boards. Upon exposure to the red-hot element, the fire-resistive boards first emitted a strong, acrid odor: and wisps of white smoke appeared after 1 or 2 minutes. By four minutes thick smoke with very strong odor was emitted; at 5 minutes many plastic surface components were "bubbling"and melting. In some cases the faces of the boards would spontaneously break into flaming combustion. If not, flaming was initiated by piloted ignition at 8 minutes. Due to the difficulty of purging the laboratory of the irritating, noxious smoke given off by the PC boards, the test fire was simulated using two pieces of 6 mm (114 inch) thick masonite board instead of PC boards. Heat from the stove element was reflected between the two surfaces, creating the representative "sandwich" tire. The heat release rate was estimated to be between 3 and 6 kW. To extinguish this fire, it would be necessary to wet or cool the board surfaces inside the 32 mm (1.25 inch) space between the boards.

Range of Spray Characteristics

A variety of nozzles were tested in order to identify the characteristics needed to extinguish the test tire. In cabinet **A,** sprays were applied from below the fire, in the same direction as the ventilation air flow; and from above the fire, counter to the ventilation air flow. Four distinct spray qualities were considered:

1. Very tine, low momentum mist ($D_{v0.9} \approx 75$ microns) intended to be drawn through the cabinet by the internal ventilation air-flows. Low-pressure, air-atomizing nozzles with a flow rate of 1.5 L/min per nozzle; spray cone angle 20°, were used.
2. A moderate momentum mist with $D_{v0.9} \approx 125$ microns. A Semco nozzle was selected, with flow rate **3** L/min at 80 bar (0.8 gpm at 1,175 psi), and spray cone angle of 90°. One or more nozzles discharged into each of the upper and lower compartments (Cabinet A). It was expected that the high velocity and small drop size would cause mist to penetrate closely spaced PC boards.
3. *A* high flow rate nozzle was used to generate a coarser spray ($D_{v0.9} \approx 300$ microns), intending to "drown" the fire in the cabinet. A Spraying Systems Company (SSC) 3/4 7GS nozzle was used, with spray cone angle of 150° and flow rate of **35** L/min at **5** bar pressure (9.2 gpm, **74** psi).
4. Mist was generated by release of super-heated water through simple orifices, to create a spray with a high percentage of very tine drops ($D_{v0.9} \approx 20$ microns) produced by condensation from steam, combined with a relatively coarse spray created by the shattering of water during the flashing process [9]. The mist was expected to reduce the oxygen concentration in the cabinet.

Summary of Findings from the Cabinet Fire Suppression Tests

Over 90 fire suppression tests were conducted in the cabinets. The experimental work demonstrated that it is possible to extinguish small fires in closely spaced electronic circuit boards using water mist. The manner in which the mist is injected into the cabinet is critical to performance, however. Inappropriate selection of nozzles and spray characteristics will result in either waste of water, or failure to extinguish tires. Key findings from the tests are stated as follows.

1. The geometry of closely-spaced printed circuit boards dominates the distribution of mist within cabinets, hence the ability to extinguish tires. Unless spray is injected in a direction that allows mist to penetrate the narrow inter-board spaces, fires are not extinguished. This finding is consistent with the study conducted by Grosshandler, et. al. [10], which describes the limited depth and width of effective extinguishment zones within parallel circuit boards.
2. Control over the direction of the spray was the single most important factor to ensure the ability of water mist to extinguish fires in cabinets filled with parallel arrays of circuit boards. Controlling direction of application had a greater effect on performance than either drop size distribution or flux density.
3. Very fine sprays with low momentum and low mass flow rate were ineffective at penetrating arrays of closely spaced circuit boards. Spray penetrated only the few channels that were parallel with the axis of the spray.
4. There was no measurable advantage to the fact that the fine spray could be carried with the ventilation air into the board spaces. At typical ventilation velocities, the total mass of water suspended in drops small enough to be carried with the ventilation air was insufficient to achieve extinguishment.
5. **As** shown in Figure 1, only the fraction of the spray that had the right "directionality" relative to the PC boards was effective. Most of the water in wide-angle cones was wasted. Increasing the drop size distribution and flow rate only meant that more water was ineffective.

6. Mist generated by flashing of super-heated water did not increase the rate of oxygen displacement by water vapor. The temperature of the steam reduced rapidly to 35C, at which temperature the water vapor concentration was insufficient to affect oxygen concentration. Extinguishment depended on the same factors as for conventional sprays. **A** discussion of these experiments is provided in reference [9].

7. Very tine drop size was not an advantage for electronic cabinets. The drifting of fine mist throughout the room raised humidity and condensation levels in areas well removed from the fire Coupled with the soluble HCI which can be expected to be present with the burning of plastic wiring, the uncontrolled spread of slightly acidic, ultra-fine mist is undesirable. Coarser sprays ($D_{v0.9} \approx 300$ microns) were just as effective, and remained in the vicinity of the point of application.

8. Changing from conical spray cones to linear spray distribution, provided extinguishing capability over the full width and height of the circuit boards. Because all of the water was used effectively, the overall water requirement from linear distributors was much less than for wide cone-angle spray nozzles, Water discharge rates of approximately *3.7* Liminim *(0.3* gpmift) were successful, (but not optimized).

9. For many types of cabinets, horizontal or vertical tubes can be installed to discharge lines of small diameter jets into the magazines of printed circuit boards. Direction can be changed as needed to suit several local geometries in a single cabinet. Due to wide variability in electronic and telecom cabinet design, the mist system tubing must be custom fit.

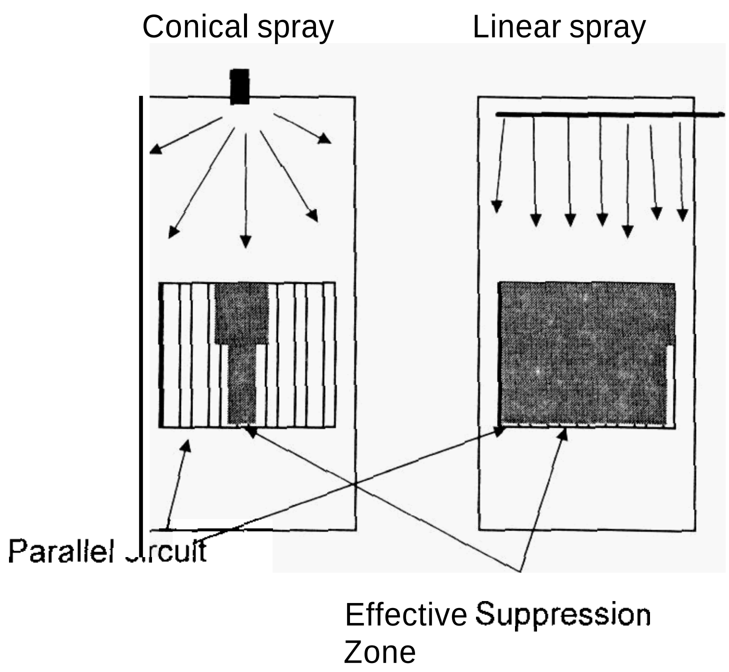

Figure 1. Zones of effective fire suppression in arrays of printed circuit boards, using conical and linear sprays.

EXTINGUISHING FIRE IN UNDERFLOOR CABLE PLENUMS

Fire scenario

Electrical power cables and communication wires in switchgear rooms, control rooms and computer rooms are often spread beneath a raised floor, from where they are brought up into the equipment cabinets on the floor above. Wires and cables may be run neatly in trenches or cable trays, or they may be run freely in every direction. In some facilities, every square metre of floor area could be covered with several layers of plastic-sheathed cables, including some abandoned older vintage wiring that was disconnected by not removed. Ignition could occur if insulation was damaged, with the eventual occurrence of a short circuit and arcing. If the power supply could not be cut (i.e., "uninterruptible" (UPS)), sustained arcing could ignite the plastic sheathing and spread.

Current North American standards for plastic cable insulation ensure low combustibility, which means that unless there is a sustained high-energy heat source, the insulation **will** self-extinguish. Nonetheless, most recent telecommunications facility fires have involved cables, rather than cabinets. As with the cabinet fire scenarios, whether passive fire safety measures are sufficient reason to omit installation of an active suppression system depends on the conditions at specific facilities.

The fire suppression tests carried out in these experiments are based on an assumed fire scenario in which arcing generates a self-sustaining fire in a bundle of closely spaced communication wiring. To simulate such a fire, a cable bundle was prepared using 12 pieces of 25 pair PVC-jacketed fire retardant communications cable, 300 mm (12 inches) long. In the midst of the 12 pieces were placed **3** lengths of 15 mm (5/8 inch) diameter sisal rope, which had been soaked in diesel fuel. Once the diesel-soaked sisal rope began to burn, plastic insulation softened and charred, and began to contribute to the burning. The fire would spread along the bundle, attaining a length of 200 mm (8 inches) within one minute. The heat release rate from the test fire was estimated to be between **3** and ***6*** kW. The bundle was laid on the cross supports of a cable tray, so that it was approximately 30 mm (1.2 inches) above a concrete floor, such that air was available from all sides.

The Plenum

Fire tests were conducted in a simulated underfloor plenum, ***6*** m x 9 m x *0.6* m (20 ft x 30 ft x ***2*** ft) high. The vertical floor supports created distinct channels, 0.4 m wide by *0.6* m high by **9** m (16 in. x 2 ft x 30 ft) long in one direction, and 0.6 m x 0.6 m **x** 6 m (2 ft x 2 ft x 20 ft) long in the other direction. When viewed at any angle other than orthogonal to the axes of the room, the floor supports obstructed the lateral distribution of water spray. The appearance was similar to underfloor arrangements viewed, in which many cables rose from the underfloor into equipment above the floor. A ventilation system was provided, such that air circulated through the underfloor plenum, and *rose* into the control room through openings in the floor covering.

Spray Nozzles and Test Arrangement

Two types of sprays were used in the underfloor. The first was a single-point discharge nozzle placed at mid-height of the plenum on an end wall, which produced a 180" fan of spray of **3** m (10 ft) radius. It was intended to extinguish fires anywhere within the fan area. The mist, produced by flashing of superheated water, was rich in aerosol-sized droplets and water vapor, but also contained a substantial mass portion with Dv0.9 > 200 microns. Discharging 50 L/min (13.2 gpm), the nominal flux density was 3.5 Liminim' (0.09 gpm/ft^2).

The second spray was produced using lines of nozzles oriented so that spray was discharged in a direction parallel with the vertical floor supports. The nozzles were spaced 0.3 m (1 ft) apart, symmetrically within each 0.6 m (2 ft) wide channel created by the floor supports. The area of coverage extended **3** m (10 ft) from the middle axis of the test room to the walls, i.e. 1.8 m^2 **(20 ft^2)** per pair of nozzles. Each swirl type nozzle discharged approximately 5 L/min (1.3 gpm), for a nominal flux density of 5.6 L/min/m^2 (0.14 gpm/ft^2). This spray had a Dv0.9 ≈ 300 microns. The cable bundle was placed at various locations within the intended area of coverage of each nozzle system.

Summarv of Findings from the Underfloor Fire Suppression Tests

The following points summarize the findings of the twenty three suppression tests conducted in the underfloor.

1. Water mist extinguished small incipient fires in electrical cables by direct fuel wetting. Very fine mist consisting of suspended droplets was ineffective, even when the fire was completely obscured by the fine mist. Extinguishment occurred only when enough water penetrated between the individual cables in the cable bundle. The finest mist fraction could not penetrate between the cables. There was therefore no advantage in using very fine water mists (Dv0.9 < 100 microns) for incipient fire suppression in underfloor cable plenums.
2. Sprays with drop size distribution in the range 200 < Dv0.9 < 400 microns, are likely to be effective with both cable fires and other class **A** combustibles, such as construction materials or debris, which can be found in underfloor plenums. Such sprays can be generated by a wide range of low pressure nozzles (< 175 psi [12 bar]).
3. Control over the "directionality"of the spray cone was of greater importance to the extinguishing capacity of the system than either drop size distribution of flux density. Cost-effective water distribution depended on minimizing the amount of wasted water by striving to apply it with the appropriate control over direction and area of coverage.
4. Total-flooding of an obstructed underfloor space with nozzles designed to cover large areas cannot be guaranteed to extinguish all fires within the coverage area. The "random splashing" of spray in the midst of obstructions left 'holes' in the flux density distribution, which corresponded to areas where small fires could not be extinguished. It was difficult to predict the location of such 'holes'.
5. Water mist nozzles should be located so that the spray direction and the flux density distribution can be reasonably well predicted at all points. This may be achievable in spaces that are sparsely filled, or which are structurally symmetrical. However, in non-symmetrical obstructed spaces, too many nozzles would be required and the piping too complex, to be practical. Complex piping arrangements will create further problems for zoning the water mist system.

EXTINGUISHING FIRES IN OVERHEAD CABLE TRAYS

Fire scenario

A third distinctive fire scenario in telecommunications facilities is fire in overhead cable trays. There are many possible arrangements of cable trays. In some facilities, cable trays are crowded into a l or 2 m (3 to 6 ft) deep space between the tops of electrical cabinets and the ceiling. In other facilities there may he **3** to **4** m (10 to 13 ft) of clear space between ceiling and tops of cabinets, with anywhere from a few to many widely spaced cable trays. Cable trays themselves may he shallow or deep, narrow or wide; partially filled or overfilled with cables. They may run parallel or orthogonally to each other; or be horizontally or vertically oriented. With such a range of conditions, it is hardly possible to establish water mist fire suppression system design criteria that are applicable without modification in all circumstances.

In the NRCC study, cable trays were located in the middle of a large volume space, well away from the walls of the compartment. The test room was 6 m wide by 9 m long by 6 m high. The space above the switchgear cabinets was approximately **3.5** m (11.5 ft) deep. Nine open-bottomed cable trays were suspended in **3** arrays around the center axis of the room, 0.6 m (2 ft) apart vertically, and 1 m (**3.3** ft) apart horizontally. The same test fire involving the bundle of cables plus diesel soaked rope was used, as for the underfloor fire tests. The performance objective was to extinguish the small test fire.

Two trial designs were used for the water mist system. The first involved arrays of nozzles mounted on opposite walls, each projecting spray horizontally toward the center of the room. The philosophy was to create a dense cloud of mist in the upper half of a **3** m by 6 m (10 ft by 20 ft) section of the room, in a total-flooding approach. Various nozzle spacings, nozzle types, and flow rates were used. The second design concept utilized narrow cone-angle nozzles placed on each cable tray to discharge along the length of the tray, spaced between 2 and **3** m (6.5 and 10 ft) apart. In the latter case, the spray cone was only wide enough to direct all of the mist into the cable tray, with as little overspray as possible.

Test fires were placed at various locations within the array of cable trays. Fires that went out within one minute of start of spray application were considered extinguished. Flux density measurements were taken using lines of collector cups at 150 mm (**6** inch) spacing. The collector cups were placed in various trays. The flux density measurements collected in this manner revealed the extent to which spray was obstructed by adjacent trays. Areas of low flux density corresponded to inability to extinguish the small test fires.

Results of the fire tests

Spray projected from wall-mounted nozzles into a large volume space could not reliably extinguish the small test fires at all points within the cable trays. The reasons for these failures, and other disadvantages to the total-flooding approach, are listed below:

1. The water mist distribution into the trays was very uneven. Wall nozzles were placed closer and closer together in an attempt to eliminate flux-density depressions between nozzles. In eliminating the weak spots. however, other areas received too much spray. And, although the top tray received reasonably uniform distribution, intermediate trays received much less spray. This problem became worse as the vertical distance between cable trays decreased.
2. Trays on either side, above and below, obstruct the distribution of spray. Effective flux density distribution might be achieved on the outermost trays (with no obstacle between the tray and the wall nozzles), hut not on the second tray in. Relying on “random splashing” to deliver water mist to critical areas is both inefficient and unreliable.
3. Nozzles arranged to discharge in a direction parallel with the cable trays were no more effective than nozzles discharging orthogonally into the array. Adequate flux density distribution was limited to only 1 m (**3.3 ft**) from the entry point of the spray. from the end of each tray.

4. The 100 mm (4 inch) sides to the tray were sufficient to shield a small tire at the edge of the tray from the spray. It is recognized that injection of a general spray would mitigate room conditions of a larger cable fire.

5. Filling the upper volume of the room with mist, or even a zone consisting of one-third of the room, will contribut to unacceptable levels of water damage. Water mist and humidity cannot be confined to the area of application.

The second design concept, involving individual nozzles dedicated to each 3 m (10 ft) of tray, (the in-tray nozzle design) was more successful. The reasons for the improved performance are listed as follows:

1. With individual nozzles mounted on each cable tray, almost all of the water from each nozzle was confined to the width of its tray. A specified flux density could be achieved at a fraction of the total flow rate of the wall-mounted nozzle system.

2. The in-tray nozzle design allowed for operation of only one or *two* low-flow-rate nozzles to protect each 3 m (10 ft) length of tray. Because flux density targets could be reliably achieved, extinguishment was predictable over the spacing. As per the in-cabinet tests, it was found that coarser sprays were preferable to finer sprays, which tended to spread humidity beyond the area of application.

Implications of the Cable Tray Test Results

The tests showed that the total-flooding (or "random-splashing") approach to system design was unreliable as a fire estinguishant, inefficient as a system, and damaging to other electronic equipment in the facility. The in-tray nozzle system, on the other hand, was effective on the small test fires, with much reduced spread of water and humidity. There are arguments that it may be "impractical" to install a line of nozzles on each cable tray. In that light, early generations of cable sprinklers were never widely accepted, because the design concept required installing nozzles in or over each cable tray. A preliminary review of the feasibility of an in-tray nozzle water mist system concluded as follows:

1. A water mist system utilizing small diameter tubing, and demanding, for example, less than 1.0 Umin per metre (0.08 gpm per ft) of tray, appears to be an improvement over systems of cable tray sprinklers, which were not well accepted. The practicality of an in-tray water mist system must be assessed on a case-by-case basis, taking into account limitations on alternatives.

2. A method of clipping pressure tubing to the side of cable trays, with branch-overs to position nozzles over the center of the tray, should be developed. Such a method should be no more difficult to install on individual cable trays than to pull a new cable through the tray.

3. Long cable trays should be divided into zones. This can be achieved by coupling a linear thermal detection device to the water supply tubing, and installing solenoid valves at selected distances along the supply line.

4. A prototype system should be constructed to confirm the reliable performance of linear thermal detection, solenoid valves and mist delivery.

FIRE DETECTION FOR A ZONED WATER MIST SYSTEM

Detection Options Review

For water mist to be accepted for use in electronic/electrical equipment rooms, water must be applied only where it is needed. To do this, the water mist system must be divided into zones, each controlled by a valve. Zoning the piping system requires the installation of an "intelligent" detection system that can locate the fire and instruct a control unit to open the corresponding valve(s). The detection system must continue to monitor conditions in the compartment, so that the logic center can make changes if conditions change. An "intelligent" fire detection system, then, uses techniques of artificial intelligence to process analog information on fire conditions, and can initiate an appropriate response. To define the performance objectives of the required detection system, the NRCC study reviewed current and emerging detection technology [2]. The review included measuring the strength of thermal signals from small (4 kW) fires in the NRCC test mockup, under ventilated and un-ventilated conditions. The possibility of using species signatures such as CO and HCI as part of a multi-sensor detection system was also examined. Brief highlights from the detection options review are as follows.

1. Many telecommunications facilities have "early detection" features which can identify the presence of very small fires, but not pin-point its location. There are multiple levels of response to the early signals, ranging from alert, to shut down of equipment, and finally activation of suppression measures. The "intelligent detection system" for control of a zoned water mist system must be integrated with the existing fire signal response structure.
2. The temperature signature was selected as the most appropriate for use in deciding when to discharge water mist, because it was least likely to be ambiguous. All other stages of planned response should have been exhausted by the time the fire is severe enough to justify activation of the mist system. At that stage, the thermal signature is obvious. In addition to the thermocouple and thermistor devices already available, new fibre optic and linear detection technologies are under development by several manufacturers, which promise to be able to locate even a small (4 kW) heat source to within I m (3.28 ft).
3. "Fuzzy logic" is the most promising signal-processing approach to handle the ranges of ambiguity in signals from a multi-sensor detection system in complex spaces. Fuzzy logic algorithms already exist which can be modified to relate multiple signals to an array of response options.

RESULTS AND FUTURE PLANS

The NRCC research concluded that water mist can be used to suppress fires in electrical and electronic equipment in a manner that will minimize water damage, if the system is carefully engineered. The critical characteristics of water mist flow rate, drop size distribution and degree of control over directionality, as well as the elements of the intelligent detection system and signal processing logic, are described. With completion of these tasks, the feasibility of using water sprays to replace Halon in electronic and telecommunications equipment rooms was established.

Further work is needed to actually assemble a working system, based on a specific set of electronic equipment, in order to establish the cost effectiveness and overall reliability of such a system. NRCC is seeking to form a consortium of water mist equipment manufacturers, expert detection system manufacturers, and potential users, to develop a proto-type system that incorporates the suppression and detection/logic elements described in this study. It is intended to develop the proto-type system for a moderate-sized facility representative of a common telecommunications room scenario, so that extension from the proto-type system to the market place can be easily realized."

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