Halon Replacement:
Water Mist Fire Extinguishing Systems

BY RONALD R. SPADAFORA

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IN THE EARLY 1980S, IT WAS CONFIRMED THAT THE earth’s ozone layer was being depleted. Although it makes up a small percentage of the atmosphere, the ozone layer is nonetheless essential to all living things. Located mostly in the stratosphere, the ozone layer protects us from the sun’s ultraviolet medium wave (UVB) light, which can be harmful to humans (can be a factor in skin cancer), crops, and marine ecosystems.

In 1987, the international document “Montreal Protocol on Substances that deplete the ozone layer” was adopted to protect the ozone layer. Originally, 25 countries, including the United States, signed the Protocol. Eighty countries signed it when it was amended in 1990. More and more countries have been adopting it in a worldwide attempt to protect the environment. A provision of the Protocol was to ban the use of halogenated hydrocarbons (halons), valuable fire extinguishing agents, because of their ozone-depleting effect: Halons decompose into chlorine, fluorine, and carbon components that react with the ozone in the atmosphere to eliminate it.

The United States Environmental Protection Agency (EPA) mandated that a search be made for acceptable alternatives for two of the most common halon firefighting agents, Halon 1301 and Halon 1211.

Halon 1301, a gas under normal conditions, is composed of carbon, fluorine, and bromine. This effective extinguishing agent, which has a low degree of inhalation toxicity, is discharged from nozzles in total flooding (enclosed space) applications. Halon 1211 is a liquefied, compressed gas containing carbon, fluorine, chlorine, and bromine. It has a slightly greater toxicity than Halon 1301 and is used with hand-held portable fire extinguishers and wheeled and outdoor mobile streaming devices.

SNAP PROGRAM

Under the Clean Air Act Amendment (1990), the EPA evaluates various substitute fire extinguishing agents that do not destroy the ozone layer but also have a low global warming potential (GWP) and atmospheric lifetime (ATL). Through the Significant New Alternatives Policy (SNAP) program, the EPA is transitioning the United States from the halons to human-safe and environment-friendly systems.

The following extinguishing agents have been approved as replacements for Halon 1301 under the SNAP program: fluorinated ketones (FKs), fluoriodocarbons (FICs), foam, hydrochlorofluorocarbons (HCFCs), hydrofluorocarbons.
As a SNAP substitute, water mist systems have been credited with enhancing visibility inside the fire enclosure. Atomized droplets have a unique smoke “scrubbing” quality that removes the soot from the smoke during the fire. Nozzle spray characteristics, nozzle spacing, ceiling height, smoke layer temperature, and the depth and spacing, ceiling height, smoke layer temperature, and the depth of the smoke are all factors that have to be taken into consideration when quantifying the amount of smoke that will be removed from the atmosphere. Water mist droplets have also been attributed with filtering out corrosive and toxic vapors generated by materials such as wood, plastics, and combustible liquids. Water mist atomized droplets, however, cannot remove insoluble toxic gases, such as carbon monoxide, which is generated in abundance during interior structural fires.

**WATER MIST SYSTEMS**

This course examines water mist extinguishing agent systems that can be used to replace Halon 1301 and Halon 1211. A water mist system is an automatic water-based fire extinguishing system. Water mist is a fine spray with 99 percent of water volume contained in water droplets less than one millimeter (1,000 microns) in diameter. Water mist systems can be designed as a total flooding system protecting a large enclosure with sprinkler heads, spray heads, or nozzles placed at intervals. They can also be used for local streaming applications. This type of system has applicators or nozzles aimed directly onto a specific piece of machinery or equipment to be protected. In 1995, the EPA asked industry to evaluate water mist as a halon alternative. A health panel that was established determined that water mist systems did not present a health hazard to humans when used in occupied spaces. Using this information, the EPA listed water mist as a SNAP substitute.

**How Water Mist Systems Work**

Water divided into very fine droplets creates a greater surface area than standard droplets emitted from sprinkler system heads. Water mist system droplets can be 20 times smaller and have a surface area 400 times greater than sprinkler system water droplets. This enhanced area allows more of the water to absorb the heat from the fire. A greater amount of the water, therefore, will turn to steam, providing what is known as the “latent heat of vaporization.”

When water changes from a liquid to a gas, it absorbs approximately 970 British thermal units (Btus) of heat energy per pound. Each gallon of water, which weighs approximately 8.3 pounds, will therefore absorb more than 9,000 Btus (energy required to raise each pound of water to 212°F plus the energy absorbed to change its state of matter). This drastically reduces the combustion rate. The steam will also occupy a much larger volume than if the droplet were in liquid form. The expansion ratio of gas to liquid is in the range of 1,700 to 1. Steam will also create an inert atmosphere as it displaces oxygen from the flame zone, thereby starving the fire of its oxidizing agent, yet another vital element of the fire triangle.

Atomized droplets being discharged continue to remove heat from the fuel source even after the fire has been extinguished. This prevents flammable vapors from being emitted and keeps the fire from reigniting. These systems also absorb and scatter radiant heat, reducing the amount of energy projected onto the burning material as well as room contents.

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**CLASSES OF FIRE**

Water mist fire suppression systems have been extinguishing solid and liquid fuel fires since the mid-1950s. They have a wide range of applications against Class A fires (wood, cardboard, paper, cloth, textiles, rubber, and certain plastics). Water mist systems have been successful in extinguishing Class A fires inside high-rise office and residential buildings, using total flooding applications. Cruise ship passenger cabins, places of public assembly, hotel atriums, libraries, archives, museums, art galleries, landmark/heritage structures, and storage warehouses are just a few more examples of buildings and spaces containing these types of material.

Class B fires (liquid, fuel, oil, lubricant, alcohol, ether, grease, and gas) originating in boiler rooms, engine rooms, spray booths, machinery spaces, gas turbine areas, road and rail tunnels, oil- and gas-production facilities, petrochemical plants, and material conveyors are ideally safeguarded using total flooding and local water mist system applications.

Water mist is also effective in extinguishing fires involving energized electrical equipment, known as Class C fires (computer rooms, telecommunication centers, electronics equipment, wiring, cable tunnels, transformers, circuit boards, electrical switchgear modules, and metro station and train carriages). The shock hazard to firefighting personnel and occupants is negligible. Additionally, the “scrubbing” effect of water mist on carbon smoke particles helps to reduce soot residue damage to sensitive electrical equipment. Both total flooding and local application systems are used.

Water mist local streaming application systems are also used on Class K fires, which involve commercial cooking and food-processing equipment that use vegetable oils (palm, olive, soybean, canola, corn, sunflower, safflower, sesame, and rice bran).

**APPLICATIONS**

**Total Flooding**

Total flooding systems are designed with nozzles that discharge water mist throughout an enclosure to provide a uniform extinguishing concentration. Enclosure openings are typically installed with automatic closing devices that activate prior to the discharge of the extinguishing agent.

**Local**

Nozzles discharge water mist directly onto the equipment or material being protected. This type of application is ideal...
for outdoor protection, since it does not rely on an enclosure to contain the extinguishing agent during the course of fire suppression.

**Zoned**

This system segments the area to be safeguarded into spatial zones. Each zone has its own detection and activation components. A zoned system can provide more efficient use of a limited water supply. Zoned systems are used to protect sensitive equipment and valuables found in complex floor layouts and compartments. Applicators apply water directly onto the hazard for dependable fire suppression. A detection system that can determine the exact location of the fire as well as a piping control system capable of opening and closing valves in the water distribution piping is required. Recent successful fire tests using zoned water mist systems in military and commercial airline passenger cabin, cargo, and lavatory compartments have earmarked this new technology as an alternate replacement for existing halon extinguishing systems.

**Hand Hoseline**

This system consists of a fuel- or electric-driven high-pressure engine with an integral water mist nozzle, hose reel, and water tank. Hand hoseline systems are designed to be used manually for direct application of water mist onto the fire. They are mounted to fire service all-terrain vehicles and pickup trucks to enhance outdoor firefighting capabilities when encountering automobile and brush fires.

**Fire Extinguisher**

Hand-held extinguishers containing water mist are portable extinguishing tools that are clean and create no risk to firefighters or occupants when used inside hospitals and health-care facilities. They can also protect telecommunications and electronic equipment rooms.

**SYSTEM PRESSURE**

The size of the water mist droplet depends on the nozzle’s orifice design and pressure. Pressure allows the droplets to be projected over long distances so that the water reaches the seat of the fire. All three pressure systems—low, intermediate, and high—can be with water under pressure. Water discharges immediately from thermally activated nozzles. This type of system is fast and highly effective.

The dry system uses thermally activated automatic nozzles attached to piping that contains air, nitrogen, or inert gas under pressure. On activation of the nozzle, the dry pipe valve opens, allowing water to flow through system piping and out any activated nozzles. This system is designed to protect unheated buildings or areas.

In the preaction system, the piping contains air that may or may not be under pressure. This system has a supplemental detection system that, when activated, opens a valve, allowing water to flow into the piping and discharge through the open thermally activated nozzles. Preenction systems provide an added safeguard against water accidentally being discharged into an area containing delicate and valuable commodities.

The deluge system also has a detection system. When the detector is activated, it supplies water throughout the piping system. In this system, all nozzles are nonautomatic and of open design. They work, however, by flooding the area to be protected with copious amounts of water from all the nozzles.

Note: Water mist systems can be categorized as single fluid or twin fluid. A single-fluid system uses a lone pipe to supply water mist nozzles. The twin-fluid system uses dual piping to supply water and compressed air or inert gas separately to water mist nozzles.
used for fixed (total flooding) and local (streaming) applications.

**Low-Pressure Systems**

The water flows through the piping at pressures similar to those of the standard sprinkler type systems (175 psi or less). Low-pressure systems are used in large open-room areas and enclosures for total flooding protection as well as local applications. Aircraft hangers, fuel truck garages, and car decks are just a few types of structures where low-pressure nozzles are found embedded in the floor to extinguish fire below planes and vehicles. These “buried” nozzles operate in conjunction with nozzles installed along the ceiling for additional protection.

**Intermediate-Pressure Systems**

Intermediate systems use pressure in the 175- to 500-psi range. Total flooding systems using intermediate pressure generate water droplets that provide good circulation and prolonged hang time throughout the protected space. These systems also demonstrate enhanced flame-cooling and oxygen-depletion characteristics. They are used inside large industrial enclosures.

**High-Pressure Systems**

Their piping can withstand pressures greater than 500 psi. In general, this type of system requires fewer nozzles and less water to achieve successful fire suppression results than low- and intermediate-pressure systems. The high pressure generates substantially smaller water droplets at the nozzle than the other two systems, enhancing the surface area and heat-absorbing capacity of the droplets.

**SYSTEM COMPONENTS**

**Water Supply**

Water mist systems must have at least one automatic water source. The minimum amount of water should be capable of supplying simultaneously the largest single hazard or group of hazards to be protected. In general, a water supply for a minimum duration of 30 minutes is required. Pre-engineered and specific-hazard systems may warrant a water supply duration of more or less than 30 minutes. Water may be found stored inside pressurized tanks, containers, or cylinders. All water vessels have a pressure gauge. A fire department connection is needed for systems protecting 2,000 or more square feet. Twin-fluid systems and intermediate- and high-pressure systems supplied only by storage cylinders may be exempt from the requirement for a fire department connection.

**Compressed Gas Supply**

When an atomizing medium (air, nitrogen) is used as part of a twin-fluid water mist system, it, too, should be automatically supplied from a dedicated source in concurrence with the water being delivered on the fire. Look for a nameplate or placard on or near the gas containers specifying the type of gas, the nominal gas volume, and the container’s pressurization level. Pressure gauges and a fire control panel will help firefighters to monitor the amount and pressure of the gas. A reserve supply may be required when the compressed gas cannot be readily replaced on activation.

**Foam Additive Supply**

Some water mist systems have an additive injection component to introduce Class A or Class B foam concentrate into the piping. A small amount of foam concentrate added to the water supply can significantly improve the water mist system’s performance when suppressing buried ordinary combustibles and liquid fuel spill fires. The resulting thin layer of foam solution blanketing the fuel spill reduces the amount of vaporization and inhibits the amount of radiant heat energy absorbed by the fuel.

**NOZZLES**

Water mist nozzles are thermally activated, using quick-response glass bulbs that have operating temperature ratings from 135°F to 650°F. They are color coded based on their temperature classification. The nozzles incorporate a high-capacity filter to shield against impurities in the water. Nozzles are designed for use in accommodation and service spaces. Other types of nozzles do not use glass bulbs. They are opened by valves that can be activated manually or automatically by an electrical, hydraulic, or pneumatic signal. They consist of an assortment of nozzles of different sizes, depending on the fire hazard. Nozzles have total flooding and local applications. Water mist nozzles are defined in National Fire Protection Association 750, *Standard on Water Mist Fire Protection Systems*, 2006 edition, as special-purpose devices containing one or more orifices designed to produce and deliver a water spray and can be of the automatic, nonautomatic, or “hybrid” type.

**PIPING**

Water mist extinguishing systems use small-diameter, stainless-steel or copper/copper alloy piping. Filters and strainers are provided at each water supply connection or system riser.
**WATER MIST SYSTEMS**

**PUMPS**

Centrifugal fire pumps are used in low- and intermediate-pressure water mist systems. High-pressure systems require positive displacement pumps. These pumps will be driven by electricity, diesel fuel, or gas. Fire pumps for water mist extinguishing systems are designed to exceed flow rate and pressure demands by a minimum of 10 percent. Pump installations must have a metal plate that provides the rated capacity and pressure of each pump.

**DETECTION**

All detection systems used to actuate water mist systems will be automatic. Very early (air-aspirating) smoke detection systems are recognizable. Must be accessible, and its intended purpose must be clearly operation is required for all water mist systems. This device will be driven by electricity, diesel fuel, or gas. Fire pumps for water mist extinguishing systems require positive displacement pumps. These pumps will be driven by electricity, diesel fuel, or gas. Fire pumps for water mist extinguishing systems are designed to exceed flow rate and pressure demands by a minimum of 10 percent. Pump installations must have a metal plate that provides the rated capacity and pressure of each pump.

**ACTUATION**

An emergency release device activated by a single manual operation is required for all water mist systems. This device must be accessible, and its intended purpose must be clearly recognizable.

**ADVANTAGES VS. STANDARD SPRINKLER SYSTEMS AND GASEOUS (CLEAN) AGENTS**

- Control of flammable liquid fires (sprinklers).
- Effective cooling of fuel and space protected (gas).
- Electrically nonconductive (sprinklers).
- Enhanced visibility (sprinklers) (gas).
- Environmentally friendly (gas).
- Extinguishing agent readily available (gas).
- Improved aesthetics (sprinklers).
- Less cleanup time (sprinklers).
- Less smoke damage (sprinklers) (gas).
- Less water damage (sprinklers).
- Low water supply requirements (sprinklers).
- Lower in cost (gas).
- Maintenance of the oxygen level (gas).
- Nontoxic (gas).
- Prevention of reignition (gas).
- Reduced water flow rates (sprinklers).
- Low space and weight requirements for extinguishing agent (sprinklers).
- Space reoccupied and operational in short time (sprinklers).
- Uses fewer materials in construction (sprinklers).
- Washing of toxic and corrosive gases (sprinklers) (gas).

**DISADVANTAGES VS. STANDARD SPRINKLER SYSTEMS AND GASEOUS (CLEAN) AGENTS**

- Cannot be used on metals that react violently with water (gas).
- Depend on electrical power to start the fire pumps (gas).
- Difficulty in extinguishing deep-seated and obstructed Class A fires (gas).
- High skill level required to install system (sprinklers).
- More expensive (sprinklers).
- More expensive in small applications (gas).
- Requires more engineering, design time, and resources (sprinklers).
- Successful extinguishment depends on the geometry of the room (gas).

Successful research efforts using water mist systems during the past decade should bring this fire extinguishing technology to the forefront in the United States. New methods include combining total flooding and local applications to enhance cooling and ensure complete extinguishment where the configuration of the enclosure may provide areas of protection for fire. In locations where water supplies are limited, water mist systems are an ideal option to traditional sprinkler systems. Using water mist systems to protect occupants in residential buildings and private dwellings, where most fire deaths in the United States occur, is still in the experimental stage.

The need for halon replacements may also accelerate the transition to this human and environmentally safe fire protection system. The International Halon Replacement Working Group, sponsored by the Federal Aviation Administration, is developing minimum performance standards and certification criteria for halon replacements for engine nacelles, cargo bays, and lavatory and portable extinguishers. The U.S. Navy recently initiated a program to use water mist as a total ship protection system. Additional research will ensure reliable and cost-effective water mist systems that provide practical applications in fire suppression well into the 21st century.

**REFERENCES**


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COURSE EXAMINATION

1. The earth's ozone layer protects us from:
   a. infrared medium light
   b. ultraviolet medium wave light
   c. ultraviolet high wave light
   d. infrared low light

2. The Montreal Protocol was adopted in:
   a. 1997
   b. 1995
   c. 2002
   d. 1987

3. The Montreal Protocol was created, in part, to eliminate the production of:
   a. halons
   b. brines
   c. chemical foams
   d. dry chemicals

4. SNAP refers to:
   a. Substantial Natural Alternative Proposal
   b. Significant Narrated Alternative Program
   c. Significant New Alternatives Policy
   d. Substantial New Alternative Program

5. To be considered water mist, water droplets must be smaller than:
   a. 10 millimeters
   b. 100 millimeters
   c. 100 microns
   d. 1,000 micron

6. Typically, the surface area of sprinkler discharge droplets are how many times smaller than water mist droplets?
   a. 1,000 times
   b. 2,000 times
   c. 3,000 times
   d. 400 times

7. Water expands how many times when converted from liquid to gas?
   a. 1,500
   b. 1,700
   c. 2,100
   d. 2,700

8. With respect to smoke soot, water mist tends to:
   a. turn it to acid
   b. keep it suspended in the compartment
   c. coagulate it
   d. scrub it

9. Water mist systems which are designed to suppress an entire compartment are called:
   a. Total extinguishing
   b. Total flooding
   c. Complete extinguishing
   d. Complete flooding

10. A zoned system may be found in a(n)
    a. airplane
    b. office floor
    c. school floor
    d. hospital floor

11. Piping in dry water mist systems may contain:
    a. Air
    b. Ethylene glycol
    c. Argon
    d. Helium

12. Intermediate water mist system pressures range from:
    a. 150 psi – 250 psi
    b. 175 psi – 500 psi
    c. 400 – 750 psi
    d. 250 psi - 500 psi
13. The minimum water supply duration for a water mist system is:
   a. 20 minutes
   b. 15 minutes
   c. 30 minutes
   d. 60 minutes

14. What class of foam can be introduced into water mist systems?
   a. A and B
   b. B and C
   c. B and C
   d. B and D

15. Water mist nozzle are automatic, non-automatic, and:
   a. dual acting
   b. dual action
   c. hybrid
   d. double action

16. Water mist piping is made of copper/copper alloy or:
   a. stainless steel
   b. iron
   c. steel
   d. plastic

17. High pressure pumps are:
   a. centrifugal pumps
   b. double acting
   c. twin-flow
   d. Positive displacement

18. A disadvantage of water mist systems compared with gaseous systems is that water mist systems
   a. produce toxic gases
   b. produce corrosive gases
   c. have difficulty extinguishing deep-seated fires
   d. allow re-ignition of fire

19. Nozzles in water mist systems use glass bulbs that actuate between:
   a. 100 F to 200 F
   b. 125 F to 250 F
   c. 135 F to 750 F
   d. 135 F to 650 F

20. A fire department connection must be installed on systems over:
   a. 1,500 square feet
   b. 2,000 square feet
   c. 2,500 square feet
   d. 3,000 square feet
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