Specifying fire suppression agents

There are a growing number of products available within today's fire suppression technologies.

By Tom Prymak, Rolf Jensen & Assocs. Inc., Dallas -- Consulting-Specifying Engineer, May 1, 2009

Gas or water? Clean agent or carbon dioxide? There are a growing number of products available within today's fire suppression technologies. Fire sprinklers and foam-water products have been on the front line of defense for many years, but new technologies have and continue to emerge that make decisions even more complex.

Before leaving sprinklers, it is important to note that when dealing with agents having a defined or limited supply, automatic fire sprinklers often will be required to provide a backup to the primary agent. In the event that a fire is not controlled or re-kindles after a discharge, sprinklers provide a backup. This is also true if the agent has been effective but requires recharging.

Sprinklers provide continued protection for a facility while the primary system is out of service. Often in electrical and high-value environments, sprinklers are installed using single and double interlocked pre-action systems to minimize the potential of an accidental water discharge. The same sprinkler requirement is true for water mist systems that are twin fluid and/or have a very limited discharge capacity.

The need for sprinkler backup is often a mandatory requirement of insurers and authorities having jurisdiction. Providing the latest fire suppression technology having a limited agent seldom eliminates the need for automatic sprinkler protection.

Sensitive electronics

The electronics age has been accompanied by concerns of adverse effects of sprinkler discharge on sensitive equipment. Those concerns fueled the growth of gaseous agents, shown to be effective without causing damage to electronics in areas such as computer and electronic equipment rooms.

Not too many years ago, the choices for gaseous agent systems would have been limited to carbon dioxide and Halon 1301. Environmental effects and concerns led to the Montreal Protocol and the elimination of the Halon gases from consideration for new installations on a worldwide basis. Production of Halons was completely halted on Jan. 1, 1994, and they have since been replaced by “environmentally friendly” products. Similarly, concerns for life safety and greenhouse effects have limited the use of carbon dioxide; these concerns are addressed in the current NFPA 12 for carbon dioxide systems. The recommended use of carbon dioxide systems for both total flooding and local application has been restricted to areas that are normally unoccupied.

So what options are available? Let's look first at many of the current offering of clean agent systems.

With respect to the latest clean agent systems, several agents/systems are readily available: FE-25, ECARO-25, Argonite, PROINERT, FM-200, Novec 1230, Inergen, and Argon. FM-200 and Novec 1230 are available from multiple suppliers, although trademarked under a different name by at least one company, and Inergen is proprietary to Ansul Corp. The FE-25 agent is a product of DuPont, and it has been branded as ECARO-25 by Fike. Fike also markets the PROINERT IG-55 system. The chemical compositions of the agents vary; components include nitrogen, hydrogen, fluorine, and argon, which are common in the atmosphere. As a result, the environmental effects are either very negligible or zero. Table 1 is a tabulated comparison of the gaseous agents.

Obviously, there are choices to be made with regard to the above agents. The UL land-based listings for all of the above agents and systems suppliers include Class A surface burning fires, Class B Flammable Liquids, and Class C occurring within an enclosure. The listing in the Factory Mutual Approval Guide for the individual agents/systems is prefaced by the same introduction that is specific to “Clean Agent Fire Extinguishing Systems.” This introduction states the following for all of the above agents: “… They are effective for total flooding protection against hazards involving liquid flammable materials, electrical equipment, and ordinary solid combustibles in occupancy arrangements, which produce only surface burning. In general, these agents are not effective or appropriate for hazards, which produce deep-seated burning, or for those which involve chemicals containing their own oxygen (such as cellulose nitrate), metal hydrides, or reactive metals (such as sodium, magnesium, or uranium).”

On the mechanical side of the cost ledger, all of the above agents are stored in cylinders. The number of cylinders may vary, as the quantity of gas will vary by agent and the volume being protected. All of the distribution arrangements will require discharge nozzles and piping, although the number of nozzles and the quantity and size of piping will vary for each of the agents. Higher storage and discharge pressures generally carry additional requirements for heavier system pipe and fittings. The requirement for Schedule 80 steel pipe and higher pressure fittings, in lieu of Schedule 40 pipe and standard weight fittings, often increases the installation costs. These can sometimes be offset by agent savings, or a reduced number of discharge devices that must be installed.

Electrically, the method of detection, number of detectors, control panel, alarms, and interconnecting wiring for any of these systems will be relatively the same. If the systems are supplemented by fire sprinklers that are installed in a single- or double-interlocked pre-action arrangement, the gaseous agent control panel is generally tied to the release of the pre-action valve. The detection and releasing system for the gaseous agent will be the same system that releases the pre-action valve to the fire sprinklers. The fire sprinkler requirements will be the same regardless of the agent used. The real cost difference for any of the above gaseous agent systems will be attributable to the mechanical side—gas (cost and quantity), cylinders (size and quantity), control heads, interconnecting piping and nozzles, and the overall mechanical installation cost. In general, the cost of the materials that must be used is in direct proportion to the system pressures.

When dealing with clean agent fire protection systems, it is also important to recognize other cost impacts. Many clean agents must be contained for a specified period after discharge. This requires shutting down the HVAC system to the area, sealing doors and windows, and securing ceiling tiles to avert displacement. Provision for the required added auxiliary contacts in the system control panel to perform all necessary shut-downs and door closures needs to be made. Added contacts within the panels for these functions generally are provided by the system suppliers, but all will require the proper hardware and wiring from the control panel to the equipment. Conversely, some high-pressure agents will require adequate room venting following discharge.

All of the above clean agents are considered to be nonhazardous in the specified concentrations. However, the systems should also be arranged to allow a time delay for personnel egress prior to discharge. This delay often can be adjusted from 0 to 60 sec. The time delay and predischarge warnings are a function of the system control panel and usually standard features. Alarms should be provided both inside and outside the protected area to warn of the impending and subsequent discharge. The exterior alarms help to prevent doors from being opened inadvertently when the agent is discharged.

Although not a new agent, high- and low-pressure carbon dioxide systems continue to be available. The agent has come under scrutiny as a harmful greenhouse gas, as well as being lethal in concentrations that must be attained for extinguishment. NFPA 12, Standard on Carbon Dioxide Extinguishing Systems, addresses the use of this agent, and it is prefaced with instructions that carbon dioxide is to be used only in areas that are normally uninhabited. This type of protection has been used for years, and carbon dioxide systems continue to be available in both high- and low-pressure storage arrangements. The high-pressure systems are at ambient temperatures, while the low-pressure systems store the gas as a liquid in a refrigerated tank. Carbon dioxide is extremely effective as both a total flooding agent and in localized applications. Carbon dioxide should not be considered a substitute for clean agents that are both environmentally friendly and much safer for human environments.

Water mist systems

Water mist has been used for many years, initially crudely applied from steam lines in the marine industry. The technology received a boost when the Safety of Life at Sea (SOLAS) regulations were amended in December 1992 to require automatic sprinkler protection for vessels built after Oct. 1, 1994, that carry a total of 36 or more passengers and crew. Ship owners were given until July 1, 2002, to comply with the new regulations. Ballast is critical to large ships, and pumping water into a ship for fire protection becomes a huge issue. In an effort to minimize the water required for a fire protection system, manufacturers began fire testing for machinery and passenger spaces using mist technology. Many of the successful shipboard tests could be equated to similar land based hazards—passenger compartments translate to hotel rooms, machinery spaces to flammable liquids applications, and shipboard retail shops to ordinary hazard applications.

NFPA 750, Standard on Water Mist Fire Protection Systems, was created to address the technology. One of the divisions within NFPA 750 is Water Mist Systems by Pressure. The standard divides systems into high-pressure (greater than 500 psi/34.5 bar), intermediate pressure (greater than 175 psi/12.1 bar, but less than 500 psi/34.5 bar), and low-pressure systems (175 psi/12.1 bar and less). The diameter of the water mist droplets are measured in microns (µ), and 1 mm = 1,000 µ. Annex A of the standard addresses the definition of mist in this way:

Dv0.50 is the volume median diameter; that is, 50% of the total volume of liquid is in drops of smaller diameter and 50% is in drops of larger diameter … the definition of water mist in this standard includes sprays with Dv0.99 of up to 1,000 µ.

Regardless of high-, intermediate-, or low-pressure ratings, the droplet sizes are actually more critical to the suppression ability of the system. Annex A explains it: "Properly designed water mist systems can be effective on both liquid fuel (Class B) and solid fuel (Class A) fires. Research indicates that fine (i.e., smaller than 400 µ) droplets are essential for extinguishment of Class B fires, although larger droplet sizes are effective for Class A combustibles, which benefit from extinguishment by fuel wetting."

Why the difference?

From a wetting agent perspective, sprinklers are far more effective. They produce relatively large droplets that absorb heat but are slow to vaporize. Most of the sprinkler discharge reaches the combustible material as a wetting agent in a fire. Tiny water mist droplets have a far higher surface area/volume ratio, and the surface area absorbs heat in a discharge condition. A high-heat-release fire tends to vaporize the droplets quickly, and as the droplets vaporize, the vapor expansion is approximately 1,700 times the original volume, thus displacing oxygen. The small droplets also quickly absorb a tremendous amount of heat from the source, resulting in cooling.

The third effect is the wetting of the combustible. In a Class A fire, the heat release can be expected to be lower than that of a Class B flammable liquid, resulting in a slower vaporization rate, and the wetting of the combustibles in combination with the vaporization of the mist droplets results in suppression. Fire tests have shown that mist is actually more effective on higher heat releases. For this reason, mist has been less effective for residential and light hazard applications. In essence, the lighter hazards do not release enough heat to quickly vaporize the droplets.

Mist systems

How effective is mist? Using flammable liquids as an example, densities of 0.30 gpm/sq ft and higher are commonly required for automatic sprinkler protection. Given an area of 3,000 sq ft, the nominal flow for the 0.30 density would be 900 gpm (plus overages due to friction losses in the piping). One intermediate pressure, single-fluid water mist system is listed for flammable liquids protection at 0.019 gpm/sq ft. That is only 6.3% of the comparable sprinkler discharge. This is not only significant where water supply is limited, but quite useful in systems where capturing sprinkler discharge must be accomplished due to potential hazardous materials discharge.

If we were to compare foam systems, long known to be effective for 2-D flammable liquid fires, the above sprinkler density would be reduced from 0.30 gpm/sq ft to 0.15 gpm/sq ft. Using the same comparison, the demand for the mist system would be 12.7% of the similar foam demand. The cleanup of the foam system discharge on flammable liquids also would be far more costly than that of the mist system.

There are multiple suppliers of mist systems on the market. Manufacturers' data show system droplet sizes that range from less than 10 μ to more than 400 μ. However, nearly all have specific listings and test data that are particular to their product. As a general rule, it is best to research the actual listings of the manufacturer for a particular hazard or application.

Single- versus twin-fluid systems

Mist systems are categorized as single fluid or twin fluid. The single-fluid systems discharge water at pressure from a nozzle or distribution device. Twin-fluid systems generally mix a gas (usually compressed air or nitrogen) at the point of discharge. The water pressure at the nozzle or distribution device can be much lower in a twin-fluid system, as the delivery pressure is boosted at the point of discharge using the gaseous agent. The pressure differences in the delivery systems are critical to the ability to distribute water droplets.

The delivery of extremely small water droplets becomes a problem of physics. To the layman, a baseball can be thrown farther than a BB. However, if enough pressure and the proper device are provided to propel the BB, the resulting distance can be greater than that of a professional baseball player throwing the baseball. For single-fluid systems, in order to drive water through the nozzle, higher pressures generally increase the distribution area. In twin-fluid systems, mixing some type of compressed gas at the point of delivery can overcome some of the problems of water alone at lower pressures.

As in the case of clean agents and carbon dioxide systems, higher operating pressures of water mist systems generally require more exotic and expensive materials. High-pressure single-fluid systems often require multiple pumps for proper operation. Many manufacturers of both single- and twin-fluid systems offer pre-assembled skid units that are pre-piped and wired in an effort to ease the installation costs, and to assure proper operation.

Nozzle flow

Mist nozzles and distribution devices can be open or closed. Closed nozzles generally employ glass bulb thermal elements, similar to sprinklers. In this type of system, each nozzle is thermally sensitive, and the distribution devices are actuated as sprinklers would be. These systems can be installed in multiple arrangements, from wet to pre-action.

With open distribution devices, in the event of a fire, the entire system will discharge, making it the equivalent of a deluge system. In order to fully supplant fire sprinklers, a mist system must be capable of an extended discharge. NFPA 750 requires a minimum duration of 30 min for the largest single hazard for both water and twin-fluid agent. Pre-engineered systems must be capable of two complete discharges or, as required by specific listing requirements, a minimum of two times the period to extinguish fires during test, the rundown time of turbine, or the time necessary to secure fuel lines to the rotating equipment, whichever is greater. Where the system media cannot be replaced within 24 h after a discharge, a reserve supply is required. The reserve is not required for systems having a 30-min minimum duration.

Flow calculations using the traditional Hazen-Williams method can be used for low-pressure, single-fluid systems (maximum 175 psi). Darcy-Weisbach calculation method is required for intermediate and high-pressure, single-fluid, single-liquid phase systems. Calculation procedures for twin-fluid systems are outlined in Section 9.4 of NFPA 750. Minimizing drafts and openings is a consideration in the design of the systems, but unlike for most gaseous agents, sealing a room or area generally is not required.

Mist system arrangements, delivery methods, and nozzle spacings vary by manufacturer, and by hazard for any given manufacturer. As with gaseous systems, the owner's insurance carrier and the authorities having jurisdiction must be consulted. For pre-engineered systems, and even for systems having a 30 minute supply, a backup fire sprinkler system may or may not be required. Pre-action and deluge arrangements will require detection/actuation systems. In some instances, and for specific hazards, the system may have been tested and listed with specific detection equipment. The manufacturers' listings and approvals are critical to understanding the proper system application. For the protection of some specific hazards, such as flammable liquids, mist systems may be a perfect substitute for traditional carbon dioxide applications.

Today's fire suppression offering affords the owners, contractors, and insurance carriers multiple choices for providing clean agent fire protection. Decisions can be based on the hazard to be protected, ability to seal the area, and water damage considerations. Mist comprises minute water droplets, and a discharge will result in the wetting of an area and equipment, though not to the degree of automatic fire sprinklers. When properly applied and installed, all will provide the most modern fire protection available.

Table 1. Comparison of gaseous agents.

Agent	Composition			Physical properties		Vapor pressure at 25 C	Minimum concentration		Maximum concentration	Boiling point at 1 atm	Freezing point
	Nitrogen	Argon	Carbon dioxide	Stored	Discharge	2252 psi	Class A	Class B			
Inergen	52%	40%	8%	Gas	Gas	153.2 bar	*	*	*	N/A	N/A
FM200	Heptafloropropane - CF_3CHFCF_3			Liquid	Gas	67.3 psi	7.20%	9.00%	10.50%	2.6 F	(-)204 F
						4.58 bar				(-)16.36 C	(-)131 C
Novec 1230	Fluoroketone - $CF_3CF_2C(O)CF(CF_3)_2$			Liquid	Gas	5.9 psi	4.20%	5.85%	10%	120.6 F	(-)162.4 F
						0.4 bar				49.2 C	(-)108 C
FE-25(HFC-125)/Ecaro-25	Pentafluoroethane - CHF_2CF_3			Liquid	Gas	191 psi	6.70%	8.70%**	12%	(-)54.6 F	(-)153.4 F
						13 bar				(-)48.14 C	(-)103 C
PROINERT IG-55/Argonite	50%	50%	N/A	Gas	Gas	2,940 psi	34.00%	45.50%	††	(-)310.2 F	N/A
						200 bar				(-)190.1 C	
Argon	N/A	100%	N/A	Gas	Gas	3675 psi	34.00%	Unavailable	††	(-)189.4 F	N/A
						250 bar				(-)123 C	
							All of the above are by volume				

* Inergen concentrations: Literature shows varying concentrations, typically 35% to 40% by volume.
FM tests showed Inergen to be effective in inerting mixtures of propane/air and methane/air at concentrations between 40% and 50% (per Ansul).
Ansul literature shows Inergen being effective for Class A surface burning, Class B flammable liquid, and Class C fires within an enclosure.
**FE-25: listings for Class B application are for unoccupied areas or areas having limited access.
PROINERT ratings also include Class C at 34% concentration by volume.
PROINERT and Argon: maximum concentration, O2 minimum level should be at least 10% for short-term occupancy and egress. Source: RJA

References:

Factory Mutual Approval Guide – January 2008

NFPA 11 – Standard for Low-, Medium-, and High-Expansion Foam – 2005 Edition
NFPA 12 – Standard on Carbon Dioxide Extinguishing Systems – 2008 Edition
NFPA 13 – Standard for the Installation of Sprinkler Systems – 2007 Edition
NFPA 72 – National Fire Alarm Code – 2007 Edition
NFPA 750 – Standard on Water Mist Fire Protection Systems – 2006 Edition
NFPA 2001 – Standard on Clean Agent Fire Extinguishing Systems – 2008 Edition