LATEST DEVELOPMENTS FOR FIRE DETECTION AND SUPPRESSION APPLICATIONS

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Much activity is occurring throughout the world with respect to the implementation of new concepts and technology for fire detection and fire suppression applications.

Obvious advances include tangible detection and suppression improvements, and also new methods and approaches such as performance based codes and standards. Examples of tangible advances include addressable detection systems, wireless detection technology, halon alternatives, water mist systems, advanced sprinkler technology, and so on. Examples of new approaches and methods include a revitalized focus on disaster planning and the need for a total fire protection plan. The concept of performance based codes and standards for the design and installation fire detection and suppression systems will be explored in detail.

THE CHALLENGES OF TODAY'S WORLD

Fire protection today is often complex and challenging. The need for fire protection is often based on some unusual constraint or physical handicap. This creates a difficult setting that will push the abilities of fire protection design or fire-fighting control to its limits. To clarify this thought, consider the following constraints that complicate the associated example applications:

temperature extremes on an offshore oil drilling platform;
highly purified air flow in a clean room facility;
environmental containment for a genetic research laboratory;
zero gravity in a space station;
lack of electrical interference in an anechoic chamber;
process purity in a molten salt bath; or
oxygen enriched atmosphere in a space capsule simulator.

The challenges of today's world are presenting new and unusual challenges upon the fire protection practitioner. The lessons from the past provide stark recognition that the special applications of tomorrow deserve additional attention. Whether a genetic research laboratory, a jumbo aircraft manufacturing plant, or a facility handling high-powered lasers, the value densities and damage sensitivities of these facilities are increasing, and the risk to society in terms of disaster or technological denial is likewise increasing. New developments in fire detection and suppression will help us address these concerns.

DETECTION AND SIGNALING

Because of advancements in electro-optics and computer hardware and software, appreciable changes have been occurring with fire and smoke detection. Years ago, the detection of fire and smoke was based on the fairly simple technical model of type of a sensor, two wires, and a power source creating an electric circuit. An alarm would be created when heat or smoke would trigger a relay that would close the circuit, and activate an alarm. Today, we are well beyond such straight-forward technology. Further information on this technology is reflected in the literature, including NFPA 72, *National Fire Alarm Code*.[1]

Detection Enhancements

Over the last decade, detectors have evolved from self-contained units whose only function was to determine that smoke build-up within its vicinity had reached a specified level. Today we find the pursuit of the perfect sensor to be a realistic goal. Such a sensing device is one with a target sensitivity that is high and a non-target sensitivity that is low.

One of the ways for achieving the perfect sensor is a unit with the capability for multi-parameters, such as the discrimination of multiple gas species and temperature, or detailed spectral information. Fires produce five types of simulation that sensors can detect. These are 1) thermal radiation, 2) heat conduction, 3) molecular gases, 4) condensed phase aerosols, and 5) acoustic waves.[2]

Among the new technologies having potential for sensing a fire's gaseous products are active films using surface acoustic waves for specific molecular recognition, micro-machined devices with temperature-programmable active elements, and open-path instruments that measure emissions over large volumes. Potential new temperature sensing technologies include piezoelectric transducers to measure ultrasonic waves created by expanding overheated materials, thermal chromic liquid crystals placed strategically throughout a room to monitor a specific temperature threshold, and optical fiber to measure temperature increase at specific points.

Actual improvements to detection sensors can be readily seen, including some methods that have already been available for quite a while. Examples of spot and linear detectors that are available today and implement some type of advanced technological enhancement include high sensitivity laser smoke detectors, optical detectors that cross function the best features of ultraviolet (UV) and infrared (IR) sensing, and rate-of-rise heat detectors that can provide an accurate detection threshold based on anticipation of the inherent thermal lag.

Another recent innovation that has seen recent proliferation for fire protection applications are air sampling detectors. These units bring the air being sampled back through a piping network to a single detector covering a large protected area. Thus, significantly fewer of these units are used than traditional spot detectors, but because they are more expensive the cost is often comparable. Their high sensitivity has proven them effective in applications like cleanrooms and atriums. They have also been effective in facilities like museums and prisons for aesthetics or tamper-resistant reasons, because a protected area only needs an air sampling port with the detector located elsewhere. These detectors are based, for example, on the Wilson Cloud Chamber, particle obscuration, or laser technology.

Signaling Enhancements

Detecting a fire or smoke condition is only half of the job of a fire alarm system. The other half is for the system to then take the necessary action. Most prominent of all actions taken is the signaling or notification of the building occupants.

Sometimes the most complicated thing about a new technology is trying to implement it in a simple way. That is the case with efforts to agree upon a standardized evacuation signal for a fire alarm system. One approach that is use of a temporal pattern comprised of three-pulse signal to allow a better recognition of the signal by occupants. This approach is recognized by standards in ISO, NFPA, and others, and is favored over a single slow whoop because it can be made with any electronic or mechanical sound.

An innovative concept now making its way into actual applications is signaling done through building lighting systems. Such an approach utilizes the existing building lights and flashes the facility lights at a reduced intensity and in a specified pattern. Despite advantages such as improved display and recognition of the evacuation signal, implementing such an approach is complex because of concerns for circuit supervision and power supply reliability.

False Alarm Reduction Technologies

Changes to technology for what occurs at a signaling system control panel has been noteworthy. Improvements in hardware and software is allowing new approaches that can significantly improve the reliability of a system and help to reduce nuisance alarms.

One such approach is through programmable controllers using addressable detectors. Microprocessing now allows system control panels to poll detectors for increasingly specific types of data at specific locations. This essentially uses a single circuit throughout the entire protected area rather than multiple separate circuits to define fire zones. Multi-sensor detectors can provide a range of information, and the control panel can be programmed to take action based on specific recognized inputs. Further, supervision of the circuit(s) can be programmed at the control panel with a much greater flexibility.

An extension of enhancements that are being achieved with programmable technology is by using a library of fire signatures, which is also referred to as "fuzzy logic". With an internal library of hundreds or even thousands of fire signatures, the control panel can discriminate between the signals being sensed by the detectors. Comparison of these signals allows the necessary action to be taken, and has the advantage of greatly reducing false alarm potential. Such an approach is considered as being close to artificial intelligence.

New Building Communication Technologies

When will be able to step back and consider all the systems within a building as a single entity and in their entirety? This day is fast approaching, as new building communication technologies are starting to mature. This would allow protective fire signaling systems, security systems, heating/ventilating control systems, elevator systems, and so on, to work together in unison.

Working together with multiplexed systems has clear advantages, but special communication protocols are needed between equipment hardware and software that has evolved within separate and distinct building industries. In the United States such efforts are underway to help establish an overall building package. Assisting with this cause are protocols under development known as BACnet, which is a inter-system based protocol, and Lonworks, which is more of a component based protocol. Such efforts will hopefully lead us into the twentieth century with fully integrated buildings.

Another new innovation with building systems is wireless detection. This technology is now being successfully used in the United States, and involves the detection units communicating with the control panel through the use of radio waves, sound waves, or some other non-wired method. Concerns for supervision, communication reliability, and power supply reliability have been addressed, and this thus provides an alternative for systems that might have challenging installation characteristics, such as older buildings requiring a new system.

WATER BASED SUPPRESSION

Sprinkler systems have proven themselves to being an effective fire protection tool for over one hundred years. For much of this time, little radical change has occurred with the technology. However, the last several decades have seen some very notable improvements, and these systems are doing more than they were ever capable of before, as reflected in documents like NFPA 13, *Standard for the Installation of Sprinkler Systems.*[3]

Sprinkler Enhancements

The increased flexibility with sprinkler design is introducing sprinklers which have specific performance objectives and which may be applicable or best suited for only certain fire hazards. An example, approximately twenty years ago came the introduction of the residential sprinkler with an objective of achieving life safety in residential dwellings. This type of sprinkler possesses a much faster operating element and produces a spray pattern that discharges water higher than does the standard spray sprinkler.

Today, it is estimated that more than 15,000 models of sprinklers are available on the global market.[4] This wide spectrum allows significant flexibility to achieve the most cost effective and appropriate sprinkler system.

Technological advancements with sprinklers include changes to affect: 1) water volume (orifice size), 2) spray pattern (deflector design), 3) response time (thermal link mass and shape), and 4) response temperature (thermal link material).[5] Each of these factors play a critical role in determining how fast a sprinkler operates, and how well it will function once it does operate. Depending on the combination of characteristics being considered, and to what degree, sprinklers with faster operating times, larger spray patterns, and better water penetration capabilities are now available.

New sprinklers that have enhanced activation characteristics include what is becoming widely recognized as fast response sprinklers. Sprinklers with fast response operating elements have changed the nature of sprinkler system design, with the intent that the faster operating sprinklers operate quicker and keep a fire small. New designs that fall into this category include residential sprinklers, quick-response (QR) sprinklers, early suppression fast-response (ESFR) sprinklers, quick response extended coverage (QREC) sprinklers, and quick response early suppression (QRES) sprinklers. Some of these types are only intended for certain types of occupancies based on achieving a specific objective, such as controlling a fire long enough for residential occupants to escape a dwelling.

Aside from the activation characteristics, enhancements have also occurred regarding the manner in which sprinklers discharge the water after activation. Already mentioned above is the extended coverage sprinkler, which provides a spray pattern over an extended protected area. This characteristic is often combined with enhancements to the sprinkler activation mechanism.

Large drop sprinklers are another technological sprinkler system advancement. These offer a water discharge pattern to meet the challenges of high challenge fires such as might occur in a high-rack warehouse. Several disastrous fires have helped clarify the need for such an enhancement. These high challenge fires create a fire plume that is so intense the sprinkler droplets that are discharged must be large enough or they will be swept up into the fire plume and never reach the base of the fire.

System Enhancements

Aside from the enhancement to the sprinklers themselves, other innovations have been occurring that address the overall sprinkler system. The hydraulic design of sprinkler systems has now existing for several decades, and this science has matured to allow the most efficient, reliable, and cost effective designs achievable.

The numerous computer calculation programs now available allow a wide range of options to achieve the optimum design. They further more easily allow gridded network systems, which provide improved flow and thus allow cost-savings through the use of smaller pipe sizes. An extension of this are the systems referred to as the "bird cage systems", which are three dimensional gridded piping networks.

Another enhancement to sprinkler system design has occurred with the type of piping used. Improved materials have led to alternatives other than the traditional steel pipe. for example, the use of copper has become popular in some regions, and allows for improved flow characteristics and possible cost savings through the use of smaller pipe.

One interesting advancement is the use of specially approved types of plastic piping for use in certain categories of residential installations. This pipe must meet all the essential parameters for other pipe types, including the ability to continue functioning throughout a fire, which is to say that it won't melt or fail. The use of plastic pipe in residential systems has the ability to allow for appreciable cost savings, and thus helps to allow the more widespread use of this life-saving technology.

SPECIAL SUPPRESSION

A wide range of special fire extinguishing systems exists today. However, the latest changes with these systems can be generally classified into one of the following three basic types: 1) halon alternatives, 2) water mist, and 3) fine aerosols.

At times, water mist and fine aerosol technology are also considered alternatives to halon systems. Yet the halon alternatives in this discussion only focus on the in-kind replacements. These types of halon replacements are the halocarbon agents and inert gas mixtures.

Halon Alternatives

Halon alternatives involving halocarbon agents are generally grouped into two categories: streaming agents and total flooding agents.

Streaming agents are used in portable fire extinguishers, while total flooding systems protect an enclosure of some kind, such as a computer room. Halon 1211 had been the most recognized halon streaming agent, while Halon 1301 was the most recognized total flooding agents. NFPA 10, *Standard for Portable Fire Extinguishers* is the NFPA document that addresses portable fire extinguishers, while for total flooding systems it is NFPA 2001, *Standard on Clean Agent Fire Extinguishing Systems*.[6,7]

It is well known that fire protection halons are being phased out along with other chemicals that are considered damaging to the Earth's stratospheric ozone layer. Based on the revisions to the Montréal Protocol made in Copenhagen in November 1992, global production of the fire protection halons have ceased in many developed countries as of January 1, 1994. Now, the entire fire protection community is on the quest for alternative substances and strategies to replace the fire protection halons that have been so effective in our past.[8]

Some of the questions that we are now faced with include: how do we properly handle all existing quantities of fire protection halons? What are the available alternatives and strategies? When will these alternatives and strategies be available, and how should there implementation be handled?

Substitutes for halons typically must meet four general criteria. They must be effective fire prevention agents, have an acceptable environmental impact, have low toxicity, and be relatively clean or volatile. One concern for total flooding halon alternatives is their toxicity and affect on the occupants of a totally flooded enclosure. For halocarbon agents the concern is for potential cardiac sensitization, while for inert gases it is for asphyxiation.

The latest edition of NFPA 2001, which was first released in 1994, addresses the design, installation, testing, inspection, operation, and maintenance of engineered and pre-engineered clean agent fire extinguishing systems. NFPA 2001 addressed the following eleven new clean agents:

- FC-3-1-10, whose chemical name is perfluorobutane and whose trade name is PFC-410.
- HCFC Blend A, a blend of hydrochlorofluorocarbons whose trade name is NAF S-III.
- HCFC-124, whose chemical name is chlorotetrafluoroethane and whose trade name is FE-241.
- HFC-125, whose chemical name is pentafluoroethane and whose trade name is FE-25.
- HFC-227ea, whose chemical name is heptafluoropropane and whose trade name is FM-200.
- HFC-23, whose chemical name is trifluoromethane and whose trade name is FE-13.
- HFC-236fa, whose chemical name is Hexafluoropropane.
- FIC-13I1, whose chemical name is Trifluoiodomethane and whose trade name is Triodide.
- IG-01, a mixture of inert gases and whose trade name is Argon.
- IG-541, a mixture of inert gases whose trade name is Inergen.
- IG-55, a mixture of inert gases and whose trade name is Argonite.

NFPA 2001 provides the necessary criteria for individuals considering these clean agents for new installations, but it neither approves nor implies acceptance of any particular agent. The standard also provides criteria for design concentration, toxicity, discharge times, and physical characteristics to allow users to develop their own comparisons.

Water Mist

Water mist technology has been with us long before the phase-out of fire protection halons helped bring this approach further attention. As early as during World War II, the United States Navy and other groups were implementing water fog using a special hose stream nozzle as an effective tool for manual fire fighting. Today the water fog nozzle continues to be a special tool of the fire service.

Yet the concept of using water mist in fixed extinguishing systems never became popular until the phase out of fire protection halons provided incentive for this approach. These systems operate much like a conventional gaseous extinguishing system, with detection and control units similar to other designs, but instead discharging finely misted water. This is distinguished from conventional water spray systems because the size of the droplets is very fine. This allows the water mist to function in an enclosure with properties that are similar to that of gaseous extinguishing systems. Documents such as NFPA 750, *Standard on Water Mist Fire Protection Systems*, provide further detailed criteria on this topic.[9]

Water mist systems are often recognized for operating at high pressures, although some also operates at relatively low pressures. Yet common to all water mist systems is their ability to use relatively low volumes of water. This distinct operating characteristic has created incentive for their use in place of traditional sprinkler systems where water supplies are a problem.

As an alternative to fire protection halons, water mist systems have the distinct advantage of being entirely without question in terms of their potential harm to the environment. Some of the applications where water mist systems are becoming popular include the protection of shipboard spaces, and electrical generating and petrochemical plants. One innovative approach is the use of water mist systems to protect turbine generators by using a rechargeable cycling system. Once the system discharges, it can be easily recharge and discharge again and again if the fire is controlled but not extinguished.

Fine Aerosol Technology

Another new innovation for gaseous extinguishing systems are those using fine aerosol technology. This should not be confused with dry or wet chemical. With fine aerosol systems, the particulates that are distributed throughout the volume are many times more fine than conventional dry or wet chemicals, and behaves like a gas rather than a solid.

This technology is still under development, but has already been used in applications in Russia, Israel, and other parts of the world. One of the challenges of this technology is the generation and suspension of the aerosol, and this is typically accomplished through the use of a pyrotechnic particle generator. Since variations of this approach can leave a residue, this technology is typically used in applications that can tolerate the indoor use of pyrotechnics and eventual residue. This technology has been the focus for military and certain other related applications.

PERFORMANCE BASED DESIGN

Over the past several years, efforts within the global fire protection community have focused on the concept of performance-based design and its mainstream application. In the United States and elsewhere, performance-based concepts are now receiving a growing level of attention, and the current trend indicates that the future will involve a wider use of these concepts in the applicable codes and standards.

The codes and standards infrastructure is now undergoing significant retooling to address an approach that has traditionally used prescriptive based criteria interspersed with localized performance-based approaches. For example, NFPA codes and standards are presently being reviewed to determine if performance based approach should be included. This applies not only to the more obvious occupancy based codes, but also to installation standards that address the design and installation of fire detection and suppression systems.

The approach being taken for NFPA documents is to include an overall performance approach in addition to the existing prescriptive requirements that presently exist. Such an approach is not necessarily new, and has similarities to equivalency options that exist today with current standards. Thus, eventually these documents will include both a prescriptive approach and a performance based design option. This will provide a gateway to allow the implementation of new technologies.

Recently a report was generated to clarify NFPA's future with respect to performance based documents.[10] Part of this report included a draft prototype to demonstrate how a document could be appropriately revised. The document revised was the 1994 edition of NFPA 13D, *Standard for the Installation of Sprinkler Systems in One- and Two-Family Dwellings and Manufactured Homes*.[11] This provides an excellent example of how an installation standard can be altered to recognize a performance based approach.

For detection and suppression systems, as well as other applications, this approach has a variety of benefits. This includes achieving the desired levels of safety with equal or reduced cost, specifying levels of safety, better directing research efforts, improving the transfer of technology, increasing design freedom, and increasing confidence with non-prescriptive methods.

CONCLUSION

Various organizations are continuing to make more widespread use of the wide range of tools and resources that are evolving to effectively support both detection and suppression design requirements. Research advances on methods to protect today's applications are advancing with increasing frequency.

Society is changing like never before, and many of the advances that are occurring are resulting in more challenging fire hazards. Fortunately, these same technological advances are also allowing for improvements in detection and suppression methods. We can expect that tomorrow's world will include the tools necessary to the planet a safer place to live.

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