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FIRE PROTECTION Engineering

SUMMER 2001

Issue No. 11

ALSO:

Intelligent Fire Detection

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SFPE

FIRE PROTECTION **Engineering**

Fire Protection Engineering (ISSN 1524-900X) is published quarterly by the Society of Fire Protection Engineers (SFPE). The mission of *Fire Protection Engineering* is to advance the practice of fire protection engineering and to raise its visibility by providing information to fire protection engineers and allied professionals. The opinions and positions stated are the authors' and do not necessarily reflect those of SFPE.

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viewpoint

An Added Level of Safety

By Brad Keyes

Rockford Memorial Hospital is located in Rockford, Illinois, and serves northern Illinois and southern Wisconsin with a 50,000 m^2 (500,000 ft^2), 490-bed facility. Like many hospitals, the campus has been built incrementally over a number of years with the earliest portion constructed in 1951. Along with major building additions, numerous internal remodelings have taken place to meet the changing needs of healthcare. Each change and addition was designed and built to meet the requirements of buildings and life safety codes in force at the time. Over the years the codes have evolved, and as a result, Rockford Memorial has tried to keep current with these changing requirements.

In July of 1993, a Health Care Financing Administration (HCFA) survey found numerous deficiencies with various aspects of the building's life safety features. At the time, the fire detection system included a combination of fire alarm panels, which were located in three different areas of the hospital. While the hospital had a working manual fire alarm system, the level of smoke detection was not consistent. One wing had detection in rooms, while another had detection only in the hallways; other areas had no detection at all. After the HCFA survey, a Fire Safety Evaluation Survey (FSES) was conducted to evaluate the existing fire safety features. As a result, it was decided to install a new automatic fire detection system to gain additional points on the FSES for smoke detection in corridors and habitable spaces in the entire facility. Along with the addition of a new fire alarm system, it was also decided to complete the installation of the water-based sprinkler system for the entire facility. This would provide additional points on the FSES and grant the hospital exceptions to certain code requirements.

These two major projects began simultaneously in December of 1993 and had to be completed by March 1995. This did not allow much time to design, implement, and commission each phase of the project. After considering several options, the hospital chose a fire alarm system which incorporated the latest generation of equipment available on the market.

For construction purposes, the building was divided into workable sections, by nursing units or department. Cooperation between staff and contractors was extraordinary. As each unit was completed, the systems were activated and placed into operation. This created challenges in keeping records and documents current, as work progressed rapidly. At times, there were six different crews installing sprinklers and three different crews installing the fire alarm system.

In February 1999, the HCFA visited Rockford Memorial for another validation survey. The survey revealed inconsistencies with testing and recordkeeping procedures. For example, the fire alarm service contractor was inconsistent with testing frequencies, providing qualified technicians, and responding to the needs of the hospital. Since the fire alarm system is an integral part of the life safety features, the Facilities Management department decided to take control of all testing and service on the fire alarm system. Technicians were trained by the fire alarm manufacturer, and all testing and service are now conducted by Rockford Memorial's own staff. This has proven to be a major improvement as the hospital can better control all activity on the fire alarm system.

Recent improvements to the fire alarm system include the addition of a networking computer allowing expanded communication between the four panels and remote operation terminals. This is a significant enhancement as technological improvements made in the hospital put increasing demands on the fire alarm system. A remote monitor was installed in the hospital's Security dispatch office which displays the location of every alarm initiated with an alphanumeric description. Alarm information is quickly transmitted to the hospital's fire response team via two-way radios. Other improvements include expander circuit cards to allow over 500 additional initiating devices to meet the needs of recent building additions.

Not everything concerning the installation went as well as the hospital would have liked. With a fire detection project this large, some problems and mistakes did occur. The most embarrassing one was the day the fire alarm manufacturer brought a contingent of facility managers from other hospitals to see the ongoing installation of the new fire alarm system. Unbeknownst to Rockford Memorial's facility manager, who was greeting the contingent at the front entrance, an installer accidentally wired line voltage into the initiating circuit on one panel and blew out all the firmware and control circuit boards. By the time the proud facility manager brought the visitors to the fire panel room, he found all the internal boards and power supplies from one panel scattered across the floor with workers frantically trying to rectify the situation.

One key issue the hospital would change is the decision to install the fire alarm wiring using plenum-rated twisted pair cable, instead of installing the wire in conduit. While this decision saved time and money at the point of installation, it has been the source of many ground fault troubles, due in part to the numerous tradesmen working above the ceilings and inadvertently damaging the cable.

All things considered, the Rockford Memorial Facilities Management department is pleased with their new fire alarm system. They have a system that is user-friendly, and they maintain excellent as-built documents and drawings. With their own staff conducting testing and repairs, they feel they have complete control over the system.

Brad Keyes is with the Rockford Health System.

INTEGRATING

Fire Alarm Systems with Building Automation and Control Systems

By Steven T. Bushby

INTRODUCTION

Integrating fire alarm systems with building automation systems can result in many economic and operational benefits. Such integration requires communication standards and careful design practices. BACnet™ is an internationally recognized communication protocol standard specifically designed for integrating building automation and control systems. Thousands of BACnet systems can be found around the world, and its popularity is growing. Newly proposed additions to BACnet make it very well suited for integrating fire alarm systems with building automation systems.

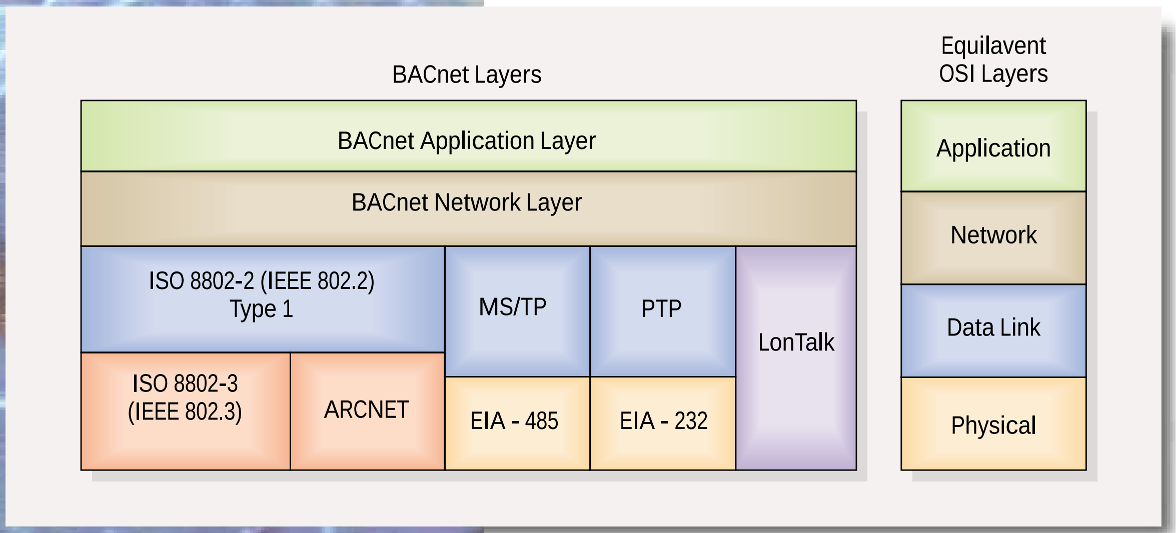

Figure 1. BACnet Protocol Architecture

Maintaining the integrity of fire alarm systems when they are integrated with other building systems requires more than just communication standards. Best design practices, appropriate testing procedures, and modernized building are also needed.

The technology of building automation and control systems has advanced rapidly over the past fifteen years. Today's technology provides building owners and designers with a rich assortment of options and flexibility. Powerful personal computer workstations and intelligent distributed controllers that process complex algorithms quickly and efficiently characterize state-of-the-art building automation and control systems. These advances have taken place across a variety of building services including heating, ventilating, and air conditioning (HVAC) control systems, lighting control systems, access control systems, and fire alarm systems.

In spite of these advances, building owners have been frustrated by the inability to bid projects competitively and to integrate innovative products made by different manufacturers in ways that best suit the unique needs of their facility. The main obstacle has been incompatible proprietary communication protocols. The adoption of BACnet[1] as the standard communication protocol for integrating building control products has changed the industry and opened the door to new innovation in building control technology and true integration of previously isolated building systems.

In the United States, the National Electrical Manufacturer's Association (NEMA) Signaling, Protection, and Communication Section (3SB) has endorsed the use of BACnet as the preferred way to integrate fire alarm systems with other building control systems. The National Fire Protection Association (NFPA) is in the process of revising NFPA 72[2] to address design issues related to integrating fire alarm systems with other building systems. First-generation BACnet fire alarm system products are already available in the marketplace in the United States and in Europe. These are clear indications of interest in integrating fire alarm systems with other building systems and in using the BACnet protocol as a means to accomplish that goal.

A BACNET OVERVIEW

BACnet is a standard communication protocol developed by the American Society of Heating Refrigerating, and Air-Conditioning Engineers (ASHRAE). It has been adopted as a prestandard by the European Community[3,4] and has been proposed as an ISO standard. Today there are over 70 companies with registered BACnet vendor identifiers. These companies are located in North America, Europe, Asia, and Australia. Commercial BACnet product offerings range from gateways that connect proprietary systems to complete product lines that use BACnet as the primary or sole means of communication. There are thousands of installed systems ranging in complexity from a single gateway to very large office buildings with top-to-bottom native BACnet systems, to campus or city- wide systems linking multiple buildings. BACnet products include HVAC controls, lighting controls, access controls, and fire detection systems.

Fundamentally, BACnet, like any communication protocol, is a set of rules that provide a way to exchange information. BACnet was designed and optimized specifically to meet the needs of building automation and control applications, and to convey the data needed by these applications including, but not limited to, hardware binary input and output values; hardware analog input and output values; software binary and analog values; schedule information; alarm and event information; files; and control logic. BACnet does not define the internal configuration, data structures, or control logic of the controllers.

BACnet is designed to be scalable from very small, low-cost devices to very large complex systems that may involve thousands of devices and multiple buildings located anywhere in the world. It achieves this by combining an object-oriented representation of the information to be exchanged, flexible choices for local area network (LAN) technology, an ability to interconnect local area networks, and an ability to use Internet protocols (IP) to link build-

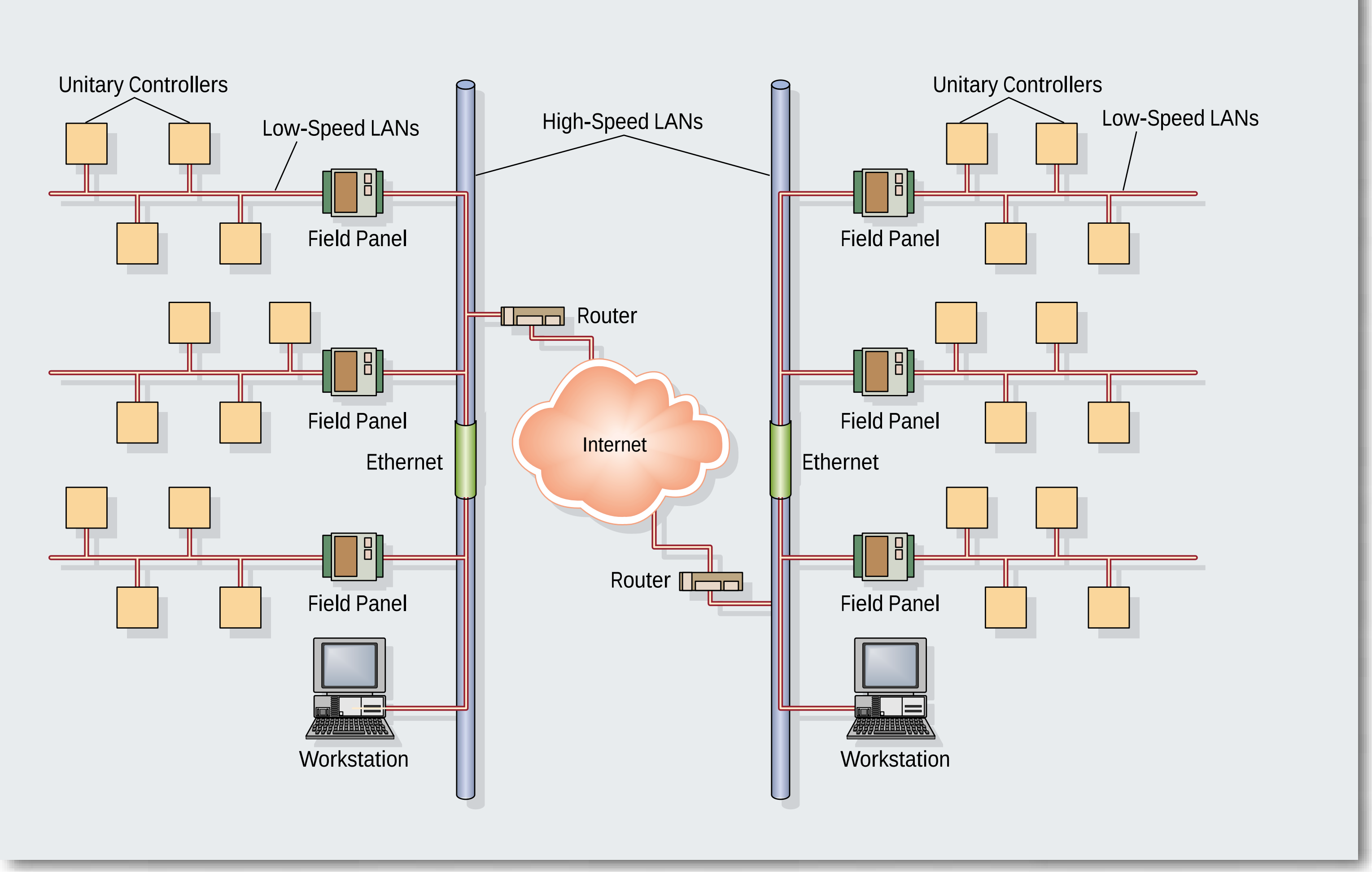

Figure 2. A Hierarchical Building Control System Structure

ings over wide area networks. The structure of the BACnet protocol and its relationship to the Open Systems Interconnection (OSI) – Basic Reference Model[5] is shown in Figure 1.

BACnet represents the information and functionality of any device by defining collections of related information called "objects," each of which has a set of properties that further characterize it. For example, an analog input is represented by a BACnet Analog Input object that has a set of properties that include its present value, sensor type, location, alarm limits, and others. Some properties are required and others are optional. A device is represented by an appropriate collection of network-visible objects. Once the information and functionality of a device are represented on the network in terms of standard objects and properties, messages can be defined to access and manipulate this information in a standard way. This combination of standard objects and standard messages to access and manipulate their properties makes up the BACnet application layer.

Once the information to be exchanged and message structures are defined, it is necessary to provide a way to transfer the information from one place to another. BACnet provides a choice of five LAN technologies to meet this need. Several choices are provided because different building control applications must meet different cost and performance constraints. A single network technology cannot meet the needs of all applications. A LAN is defined by a combination of the data link and physical layers of the OSI model. The LAN options available in BACnet are shown in Figure 1.

The first option is ISO 8802-3, better known as "Ethernet." It is the fastest option and is typically used to connect workstations and high-end field devices. The second option is ARCNET, which comes in modestly high speeds or in slower, lower-cost versions. BACnet defines the MS/TP (master-slave/token-passing) network designed to run over twisted-pair wiring. Echelon's proprietary LonTalk* network can also be used. The Ethernet, ARCNET, and LonTalk options all support a variety of physical media. BACnet also defines a dial-up or "point-to-point" protocol called PTP for use over phone lines or hardwired EIA-232 connections.

A key point is that BACnet messages are the same no matter which LAN is used. This makes it possible to easily combine LAN technologies into a single system. The purpose of the network layer is to provide a way to make such interconnections. It is common in large systems to combine high-speed (and high-cost) networks with lower-speed (and lower-cost) networks in a single system. Such a system is shown in Figure 2. Figure 2 also illustrates that BACnet has wide area networking capability that is implemented using IP.

In principle, BACnet messages can be transported by any network technology. This means that technologies that have not even been invented yet can be used in the future to convey BACnet messages, and they can be integrated into today's systems in the same way that multiple existing network technologies can be combined today. This lack of dependence on today's technology is a very important feature of BACnet.

The object-oriented structure also provides a way to add new application functionality to BACnet by defining new objects and/or new application

services. This is being done to add functionality needed for fire alarm systems. Two new BACnet objects, Life Safety Point and Life Safety Zone, have been developed. The Life Safety Point object represents the features of an individual detection or enunciation device. The Life Safety Zone object represents the status of a collection or "zone" of life safety devices. When these objects detect an alarm, the alarm status latches until a reset command is executed. A new application service has also been developed that provides a way to reset latched alarms and to silence annunciating devices. All these additions were developed with assistance from the fire alarm industry and have been approved by the BACnet committee. They are currently undergoing a public review process and are expected to be approved as part of the BACnet standard.[6]

More detailed information about BACnet concepts and structure may be found elsewhere.[7] There is also tutorial information and an extensive bibliography available on a Web page maintained by the BACnet committee (www.BACnet.org).

WHY INTEGRATE FIRE ALARM SYSTEMS WITH OTHER BUILDING SYSTEMS?

There are many reasons for integrating fire alarm systems with other building automation and control systems. Examples include smoke control, single-seat access to building information, easier maintenance, sharing sensor data, obtaining information about the location of people during an emergency, and providing infrastructure for new technology to improve performance and safety.

Fire detection systems have been integrated with door locks and with HVAC fan and damper controls for smoke management for several years, but these systems have relied on relays controlled by the fire alarm system to override the normal controls. This kind of integration has primarily involved constant-volume HVAC systems and required only on/off control of fans and dampers to be moved to fully open or fully closed positions.

Many modern HVAC systems are far more complex. Variable air volume systems are used to reduce energy consumption. These systems require sophisticated control algorithms to operate either a continuously variable-speed fan or inlet guide vanes to control the static pressure in the supply air duct. Variable-air volume boxes control the airflow from the supply duct into individual rooms by modulating dampers. The control algorithms for these systems are complicated and require interlocks and safeties to prevent overstressing ductwork in the event that dampers do not open when fans are turned on. Smoke management is much more complicated with these systems and outside of the capability of most fire alarm systems. What is needed is a way for the fire alarm system to command the HVAC control system to enter a smoke control mode and let the HVAC controllers manage the equipment.

New sensors are being developed that can recognize various contaminants in the air that can represent a fire signature or a hazardous contaminant that poses a life safety threat. In an integrated system, these sensors could be used by the HVAC control system to control ventilation rates with no adverse impact on their life safety functions. Multiple uses for the same information will make it more cost-effective to implement new sensor technology.

In some buildings, access control systems monitor the location of building occupants. Providing access to this information to the life safety systems could be very helpful in an emergency. Emergency response personnel would know where to look for occupants who need to be evacuated. They could also reduce the risk to themselves by avoiding dangerous areas where no people are present.

Research is now underway at the National Institute of Standards and Technology (NIST) to develop a new generation of smart fire alarm panels that can make use of sensor data from an integrated system to calculate heat release rates in a fire. Using this information, a fire model in the panel can predict how the fire will grow and spread. Emergency response personnel can use these predictions to plan a strategy for fighting the fire. It could even be transmitted by the building systems to fire stations or fire trucks so that planning can begin before emergency personnel reach the site. This could significantly improve response time, saving lives and reducing property loss.

For all of these reasons and probably others, integrating fire alarm systems with other building systems makes a lot of sense. The technology is already being driven in that direction by market forces.

OTHER INTEGRATION ISSUES

Several important integration issues must be addressed if these potential benefits are to be realized. The primary concerns are ensuring the integrity of fire alarm systems in emergencies and isolating them from interference caused by failures of other building systems, meeting code and Underwriters Laboratory (UL) listing requirements, and regulating and tracking human responses to alarms and trouble conditions.

Maintaining the integrity of the fire alarm system and protecting it from failures in other building systems are primarily a matter of system design practice. Today this is being handled by using a gateway to isolate the fire alarm system from outside interference. All components of the fire alarm system reside on one side of the gateway and communicate using proprietary protocols in the same way that they did before BACnet. The BACnet gateway provides a way for other building systems to get information from the fire alarm system but protects it from interference from outside. This provides the necessary protection, but it also limits the integration possibilities.

An alternative approach is to develop best design practices for constructing networks of integrated systems. By appropriate selection of network technology and appropriate use of routers and bridges to filter traffic, interference problems and concerns about guaranteed access to network bandwidth in an emergency can be effectively eliminated. Business network systems commonly use these techniques today, and there is no reason why they cannot be applied to building automation systems.

Having fire alarm systems tested by UL and listed for their intended purpose is an expensive and time-consuming practice. It is unrealistic to expect manufacturers of other building automation devices to absorb this expense when their products are not directly involved in detecting or responding to a fire just because they can communicate with listed fire-detection devices. The testing and listing procedures need to be updated to recognize this reality. By combining good design practices with tests that ensure the integrity of the fire alarm system under conditions that can occur if the design practices are followed, safety concerns can be satisfied without sacrificing the benefits of integration. In some locations, building codes may need to be modified so that they are based on performance criteria instead of prescriptive requirements.

In fire alarm systems, it is very important to ensure that only authorized personnel can silence alarms, reset alarms, and perform other operations that significantly affect the performance or status of the system. Traditionally this has been accomplished by having dedicated fire system workstations that provide the operator with capabilities that are assigned when the operator logs in. In an integrated system, there may be many workstations with the ability to send messages to fire alarm system components. Fire alarm panels need to be protected from accidental or intentional disruption from other devices or workstations in the building. BACnet provides mechanisms for authenticating messages but they are not widely implemented. This is another design issue that needs to be addressed.

INTERNATIONAL STANDARDS ACTIVITIES

As stated before, BACnet has been adopted as a standard in the United States and as a prestandard in the European Community. The International Organization for Standardization (ISO) Technical Committee 205 is deliberating the adoption of BACnet as a world standard. This is being done as part of the activities of Working Group 3, Building Control System Design. The participants in this activity include representatives from the United States, Europe, Japan, and Australia. BACnet is now at the “committee draft” (CD) stage and is expected to advance to the “draft international standard” (DIS) stage soon. The ISO activities are being coordinated with the ongoing maintenance of BACnet in the United States. The intention is to incorporate into the U.S. standard any additional features needed to obtain international acceptance of the protocol. It is also expected that any additions that come from the continuous maintenance process in the U.S. will be incorporated into the ISO standard. An effort is being made to coordinate BACnet testing and certification programs in Europe and the U.S. There is a strong international consensus that it is in everyone’s interest to be able to freely market BACnet products anywhere in the world. A common standard and reciprocal certification recognition are critical if this is to happen.

There are a variety of important reasons for integrating fire alarm systems with building automation systems. These include smoke control, single-seat access to building information, easier maintenance, sharing sensor data, obtaining information about the location of people during an emergency, and providing infrastructure for new technology to improve performance and safety. A standard communication protocol is a critical infrastructure component to make this integration possible. BACnet is such a protocol, and it is gaining popularity around the world.

More than just communication standards need attention. Systems must be designed and maintained in ways that will assure the integrity of the fire alarm system even when other components of the building automation system fail. It is also necessary to design the system so that bandwidth is available to the fire alarm system when an emergency arises. Best practice design guidelines can meet these needs. UL testing and listing procedures need to be updated to address open integrated systems. In some cases, building codes may need to be revised to performance-based approaches.

Market forces are already pulling the industry in the direction of integrated systems. As new technology is developed that adds capabilities because of the integration, the pressure to integrate systems will grow. The end result will be buildings that are easier to operate and are safer for the occupants.

Steven Bushby is with the National Institute of Standards and Technology.

** Certain trade names and company products are mentioned in the text in order to specify adequately the equipment used. In no case does such identification imply recommendation or endorsement, nor does it imply that the products are necessarily the best for the purpose.*

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Intelligent Fire Alarm Systems

By Jeffrey S. Tubbs, P.E.

INTRODUCTION

The fire protection community faces growing needs for reliable fire-detection systems that give the earliest possible warning of fire. These needs draw attention to problems associated with false or unwanted fire alarms. Unwanted fire alarms can seriously undermine the effectiveness of installed alarm systems, interrupt business, and, at worst, may cause occupants to ignore the fire alarm system during an actual fire.

Historically, fire alarm manufacturers have addressed unwanted alarms through two approaches:

- Decreasing detector sensitivity. Maintenance personnel are able to set individual detectors to be less sensitive after the devices are installed to alleviate false alarms. Typically, detector sensitivity is only decreased; the sensitivity is rarely increased to improve detection capability.
- Using alarm verification. Alarm verification essentially introduces a detection delay time. When the detector reports an alarm condition, the fire alarm system waits for a specified programmed delay time (typically, a 30-second delay) to confirm that the detector continues to report an alarm condition. If the detector is in alarm after the delay time, the alarm sequence is actuated.

Although decreasing detector sensitivity and using alarm verification can reduce the potential for unwanted alarms, occupant notification may also be delayed

Intelligent fire alarm systems have been developed to address unwanted alarms while maintaining the desired level of detector sensitivity. Although the capabilities of intelligent systems vary between manufacturers, intelligent systems can provide a number of benefits, including faster occupant notification, increased detector sensitivity, and decreased potential for unwanted alarms. Also, intelligent systems can provide users with notification of needed detector maintenance.

INTELLIGENT VS. CONVENTIONAL DEVICES

Artificial intelligence has become a buzzword in many fields involving technical products. Intelligent systems have been used in virtually every technical field involving a wide range of industries, from systems designed for the space shuttle to many computer games. The term "artificial intelligence" is typically associated with systems that have the ability to reason or learn.

A number of new fire alarm products have become available, many of which are labeled as components of intelligent fire alarm systems. While intelligent fire alarm systems are not as advanced and sophisticated as what is typically thought of as artificial intelligence, they do incorporate some of the simple logic techniques incorporated in such systems.

Intelligent fire alarm systems were initially another name for addressable systems. Addressable systems provide a unique address for each detection device, providing a increased level of information to the user. Today's intelligent systems do more.

Currently, intelligent fire alarm systems incorporate detectors that use decision-making algorithms to determine alarm conditions. Some employ multisensor approaches, while others use multidetector approaches or profile comparisons. In most cases, measurements, such as smoke concentration and temperature, are received by one or more sensors. This information is then analyzed by specific algorithms to determine if these measurements indicate that a fire condition may be present.

Some intelligent detection devices make all the alarm decisions, while others report conditions to the alarm system control equipment which makes the alarm decision. Conversely, conventional fire alarm detectors use set thresholds in a single sensor to determine alarm conditions. Thus, conventional devices are rigidly designed to signal alarm conditions only after a specific level has been reached.

INTELLIGENT DEVICES

Fire alarm devices labeled as intelligent are usually thought of as analog-type detectors.[1] Analog-type detectors provide continuous, real-time measurements of air properties within a detection chamber which is, in turn, affected by the surrounding air. These detectors can have set thresholds such as conventional detectors to initiate an alarm sequence based upon these measurements. In addition, many intelligent detectors use algorithms to process levels lower than those threshold values set to indicate an alarm. These are defined here as prealarm signals. Prealarm signals can be compared with a number of analog signals from other detectors and sensors within the space, compared with previous signals received from the affected detector or compared with predetermined fire profiles obtained through fire tests. These techniques allow an increase in detector sensitivity, while decreasing the potential for false alarm potential.

To be listed or approved, intelligent detectors must meet the criteria for conventional detectors. As such, when an intelligent detector reaches the alarm threshold specified for conventional detectors, it must initiate an alarm signal.

A discussion of some of the decision-making algorithms used in intelligent fire alarm systems follows.

AUTOMATIC SENSITIVITY COMPENSATION

Dust, dirt, humidity, age, and other environmental factors affect smoke detector sensitivity. These factors shift the base reading of detectors closer to or further from an alarm threshold, depending upon the type of contamination and type of sensor. As this base reading is shifted, higher or lower concentrations of smoke are required for conventional detectors to reach the preset alarm threshold. This makes smoke detectors more susceptible to unwanted alarms or delayed activation over time.

Many analog detectors are designed with automatic sensitivity compensation. While detectors incorporating automatic sensitivity compensation, or "drift" compensation, may or may not be classified as intelligent detectors per the definition suggested within NEMA Training Manual on Fire Alarm Systems,[1] "drift" compensation is included within some intelligent detection and is discussed here to provide background.

Since the detectors have a continuous range of sensitivities, the alarm threshold can be shifted higher or lower, based on the analog prealarm signal. If the sensitivity increases as the detector becomes dirty, the alarm threshold is shifted upward within the detector's range of sensitivity, compensating for the increased analog readings. When, over time, the analog signal is shifted close to the upper sensitivity limit, the detector provides a maintenance signal, notifying the user of service requirements before unwanted alarms occur. This allows the detector to compensate for contamination and environmental factors while allowing for optimum detector sensitivity.

PRESET SENSITIVITY ADJUSTMENT

Detectors with preset sensitivity adjustments operate similar to those with automatic sensitivity compensation. This design adjusts the sensitivity according to preset conditions. Some spaces may routinely require an increase or decrease in detector sensitivity. For instance, a highly protected space may require a higher level of protection during off-hours or a night club may require a decrease in detector sensitivity during normal business hours to compensate for occupant smoking. This allows optimum sensitivities to be used for each predictably changing background condition within a given space.

PROFILE COMPARISON

Fires tend to have unique smoke and heat profiles based upon specific fuels burning. For instance, fires in plastic materials tend to produce more smoke than fires in flammable liquids. Some fire alarm manufacturers have developed proprietary databases with details characterizing products of combustion for a large range of fuels. These databases include measurements of time-dependent properties, such as photoelectric detector readings, ionization detector readings, and temperature readings. Data have been grouped according to fuel packages and specific traits have been determined for each type of fuel package.

Although individual fire alarm manufacturers use different methods, analog measurements from individual detectors are compared with predetermined values obtained in fire tests. This allows detectors to filter out conditions that are not typically associated with fires. The comparison algorithm is based on the predetermined values obtained from testing. Therefore, large spikes in properties such as obscuration noticed when insects enter smoke chambers or large spikes in ionization values due to radio frequency interference can be recognized and ignored.

Since alarm verification allows detectors to use a time delay to confirm alarm conditions, the detector can use the alarm verification delay time to analyze the prealarm signal. If the prealarm value is consistent with conditions typically associated with fire conditions, the alarm is verified, and an alarm is reported immediately. Since unwanted alarm conditions are filtered out, detector sensitivities can be significantly lowered, allowing early detection of fires.

Various manufacturers use different methods with this approach. Some group the test results from various environments such as offices, warehouses, or hospitals, while others use a single-representative approach to compare recorded readings to actual readings.

MULTISENSOR COMPARISON

Detectors using multisensor comparisons operate similar to single-sensor comparison detectors described earlier. However, several methods of detection are used. Combinations of ionization, photoelectric, and heat detectors are incorporated into a single detection device. This device can then compare information from several different sources. This approach may enhance the ability to filter out unwanted conditions and allows for increased sensitivities. For instance, a quick rise in obscuration, without any associated rise in temperature, can be filtered out. Another benefit may be that these detectors use algorithms to process the analog values from all of the sensors. The conditions for reporting an alarm can then be based upon a combination of inputs from each sensing element, which further increases reliability by enhancing stability, sensitivity, or both.

MULTIDETECTOR COMPARISON

As smoke flows across a ceiling, it tends to affect more than a single detector. Multidetector comparisons make use of this trend. Affected detectors analyze adjacent detector prealarm conditions. Alarms are initiated when the prealarm conditions of adjacent detectors indicate a similar rise in the associated value. Similar to the detectors that compare profiles, these detectors can compare multiple locations and eliminate local spikes caused by an insect or radio frequency interference. This allows decreased alarm thresholds, faster detection times, and greater system stability.

OTHER FEATURES

Powerful system processors allow additional features, such as:

- Automatic Addressing: detectors automatically determine an independent address and integrate it into the system.
- Setting of Prealarms: one or more prealarms can be set.
- Detector Memory: detectors can store a variety of information including the rate of environmental compensation, last maintenance date, and analog signal for last alarm.
- Intelligent Notification: notification devices can be given discrete addresses to allow a single circuit to cover multiple independent notification zones. This also allows individual notification device testing.

Intelligent fire alarm systems can provide additional information to the control equipment and ultimately to the user. Each building layout and environment is unique, and application of these systems should be carefully evaluated to provide the best approach. Since analog detectors can compare conditions with known values and provide increased information, this technology provides many enhancements to today's systems.

Intelligent detectors will likely become the typical or standard detector for many applications. This will be due, in part, to the cost of these detectors becoming comparable to that of typical detectors. Currently, several intelligent devices are only slightly more costly than that of standard devices. As the cost of intelligent technology decreases, more and more of these devices will be used in fire alarm systems.

Finally, it is important to note that all detectors, whether combination and/or intelligent, require maintenance to be effective. Even with all of the new technology, maintenance programs for detectors and fire alarm systems should be viewed as one of the most important aspects of fire alarm systems.

Jeffrey Tubbs was formerly with Rolf Jensen & Associates.

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Performance Metrics for Fire Detection

By John M. Cholin, P.E., and Chris Marrion, P.E.

OVERVIEW

The concept of a smoke detector is over 75 years old. In E. Meili's book "My Life With Cerberus,"[1] Meili states that H. Geinacher reported in the Bulletin of the Swiss Association of Electrical Engineering in 1922 of experiments he performed using an ionization chamber and how they could be applied to analyzing smoke concentrations. The next documented indication of a similar-type device was from French patent applications dated 1937/1938 by Malsallez and Breitman[1] describing a fire detector based on using ionization chambers.

Over 25 years ago, Custer and Bright published their seminal publication, *Fire Detection: State of the Art.*[2] In this document, they conclude:

"Several areas of the detection picture, however, need improvement in order to provide data which will allow effective engineering judgements to be made in selecting the appropriate detector for specific applications...

Changes need to be made in the testing and approval procedures to provide engineering data for approved detectors. Data should be provided which accurately describe the performance of approved units over a wide range of smoke sources, air velocities, rates of heat evolution, and installation configurations. These data can permit better engineering of detection systems with respect to the expected fire exposure and response time criteria. By limiting approval testing to a narrow range of fire signatures, ambient conditions and installation configuration, or testing against a standard device such as an automatic sprinkler head, many detectors which have desirable characteristics for specific applications may be excluded from the marketplace while others which may have undesirable properties, such as insensitivity to certain fire signatures, may be accepted. This can result in detector failures due to lack of engineering data concerning the capabilities of a listed or approved unit."

Over 20 years ago, Heskestad and Delachatsios stated in their landmark research:

> *"There is a need to tie the spacing of detectors, heat as well as smoke, to realistic fire situations, recognizing effects of fire-growth rate, ceiling height, combustible material (in the case of smoke detectors), and ceiling configuration. The spacing should be such that a threshold fire size, Q_d (kW,Btu/s), is not exceeded at detection."*[3]

As seen, it has been almost 80 years since the initial development of smoke detectors and at least 20 years since two significant publications in the fire protection industry identified the need for developing performance metrics for detectors. Yet given all this time, and the identified need, the fire protection industry has made virtually no progress toward a credible metric for accurately predicting the performance of either heat or smoke detectors.

The engineering community has accepted the concept of performance-based fire engineering design for the built environment. The *SFPE Engineering Guide to Performance-Based Fire Protection Analysis and Design of Buildings* outlines the framework and the design methodology for performance-based design. The *Life Safety Code,*® NFPA 101-2000, and the *ICC Performance Code* adopt the performance-based design method as representing an acceptable means to provide equivalent life safety through alternative designs. Now that the concept of performance-based design for the fire protective systems has been accepted, how can its promise be fulfilled? How can a performance-based design or analysis be conducted effectively when the response of heat or smoke detectors to even the simplest of fire scenarios cannot be predicted with any reasonable degree of engineering precision or confidence? Since many fire safety aspects (including occupant notification, notification of the responding fire service, activation of special suppression systems, initiation of smoke management systems, release of door holders and other devices to complete the compartmentation, etc.) rely on determining when smoke or heat detectors will respond, an accurate assessment of detector performance is necessary. Yet fire detection systems are relied upon for all of these critical fire safety functions with no credible means of accurately predicting when, if ever, these functions will be initiated.

It is interesting to note that the least commonly used type of fire detection has performance metrics and, hence, the best design tools. A Nationally Recognized Testing Laboratory (NRTL) listing radiant energy-sensing detectors in the U.S. has a long-standing, established practice of providing a performance metric for flame detectors. This performance metric has permitted performance-based design in conformance with NFPA 72, the *National Fire Alarm Code,*[4] and its predecessor document NFPA 72E-1990 *Standard on Initiating Devices.*[5] Indeed, performance-based design has been the required method of designing flame and spark/ember detection systems since 1990. Unfortunately, over 10 years after performance-based design utilizing detector performance metrics was first incorporated into NFPA 72, the designer still has no such method and metric for heat detectors and smoke detectors, the most commonly used types of detection.

HEAT DETECTOR PERFORMANCE METRICS

The fundamental premise underlying performance-based design is that, if the information regarding the compartment, ambient conditions, detection system characteristics, and hazards are adequately defined, engineering tools can be used to predict how a fire can develop once ignited. These same engineering tools can be used to predict conditions in the compartment of fire origin at a location relative to the fire plume and some specified time subsequent to ignition. This would then enable one to predict the intensity of the fire signature at a hypothetical detector location as a function of the fire size and growth rate, and room configuration. Ostensibly, this permits the engineer to predict detector response.

This concept was the basis for *Appendix C – Engineering Guide for Automatic Fire Detection Spacing* to NFPA 72E-1984, *Standard on Automatic Fire Detectors.*[5] This appendix utilized the correlations developed by Heskestad and Delachatsios[3] to produce a set of tables that specified heat detector spacing as a function of design fire size, fire growth rate, detector location relative to the fire, ceiling height, and detector response parameters including operating temperature and thermal response. The thermal response of a heat detector was estimated by using a correlation to the test methodology for determining Response Time Index (RTI) for sprinklers. This correlation is outlined in Section B-3-2.5.1 of NFPA 72-1999, the *National Fire Alarm Code.*[4]

Unfortunately, as Schifiliti and Pucci[6] have pointed out, this correlation introduces an error of unquantified magnitude due to the different ceiling jet velocities encountered at fire sizes normally associated with heat detector response versus the fire size required for sprinkler response. Heat transfer between a fluid and a heat sink is a function of fluid flow velocity.[7] Consequently, when a simple coefficient of heat transfer is to be determined for any heat transfer device, sprinkler, or heat detector, it must be measured at flow velocities close to those for which the device is being designed. The test methodology for determining RTI utilizes a flow velocity of 1.5 m./sec. (5.0 ft./sec.), considerably larger than the ceiling jet velocity one would expect to observe at a heat detector location during a fire that would normally be anticipated as the design basis for a heat detection system. The magnitude of the error introduced by using the test methodology for RTI has not been quantified and may be large enough to invalidate a design. Without conducting further research, however, it is difficult to tell.

Since heat detectors are not, as part of their listing examination, subjected to the test to determine RTI, a correlation table was included into the *Appendix C – Engineering Guide for Automatic Fire Detection Spacing* to NFPA 72E-1984, *Standard on Automatic Fire Detectors.*[5] However, this correlation is of limited precision as the exact same heat detector may obtain a different "listed spacing" from the various NRTLs due to the slightly different test conditions that may be found at each NRTL. Listed spacing is a lumped parameter comprised of numerous independent variables, many of which are determined by the test and not the detector under test. Consequently, a correlation between listed spacing and RTI is tenuous at best. Thus, RTI may be of quite limited use in the context of being able to accurately predict the response of heat detectors.

Listed spacing was originally intended as a means of comparing one detector to another and not as a design tool. Since listed spacing is a lumped parameter that encompasses detector characteristics, fire characteristics, test room characteristics, and test conditions into a single value, the designer has no method of separating out the effect of any one parameter from the lumped parameter for design purposes. Consequently, the lumped parameter of listed spacing is of very limited usefulness in the context of performance-based design. It does not appear that any published study exists that supports the notion that heat detectors installed pursuant to their listed spacing actually provide the expected performance in terms of fire size at alarm initiation. This therefore leaves the engineer without the proper tools to accurately predict when the detector will respond to a given fire scenario with a high degree of certainty.

To confidently and accurately design a heat-detection system in a performance-based design environment, the designer must know the operating temperature (T_r) and the Thermal Response Coefficient (TRC) of the detector. Without both of these metrics, the designer is forced to estimate response by using a correlation between the listed spacing of the detector and RTI. Since there are unknown inaccuracies in the listed spacing to RTI correlation, the designer must perform their design calculations using a range of RTI values and analyze the sensitivity of the design to inaccuracies in the correlation. The result is a design of questionable credibility and hence large safety factors. Such a design rarely lives up to the full potential of performance-based design as an engineering concept.

A SOLUTION

In view of the need for a heat detector performance metric, the Technical Committee on Initiating Devices for the *National Fire Alarm Code* (NFAC) adopted language in the 1999 edition mandating the determination and publication of the Thermal Response Coefficient, a performance metric analogous to RTI, for a heat detector as part of its listing. This requirement was established with an effective date of June 2002 to provide sufficient time for the development of the test methodology and the determination of the TRC for currently listed detectors. With a properly developed method for determining TRC, the design of fire detection systems using heat detectors could be based on the principals of fire dynamics rather than listed spacing, yielding designs whose performance could be predicted more accurately. The strategy was to publish a TRC that had the same form as RTI. This would enable the fire protection engineer to use existing performance prediction correlations and fire models, originally developed for sprinklers, to predict the performance of detection systems using heat detectors.

Unfortunately, as of this writing, despite the fact that two research proposals were presented to the manufacturers of heat detectors and UL over two years ago, there has yet to be agreement on how to fund the research to develop the test methodology. In addition, recent proposals to NFPA 72 have been made to retract this requirement from the code. Consequently, the engineering community is still left with no validated performance metric for heat detectors.

SMOKE DETECTOR PERFORMANCE METRICS

As if the situation with heat detectors is not sufficiently challenging, the situation does not get better when it comes to performance metrics for smoke detectors. Optical density or obscuration is usually used as a measure of smoke concentration. This measure was apparently adopted due to the presumed objective for smoke detection: to provide occupant notification while there was still sufficient visibility to allow escape of the occupants prior to the onset of untenable conditions. Unfortunately, the optical properties of smoke vary substantially with variations in a number of parameters including fuel, fire ventilation, smoke temperature, and smoke age. A more detailed analysis of smoke also leads to other measurable parameters such as particle size distribution, mass concentration, particle number concentration, and smoke color that determine the gross, macroscopic optical properties of smoke. The dynamics of smoke production, aging, and movement have been and continue to be an area of ongoing research.[8]

In the U.S., the sensitivity of smoke detectors is stipulated as the percent per foot obscuration at which the detector renders an alarm in the UL 268 Smoke Box.[9] This is also a lumped parameter. The test for determining this value relies on a carefully controlled air flow, temperature, relative humidity, fuel (a cotton lamp wick obtained from a specific source), and test box. Consequently, the sensitivity stipulated on the detector that is derived from the UL 268 Smoke Box is only valid in the smoke box. No research has been found that substantiates the use of the marked sensitivity on the smoke detector as an engineering basis for the design of a smoke detection system; unless, of course, the design objective is to detect a smoldering lamp wick located inside a UL 268 Smoke Box. Yet designers routinely use the sensitivity marked on the detector in conjunction with a fire model to leap to the conclusion that a smoke-detection system will respond at a given smoke obscuration level.

The closest thing to a performance metric for smoke detectors available to designers using U.S. products is the performance implied by the full-scale room fire tests that are conducted as part of the listing evaluation by UL. UL conducts three room fire tests with the detector under test located 5.3 m (17.5 ft) from the fire plume center-line, implying a spacing of 7.6 m (25 ft.). These fires are summarized in Table 1.

The maximum obscuration levels tabulated in Table 1 represent the minimum acceptance criteria for smoke detectors that are marked with the 1% to 4% obscuration sensitivity found on the detector label. Note that for the paper fire in an actual room test, the obscuration level can be up to 37 times that which is listed on the detector before it is required to alarm. The smoke used in the smoke box is a light gray in color, ideally suited for detectors that rely on reflected light for detection, whereas the smoke produced by the test fires is far from optimal. Nevertheless, the disparity in the criteria for the room fire tests and the marked "sensitivity" gives rise to concern that there might be significant delays in smoke detector response under real fire conditions.

The size of the test fires is not explicitly stipulated in the UL test standard. Consequently, if a designer were inclined to use this test data as a basis for a performance prediction, they must infer the fire size from the

Table 1. Summary of the UL Full-Scale Room Fire Tests in UL 268

Test	Fuel	Max. %/m (%/ft) Obs.	Max. Response Time
A	Paper	78 (37)	4 minutes
B	Wood	46 (17)	4 minutes
C	Toluene/Heptane	37 (13)	4 minutes

Table 2. UL 268 Smoke Detector Test Acceptance Criteria for Different Colored Smoke[9]

Smoke Color	Acceptable Response Range	Variance (Max/Min)
Grey Smoke	1.6 %/m (0.5 %/ft) to 12.5 %/m (4.0 %/ft)	7.8
Black Smoke	1.6 %/m (0.5 %/ft) to 29.2 %/m (10.0 %/ft)	18.25

Table 3. Values for Optical Density at Response (for flaming fires only)[6]

Material	$10^2 D_{ur}$ $m^{-1}(ft^{-1})$		Relative Smoke Color
	Ionization	Scattering	
Wood	1.6 (0.5)	4.9 (1.5)	Light
Cotton	0.16 (0.05)	0.26 (0.8)	Light
Polyurethane	16 (5.0)	16 (5.0)	Dark
PVC	33 (10.0)	33 (10.0)	Dark
Variation	200:1	12.5:1	

Table 4. Temperature Rise for Detector Response[6]

Material	Temperature Rise ˚C (˚F)	
	Ionization	Scattering
Wood	14 (25)	42 (75)
Cotton	1.7 (3)	28 (50)
Polyurethane	7.2 (13)	7.2 (13)
PVC	7.2 (13)	7.2 (13)
Average	**7.5 (14)**	**21 (38)**

descriptions in the standard and then scale up to their design fire. While possible, this process has the potential for producing errors in accurately predicting response.

Also, there is no "listed spacing" for a smoke detector resulting from the UL listing evaluation. Instead, the manufacturer is left to "recommend" a spacing for its detector. In spite of the fact that the implied spacing derived from the UL Full-Scale Room Fire Test is 7.6 m (25 ft), most manufacturers and NFPA 72 recommend a spacing of 9.1 m (30 ft), with no reference to design goals/objectives or the design fire for which this spacing is deemed appropriate.

Finally, while UL at one time included a Black Smoke Test in UL Standard 268 to determine the differential between the response of a detector to black smoke compared to its response to the light gray smoke produced by the cotton lamp wicking, there is no current evaluation for the impact of smoke color on the response of the smoke detector listed by UL Since most spot-type photoelectric smoke detectors operate on a reflected light principal, smoke color can have a profound effect on the ultimate response of the detector to real-life fires. Table 2 illustrates the variation in response to gray and black smoke.

This difference in response is the artifact of a number of variables, including smoke concentration measurements and reflectance properties of smoke. The smoke concentration is derived from the attenuation of a projected light beam while, for instance, spot-type photoelectric smoke detector response is derived from the intensity of reflected light. Optically absorbent smokes produce high attenuations but poor reflectance, while light gray smoke is deemed to be equally absorbent and reflectant. This divergence between the smoke measurement and smoke detection methods contributes to inconsistency of the test results. However, the smoke yield of the fires in question also contributes to the divergence in the test results. This fact is inescapable: the same detectors can respond at different obscuration levels to different fuels, different combustion modes, and different types of smoke.

Examples of this wide variation in response were shown by Heskestad and Delachatsios[3] in full-scale tests they performed almost 25 years ago. Some of their results are summarized in Table 3.

Note the large variations of optical density at response that can vary by a factor as large as 200. These variations are due not only to the variations in the detector technology but also the variation in smoke concentration and color. This underscores the importance of having a means to accurately predict smoke detector response that can be correlated to the detector as well as the characteristics of the smoke, if smoke detectors are to be relied upon for critical fire safety functions.

The above should not be construed as a criticism of UL or its test standard, UL 268. UL 268 was designed to provide a uniform test of product allowing a purchaser to be assured that the product was generally acceptable for a specific purpose. It has never been the intent of UL 268 to provide a performance metric for use in the design of systems. However, as the needs of society change, the testing standards upon which that society relies must also change. If society's need for fire-safe built environments are to be addressed through performance-based design, then the testing standards must evolve to serve that emerging need.

Having no credible performance prediction methodology from either UL or the manufacturers, one is tempted to look to fire plume and ceiling jet

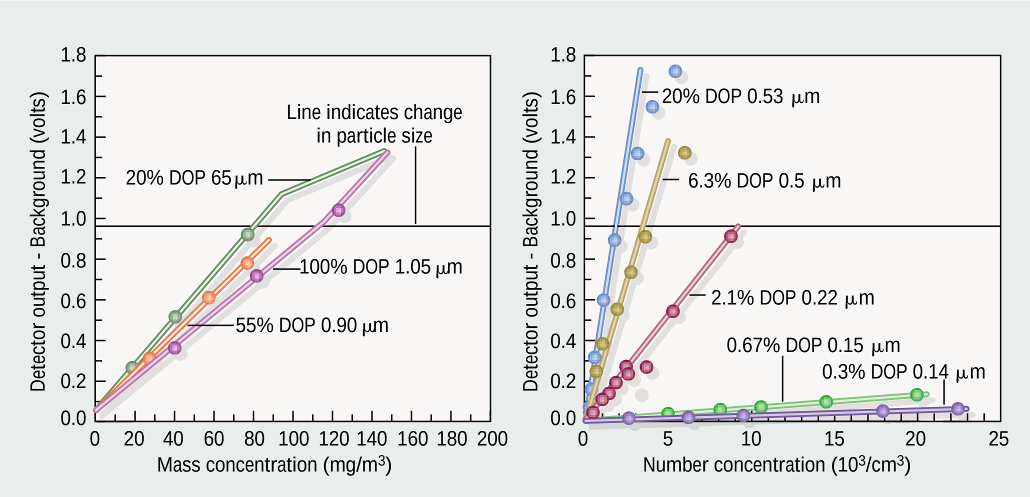

Figure 1. Response of photoelectric smoke detector plotted for a) mass concentration versus b) number concentration for monodisperse DOP aerosol.[11]

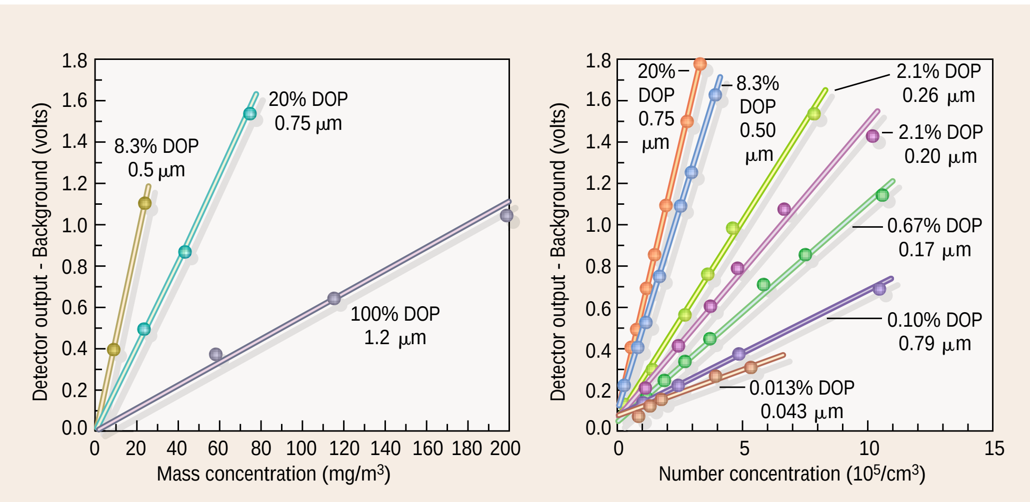

Figure 2. Response of ionization smoke detector plotted for a) mass concentration versus b) number concentration for monodisperse DOP aerosol.[11]

dynamics for a method. Heskestad and Delachatsios offered the notion that, for a given fire and detector, the temperature rise at the detector and smoke concentration could be deemed to be a constant.[3] In fairness to these researchers, it should be noted that they contemplated the development of a series of temperature rise versus response correlations over a range of fuels for each smoke detector as part of its listing evaluation. To illustrate their hypothesis, they selected a temperature rise correlation of 13°C (20°F). Unfortunately, readers of this research incorrectly concluded that such a correlation actually existed, assumed one number as representative for all detectors and all fuels, and then began using it as the basis for design. The truth is that no such correlation exists. Schifiliti and Pucci[6] have shown that there is not a basis for using a 13°C (20°F) temperature correlation as the basis for an actual design. Table 4 shows the temperature rise at alarm for the range of fires used by Heskestad and Delachatsios. Clearly, this data does not support the notion of a single correlation for all fires.

Furthermore, even if there was a reliable correlation between temperature rise and smoke concentration, the temperature rise would be a different value for each pairing of fuel and detector. Despite the fact that the "13°C temperature correlation" does not exist, many designs have been based upon the assumption that it does. Engineers still cling to the idea because it gave them an ability to predict smoke detector activation based upon the plume and ceiling jet produced by the fire. Clearly, this is what the design community needs in order to execute a performance-based design. Indeed, the enthusiasm with which the illusion of a correlation was embraced underscores the urgency of the need for a performance-predictive tool for smoke detectors. Sadly, the practicing engineer has very limited performance estimation methods at their disposal when designing fire-detection systems utilizing smoke detection.

A SOLUTION

To confidently and more accurately design systems using smoke detectors, the designer needs two metrics. The first is the inherent sensitivity of the detector. There is some disagreement regarding the actual form of this metric. Some propose a metric based upon the optical characteristic of the smoke, while others propose the use of mass per unit volume of air and correlations to correct for the optical characteristics.

In 1980, Mulholland wrote,[11]

"The two most important aerosol properties affecting the performance of these detectors are the concentration of the smoke aerosol and the particle size."

This statement was taken from his work with the National Bureau of Standards – again almost 20 years ago. His statement is based on the relationships observed for these characteristics, as indicated in part in the Figures 1 and 2.

From the figures, it is clear that Mulholland's research demonstrated a significant correlation between detector response, mass concentration, and number concentration. Clearly, additional research is necessary to provide sufficient data to develop a basis for a design correlation. Nevertheless, Mulholland's findings look quite promising. It certainly justifies the notion that, given a few years and a concerted research effort, reasonable test methods could be developed that would provide a performance metric that can be used to predict response to a given design fire under a range of environmental conditions.

Research is needed to determine the most effective form of the smoke detector performance metrics as well as the means of determining their numerical values for real smoke detectors. For example, is it more practical to quantify detector sensitivity as a function of optical density, or is it more practical to characterize it as a function of aerosol mass per unit volume and correlate for optical properties? Without research, the potential efficacy of these two approaches remains unresolved. Currently, the concept of two metrics, one quantifying detector sensitivity to the smoke aerosol and a second quantifying the smoke entry time delay, still seems to make the most sense. Ultimately, the objective is to have one or more performance metrics that can be used in the context of currently available fire modeling tools to predict smoke detector response within a range of situational conditions.

A proposal requiring the publication of smoke detector performance metrics in the form of a Sensitivity Factor and a Smoke Entry Factor has been submitted to the Technical Committee on Initiating Devices for the 2002 edition of NFPA 72, the *National Fire Alarm Code*. This proposal has been offered to create the necessary sense of immediacy to galvanize the manufacturing community into funding the research. Ostensibly, a code requirement would produce the necessary economic incentive for action. However, the reality is that this proposal will not survive without the support of the engineering community.

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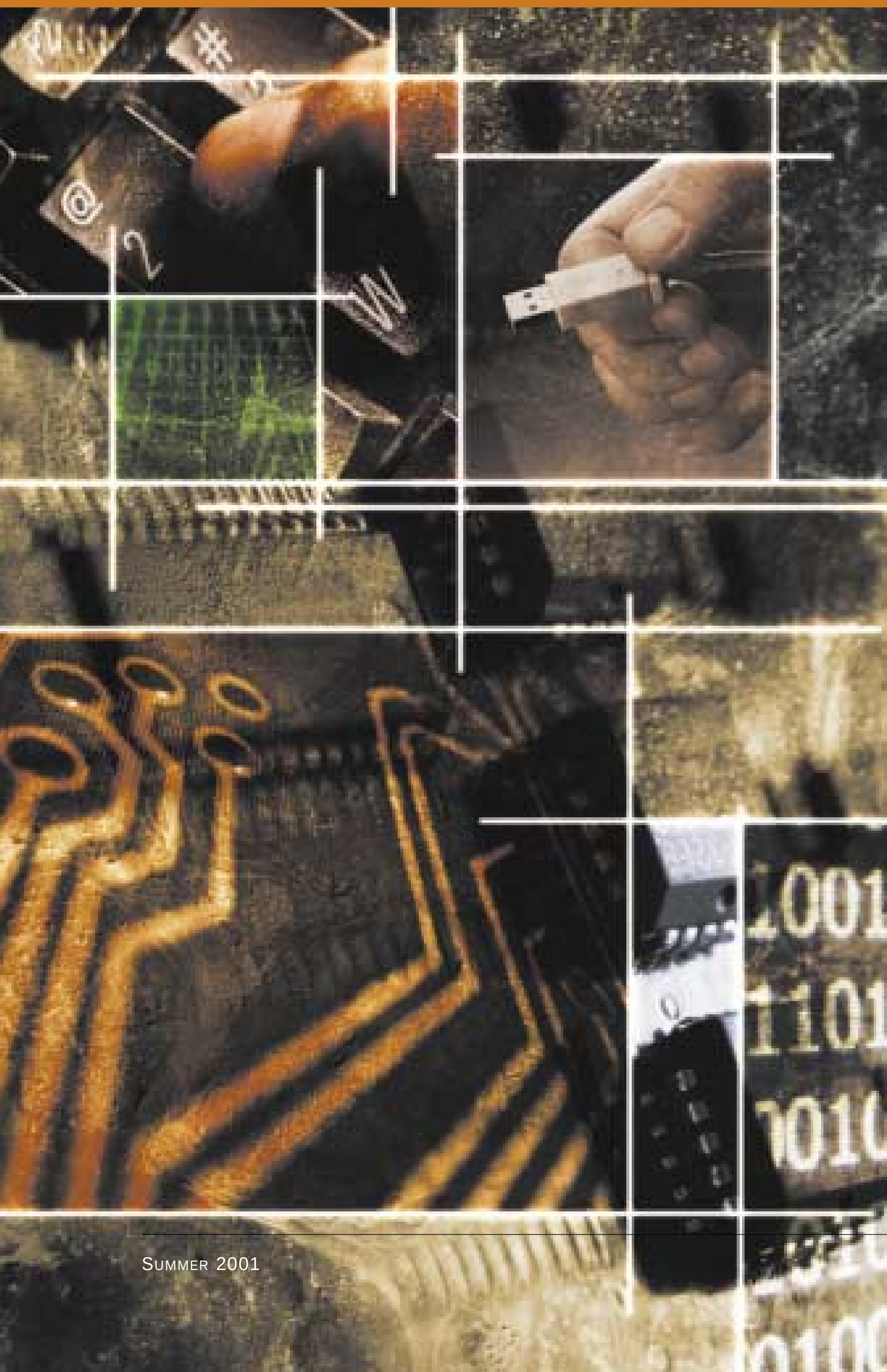
Underwriters Laboratories Contributions *for* FIRE ALARM SYSTEMS



By John L. Parssinen, P.E., Paul E. Patty, P.E, and Larry Shudak, P.E.

Factors that assure that fire alarm systems function effectively include: (1) initial device design, (2) third-party certification, (3) analysis of the protected area, (4) testing, and (5) maintenance of the system. This article describes the certification activity performed by Underwriters Laboratories (UL) that contributes to the predictable operation of a fire alarm system. UL's certification includes review of installation instructions, product construction analysis, performance tests for compliance with requirements in *Standards for Safety*, follow-up surveillance to confirm that products when shipped match the products tested during the initial product investigation, and certification of the installed fire alarm system.

Table 1. UL Standards Relating to Fire Alarm Equipment

STANDARD	TYPE OF EQUIPMENT OR SERVICE	UL LISTING CATEGORY
UL 268 – Smoke Detectors for Fire-Protective Signaling Systems	Smoke Detectors	UROX
	Smoke Detectors for Releasing Service	SYSW
	Smoke Detector Accessories	URRQ
	Smoke Detectors for Special Application	URXG
UL 268A – Smoke Detectors for Duct Application	Duct-Type Smoke Detectors	UROX
UL 38 – Manual Signaling Boxes for Use with Fire-Protective Signaling Systems	Noncoded Boxes	UNIU
	Coded Boxes	UMUV
UL 228 – Door Closures-Holders, With or Without Integral Smoke Detectors	Releasing Devices for Door Holders	GTIS
UL 346 – Waterflow Indicators for Fire-Protective Signaling Systems	Extinguishing System Attachments	USQT
UL 521 – Heat Detectors for Protective Signaling Systems	Heat Detectors	UQGS
	Heat Detectors for Release Device Service	SZGU
	Heat Detectors for Special Application	UTHV
UL 464 – Audible Signal Devices	Audible Appliances	ULSZ
UL 1971 – Signaling Devices for the Hearing-Impaired	Visual Signal Appliances for the Hearing-Impaired	UUKC
UL 1638 – Visual Signaling Appliances – Private Mode Emergency and General Utility Signaling	Visual Signaling Appliances	UVAV
UL 1480 – Speakers for Fire-Protective Signaling Systems	Speakers	UUMW
UL 864 – Control Units for Fire-Protective Signaling Systems	Control Units	UOJZ
	Control Unit Accessories	UOXX
	Releasing Device Control Units	SYZV
	Control Units and Accessories, Marine	UXWK
	Releasing Device Equipment	SZNT
	Releasing Device Accessories	SYSW
	Emergency Communication and Relocation Equipment	UOQY
UL 1711 – Amplifiers for Fire-Protective Signaling Systems	Amplifiers	UUMW
UL 1481 – Power Supplies for Fire-Protective Signaling Systems	Power Supplies	UTRZ

INSTALLATION INSTRUCTIONS

The initial activity of UL's investigation of devices intended for use in fire alarm systems is the review of the manufacturer's installation instructions. These instructions, which cover both the intended application of the product and how the product is to be used to meet that application, are primarily reviewed for consistency with the *National Fire Alarm Code*, NFPA 72. UL additionally reviews the instructions for operational claims and uses the document as the basis for electrically loading and interconnecting the product during the evaluation. Because of the significance of the document in relating UL's testing to the actual use of the product, the drawing number and revision level of the installation instructions/wiring diagram are required to be included in the product marking for reference by both the installer and inspection authority.

PRODUCT CONSTRUCTION

The second component is an analysis of the product's construction. This involves a review to confirm the product is constructed so that it will be practical and sufficiently durable for its intended installation and use. Generally, all electrical parts of a product shall be enclosed to provide protection of internal components and prevent contact with uninsulated live parts. Enclosures must have the strength and rigidity necessary to resist the abuses to which the product is likely to be subjected during intended use without increasing the risk of fire, electrical shock, and/or injury to persons. All current carrying parts must be sufficiently rated for the application, and the product must provide maintained spacings between uninsulated live parts and the enclosure or dead metal parts, and between uninsulated live parts of opposite polarity.

PERFORMANCE TESTS

The third component is performance evaluation that is based on the Standard for Safety for the specific product. The standards in Table 1 are used in the evaluation of fire alarm equipment.

The performance tests in the applicable UL Standard are used to help determine the reliable performance of the product. The evaluation generally includes a series of tests as follows:

1. Environmental tests to test for false alarms (variable temperature and humidity for control, detection, and notification equipment; corrosion for both detection and notification products; and accelerated aging, stability, and velocity sensitivity for detection units);
2. Mechanical abuse tests to evaluate the stability of the mechanical assembly and circuit connections (jarring for all equipment; vibration for both detection and notification products; and drop/impact for portable equipment); and
3. Various electrical tests (endurance, variable input voltage, transients, abnormal, and component temperature for all equipment; and static discharge for detection products).

As part of the aforementioned tests, the acceptable operation of the product is verified before and, depending upon the conditioning, either during or immediately after each test. This involves examining control equipment for minimum required operation, evaluating amplifiers for acceptable harmonic distortion and frequency response levels, verification of stable sensitivity for detection products, and maintaining rated audible and visual outputs, as applicable, for notification appliances.

Additionally, the above tests are conducted to determine that no false alarms occur and to confirm the conditioning does not have an adverse affect on the threshold response for smoke detectors when adjusted to maximum sensitivity settings. This procedure also establishes the upper sensitivity limit of the production window. During the smoldering smoke test, no alarm may occur before 0.5 percent per foot obscuration.

Smoke detection initiating devices are subjected to wood, paper, gas, and plastic fire tests as well as a smoldering smoke test while calibrated to their least favorable production sensitivity. Heat detectors are subjected to full-scale fire tests while mounted on their rated spacing.

The evaluation of compatibility of interconnected equipment is critical in confirming an effective fire alarm system. The compatibility evaluation may involve:

1. The confirmation of the required operation of interconnected control equipment such as fire alarm control units and related accessories, networked fire alarm control units, all products on signaling line circuits, and interoperability of protected premises and receiving equipment. This testing is conducted with maximum and/or minimum number of devices (or electrical load simulation where possible) and maximum and/or minimum line losses;
2. Confirming voltage and current output levels of the fire alarm control units and accessories consistent with the input ratings for the notification appliances and detection devices referenced in the installation instructions/ wiring diagram for the control equipment; and
3. Verification of operability of two-wire smoke detectors with any control equipment.

In 1989, UL issued new requirements for the evaluation of compatibility of fire alarm control equipment and two-wire smoke detectors. As part of this program, UL verifies various electrical specifications provided by the manufacturers through laboratory tests, and a comparison of the specifications is conducted to confirm that the operating parameters of each product are being met.

FOLLOW-UP SERVICE

A fourth component contributing to an effective fire alarm system is UL's Follow-Up Service (FUS) for the components of the system. This program consists of periodic visits by specially trained Field Representatives to each manufacturing location of the fire alarm system component. During these visits, the Field Representatives examine the construction of the product, verify that required production line testing has been performed, and review items such as marking and installation instructions.

UL Standards for the product cover not only the required minimum performance the product must demonstrate during the UL investigation, but also specify requirements for product construction and minimum marking and instruction requirements. As a part of the UL initial product investigation, an FUS Procedure is prepared. This procedure is for the use of UL's Field Representatives during their visits to the factory. It contains product-specific instructions for the Field Representative's use during the visit, a description of the specific UL Marks to be applied to the product, and a description of the product.

Using a combination of product photographs, written product description, and manufacturer's prints, all of which are included in the FUS Procedure, UL's Field Representative will verify that the product being manufactured is the same as was tested during the initial product investigation. The Field Representative verifies that any production line testing, as specified by the specific UL Standard covering the product, is being performed. Should the Field Representative note any discrepancies in product construction during the visit, the variation is noted and, if deemed significant, use of the UL Mark may be withheld until UL has evaluated the variation. The FUS program assures that the product is equivalent to the product that was evaluated during the initial product investigation.

ALARM SYSTEM CERTIFICATION

Another component that contributes to an effective fire alarm system involves a method to identify alarm systems that have been properly installed, tested, monitored, and maintained in accordance with applicable installation codes and standards. The standard used by UL to evaluate the alarm system certification is UL 827, Central Station Alarm Services [UUFX]. This service is identified as UL's Alarm System Certificate Service.

The certification process begins by qualifying the alarm service company. A company can be qualified after NICET-Certified members of UL's alarm systems auditing group review examples of the company's work. UL typically charges between $1,800 to $3,900 for this one-time, initial qualification, depending upon the level of service provided by the alarm service company. UL then charges the alarm service company an annual fee that currently ranges between $1,270 to $1,920, plus $30 for each active certificate. There can be additional costs incurred by the alarm service company if an installed system is found to require upgrades to bring it into compliance with the codes. These equipment and installation costs can vary depending upon the degree of modifications necessary.

If it is determined that a company can install these systems in accordance with the applicable codes and standards, the company is authorized to issue certificates to cover the systems that they install. The certificate is a document that identifies the type of alarm system, the protected property location, the alarm servicing company, and a description of the system equipment. Each certificate includes both the issue and expiration dates and a serial number. The alarm company retains a copy of the certificate, while inspection authorities can verify specific certificates either online at UL's Web site (www.ul.com/alarmsystems) or via printed documentation available from UL.

Once an alarm service company has been qualified to issue certificates, a certain number of their certificated installations are audited annually by UL to verify that they continue to comply with the applicable standards and codes.

The authors are with Underwriters Laboratories.

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PSYCHOLOGICAL VARIABLES THAT MAY AFFECT FIRE ALARM Design

By Dr. John L. Bryan

Beginning with the 1996 edition, the *National Fire Alarm Code®* specified a distinctive "evacuation signal" that used a three-phase temporal pattern signal in all new fire alarm systems. The specification for the three-phase temporal pattern can be seen in Figure 1.

The three-phase temporal pattern (ANSI S3.41) *Audible Emergency Evacuation Signal* is intended to be used where immediate evacuation is intended. Where relocation of occupants or defense in place is intended, the *National Fire Alarm Code* contains requirements for an "emergency voice/alarm communications service," which provides for verbal communication to the occupants to facilitate the selective evacuation or protection procedures.

The *Life Safety Code*, NFPA 101[1] specifies when a fire alarm system is required and the features of the system that may vary from the requirements of the *National Fire Alarm Code*.[2] The *Life Safety Code* provides two exceptions to the activation of the "general evacuation alarm signal" throughout the building. One of these exceptions provides buildings with physical environments which make total evacuation of the occupants impractical, e.g., many high-rise buildings. The second of these exceptions provides for the occupancies in which the occupants are incapable of "self-protection" and evacuation without the assistance of staff personnel is not feasible, such as occurs in healthcare or detention and correction facilities.

The *Life Safety Code* permits automatically transmitted or "live voice" evacuation instructions. This provision for the utilization of recorded or "live voice" communications with the exceptions to the general evacuation notification were first introduced in the 1981 edition of the *Life Safety Code*.

INITIAL DESIGN AND UTILIZATION OF VOICE ALARM SYSTEMS

One of the first evaluations of the design criteria for a voice alarm system was established and reported by McCormick as early as 1964. This design criteria consisted of the following critical elements for an effective vocal alarm system.[3]

1. Audible (heard above background noise)
2. Quick-acting (capable of evoking a quick reaction)
3. Alerting
4. Discriminable (easy to differentiate from other signals)
5. Informative
6. Compatible (consistent with others in use)
7. Nonmasking (not prone to interfere with other functions by drowning out other audio signals)
8. Nondistracting (not startling)
9. Nondamaging (not prone to cause irreversible damage to hearing)

One of the early listings of the characteristics of a voice alarm system was developed at the International Conference on Fire Safety in High-Rise Buildings in 1971.[4, 5] These characteristics were reported to have consisted of the following nine factors:[6]

1. A voice alarm system can give precise instruction under varying emergency conditions (fire, bomb threat, etc.).
2. Instructions can vary for different zones of the building.
3. Recorded alerting sounds can capture attention of the people and alert them to emergencies at hand by preconditioning.
4. Prerecorded messages can be used for preplanned conditions.
5. Prerecorded voice announcements can be used automatically to respond to manual or automatic fire alarms.
6. The voice system can be used to modify or update information.
7. Number and type of speakers are dependent on the situation of the area covered.
8. A voice alarm system may be combined with a music/paging system. If so, the music system can be turned off, and the emergency announcement system can operate at predesignated volume levels.
9. Manual voice directions can override or cancel automatic voice transmission.

One of the first “vocal alarm systems” was designed by Keating and Loftus in the Seattle Federal Building in 1974. The critical design variables of this system consisted of the following features:[7]

The alerting tone consisted of a 1000 Hz, pure sine wave tone (the then-authorized FCC warning signal). The human ear is reported to be most sensitive in the 500-3000 Hz range.[7]

The voice qualities of the communicator were varied with a female voice to initiate the announcement and a male voice to provide the emergency communication.

The actual wording of the messages provided the following three essential elements:

1. Tell the occupants exactly what has happened.
2. Tell the occupants what they are to do.
3. Tell the occupants why they should do it.

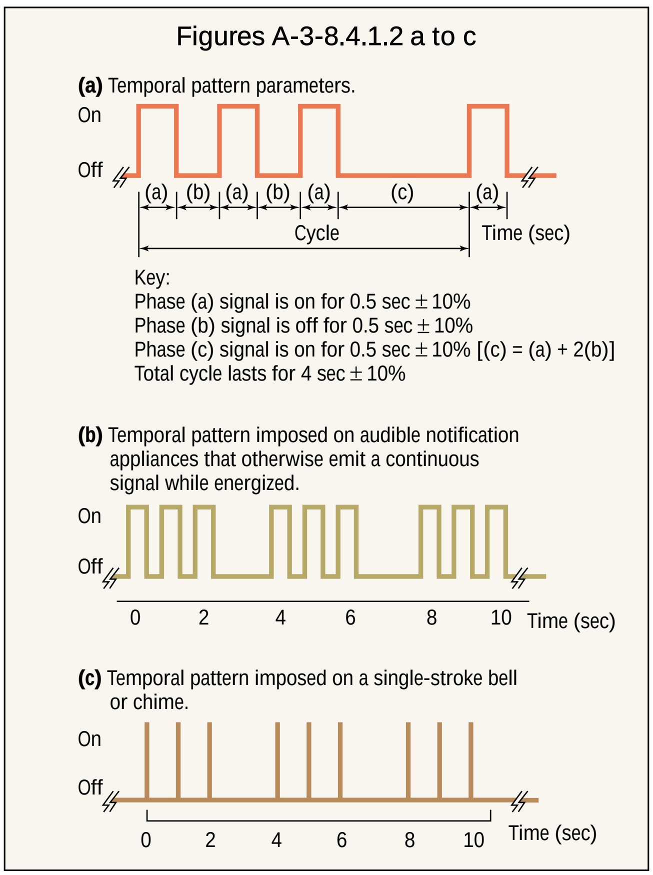

Figure 1. Figures A-3-8.4.1.2 a to c

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STUDIES AND OBSERVATIONS OF OCCUPANTS’ RESPONSE TO ALARMS

There have been both experimental and observational studies involving practice evacuations and fire incidents. These studies have involved both systems using evacuation signals and voice notification systems over the past thirty years. The following summaries of study reports are illustrative of the published observational and experimental research studies relative to the responses of building occupants to the various types of alarm signals or voice messages:

1. Seattle Federal Building, Seattle, WA, 1974.[6]

Keating and Loftus conducted two practice evacuations involving 205 participants consisting of adults, both visitors and employees. The alarm system consisted of a voice notification to the floors involved with the relocation and the floors receiving the relocated personnel. The report indicated the occupants on the floors being relocated had vacated these floors within 1.5 minutes of the alerting tone initiating the voice announcements. This report indicated the following general observation of the relocating occupants in response to the voice announcements:[6]

> *“Personnel unhesitatingly went to the stairwells to evacuate, no one attempted to use the captured elevators, nor was there any pushing, running, or other panicky behavior observed.”*

2. World Trade Center, New York, NY, 1975.[8]

Lathrop has reported on a voice alarm system involved in a fire incident in the South Tower on April 17 at approximately 9:04 a.m. The fire involved a trash cart in a storage area on the fifth floor, adjacent to an open stairway door. This configuration with the thermal column from the cart fire enabled smoke to penetrate the ninth through the twenty-second floors. The occupants on these floors moved into the core corridors of the floors as previously conducted during the practice evacuations. At approximately 9:10 a.m., a voice announcement from the Tower Communications Center monitoring these areas advised the occupants to remain calm and to return to their respective office areas. In spite of this announcement, the occupants remained in the corridor areas and became more concerned about the visible and irritating smoke condition. The Tower Communications Center then announced an evacuation message at approximately 9:16 a.m. It should be noted that the validity of any announcement will be questioned by occupants if the announcement is in conflict with direct physical awareness cues evident to the occupants. Thus, in this situation, the physical presence and discomfort from the smoke resulted in the occupants disregarding the information presented by the voice announcement.

3. Conference Room, London, UK, 1987.[9, 10]

Pigott has described an experimental study in a basement conference room in an office building with two randomly selected groups, consisting of ten adults, five males and five females. The adults were seated at two tables, six at one table and four at the other, with the seating selected by the participants. They were given questionnaires to fill out prior to being called for interviews on market research. The participants were given biscuits and coffee while filling out the questionnaires.

The first group was subjected to a continuous sounding alarm bell. After the bell had operated, the ten subjects discussed among themselves the meaning of the bell. The first subject to leave the room left after a period of three minutes, with the remaining nine persons leaving after eleven minutes. The second group of ten subjects had the identical refreshments and questionnaire. This group was subjected to a voice alarm announcement initiated after three seconds of the ringing bell stated in the following manner:[10]

"Attention. This is an intelligent fire warning system. There is a fire above you on the ground floor. Evacuate now."

The second group subjected to the above voice announcement all left the conference room within thirty seconds. It should be noted, as in many practice evacuations, the ten subjects in each group all left the basement level of the building by the way they entered, disregarding a corridor door marked as a "Fire Exit."

4. Lecture Theatre, Portsmouth, UK. 1989.[11]

Michiharu and Sime studied two practice evacuations with biology and pharmacy students in the age range of 18-19 years. Two different lecture theatres were utilized, one with the fire exit and the entrance/exit at the rear of the theatre, and one with the fire exit at the front of the theatre and the entrance/exit at the rear of the theatre. The fire alarm notification was by a continuous bell. The first evacuation practice involved the theatre with the entrance/exit and the fire exit at the rear of the theatre. This evacuation involved a total of 56 individuals with 31 persons (55 percent) leaving by the entrance/exit and 25 (45 percent) leaving by the fire exit. Upon hearing the bell alarm, the lecturer, after a period of 13 seconds, indicated the following:[11]

"We'd better all run for exits."

The second evacuation practice involved the theatre with the entrance/exit at the rear and the fire exit at the front of the theatre. This evacuation involved a total of 77 individuals, and they all evacuated through the fire exit due to the directions of the lecturer. The lecturer issued the exiting directions after a few moments of hesitation, upon hearing the alarm bell in the following manner:[11]

"I gather it sounds like a fire alarm, have to go that way."

The authors of this study indicate the importance of instructions from a valid and reliable source in influencing the behavior of the occupants as follows:[11]

"The fact that everyone in the R lecture theatre left by the fire exit, as a result of the lecturer's instruction, demonstrates how crucially important evacuation instructions from an authoritative and credible source can be."

5. Underground Station, Newcastle, UK, 1991.[12]

Proulx and Sime conducted five practice evacuations in the Monument underground transit station These evacuations involved approximately 304 participants, consisting of adults, children, and infants. The study utilized seven observers in the station, the 12 closed circuit television cameras in the station, and 133 questionnaires completed by adult participants. The practice evacuations were all conducted at approximately noon time on a weekday, and 5 seconds after Train 124 arrived in the station. Five different alerting scenarios were utilized in the practice evacuations, consisting of the alarm bell, staff directions, and public address system announcements.[12]

Evacuation 1: The alarm bell was rung; there was no staff in the station and no public address (PA) used.

Evacuation 2: Two staff members on Platform 3 knew a drill was scheduled, gave a PA announcement to *"evacuate the station,"* and directed evacuation.

Evacuation 3: Each 30 secs. (10 sec. message, 20 sec. interval) PA announcement *"Please evacuate the station immediately."* No staff in the station.

Evacuation 4: Two staff members assisted evacuation with PA directions to passengers on platform to take trains and those on concourse to leave by exits.

Evacuation 5: No staff in station. Directed PA was used: *"To all passengers. There is a suspected fire on the North/South escalator between the concourse and platforms 1 and 2. Passengers on all platforms should board the first available train. Passengers at concourse level should leave by the nearest exit. Do not use the lift."*

Table 1 contains a summary of the results of these evacuations.

Table 1. Summary of Times and Movements:[12]

Evacuation	Time to Start to Move		Time to Clear the Station	Appropriateness of Behavior
	Concourse	Bottom Escalator		
1 Bell only	8:15	9:00	Exercise ended 14:47	Delayed or no evacuation
2 Staff	2:15	3:00	8:00	Users directed to concourse
3 PA	1:15	7:40	10:30	Users stood at bottom of escalator
4 Staff + PA +	1:15	1:30	6:45	Users evacuated
5 PA ++	1:30	1:00	5:45 (10:15)	Users evacuated by trains and exits

Note: In Evacuation 5, the indicated time of (10:15) to clear the station was by a woman with two small children and a baby in a push cart.

6. Apartment Buildings, Ottawa, Montreal, North York, Vancouver, Canada, 1993.[13]

Proulx studied practice evacuations in four 6- and 7-story apartment buildings, one evacuation in each building. The total study population consisted of 254 participants with adults, seniors, impaired adults, and children. The alarm/notification systems consisted of bells. The results of these practice evacuations indicated the time to initiate the evacuation varied from 30 seconds to 24 minutes, with a mean time of 2.5 minutes. The most prevalent pre-evacuation activities were:[13]

> *"Find pet, gather valuables, get dressed, look in corridor, move to balcony, find children."*

7. High-Rise Apartment Building, Ottawa, Canada, 1997.[14]

Proulx studied this fire which occurred in a unit on the sixth floor of a 25-story apartment building at approximately 4:30 p.m. This study involved the conduct of interviews with occupants of the sixth and seventh floors and the distribution of questionnaires to all the other units. A total of 137 questionnaires were utilized in the study consisting only of persons that were in the building at the time of the fire. The population in the building was predominately adults with 68 percent over 65 years, 29 percent between 21 and 65 years, and only 3 percent children or teenagers. A total of 43 adults consisting of 23 percent reported perceptual, physical, or mental impairments. The fire alarm system consisted of a sounding device through speakers in each unit, with the fire alarm signal being overridden by voice messages through the speakers. The building manager operates the voice communication system and made the following four announcements as indicated in the report:[14]

The first message was given before the arrival of the fire department; it stated: *"There is a fire on the sixth floor. The fire department is on its way."* After the fire department's initial assessment of the situation, the chief in command gave the order to evacuate. The resident manager issued the message: *"All occupants should evacuate using Stairwells B and C."* After encountering occupants coming down Stairwell A that was being used for fire-fighting, another message was issued: *"Occupants should not evacuate through Stairwell A."* Finally, many exhausted, anxious occupants exited from all stairwells into the lobby complaining of the crowd and smoke conditions they encountered. The chief in command decided to change strategy, and a last message was issued: *"Occupants who have not started to evacuate should remain in their units."*

A new alarm system had been installed five months before the fire, and this system was tested monthly with a voice announcement prior to the test. The ten occupants who indicated they had hearing impairments all indicated they were alerted by the fire alarm and eight indicated the voice announcements were clear. Considering all the occupants responses, 95 percent indicated the instructions over the voice announcements were clear.

In spite of the confusion created by the contradictory voice instructions "to evacuate" and then "not to evacuate," the report of this fire incident concludes in the following manner relative to the utilization of the voice announcements:[14]

> *"The occupants placed considerable trust in the information received over the voice communication system. This is evident from the 83 percent of the respondents who attempted evacuation as a result of evacuation instructions given over the voice communication system. It confirms that, in most instances, the public is prepared to follow voice communication instructions, especially if this means of providing information has been accurate in the past and if the message comes from a person in which they confide or from figures of authority such as the fire department."*

SUMMARY

The characteristics of voice alarm systems have been established since the 1960s and early 1970s. The effectiveness of these systems has been demonstrated in both practice evacuations[6, 9, 10, 12, 15] and actual fire incidents.[8, 14] The critical function needed for a fire alarm system is to direct an adaptive behavioral response of the occupants by providing the essential definitive and directive information relative to the fire incident to the occupants. This information cannot be conveyed by a signaling type of system, due to the lack of the communication capability to provide the following information to the occupants:[7, 14]

What has happened.
What they are to do.
Why they should do it.

Ramachandran in his review of the studies on human behavior in fires in the United Kingdom formulated the following conclusions which emphasize the importance of providing complete and valid information to the building occupants upon the detection of possible fire cues:[16]

> *"Early behavior is characterized by uncertainty, misinterpretation, indecisiveness, and seeking additional information for confirmation – the 'gathering phase.' Such delay can be dangerous, as actions taken at the early stages of a fire have the most decisive effect on the eventual outcome."*

The response to fire alarm bells and sounders tends to be less than optimum. There is usually skepticism as to whether the noise indicated a fire alarm and if so, is the alarm merely a system test or drill?

In the stress of a fire, people often act inappropriately and rarely panic or behave irrationally. Such behavior, to a large extent, is due to the fact that information initially available to people regarding the possible existence of a fire and its size and location is often ambiguous or inadequate.

Valid information is needed relative to a perceived fire incident by the occupants of a building, and both the *National Fire Alarm Code*[2] and the *Life Safety Code*[1] permit the utilization of voice alarm systems which provide the needed communication capabilities to transmit this information.

Ramachandran in the report on an informative fire warning system developed a psychological design criteria for a fire alarm system:[17]

1. The meaning of a fire alarm must be obvious and distinct from other types of alarms.
2. Fire alarms must be reliable and valid indicators of the presence of a fire.
3. People need to know the location of a fire so they can authenticate the alarm and plan their response.
4. There is a need to provide infor-

mation to building occupants on the most appropriate response to an alarm, including information on available escape routes.

The adaptation of the behavioral and psychological principles previously illustrated should enable fire protection engineers to more effectively utilize the communication and information capabilities of voice alarm systems in the design, specification, and installation of fire alarm systems.

Significant scientific research is also needed to compare the effectiveness of the human behavioral response of various populations to the ANSI S3.41 *Audible Emergency Evacuation* signal as compared with voice alarm systems and other existing audible signaling systems.

John Bryan is Professor Emeritus in the Department of Fire Protection Engineering, University of Maryland.

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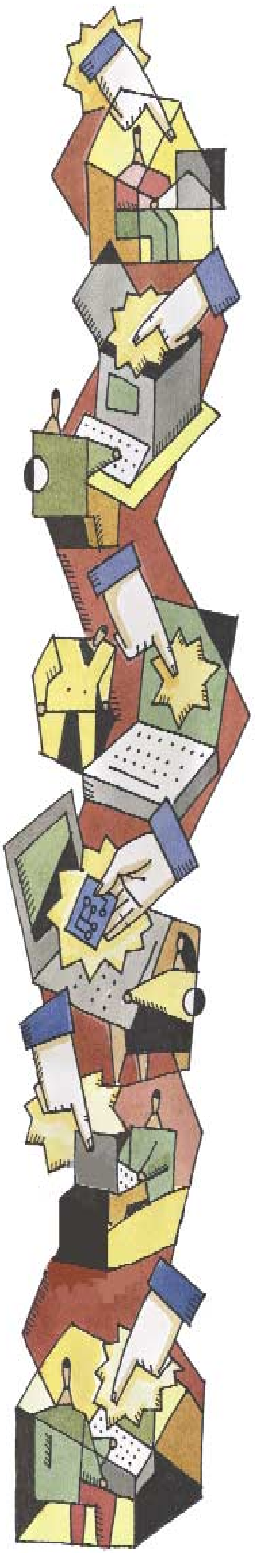

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Miami, FL
Info: http://nijpcs.org/SL_2001/SLBrochure.htm

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Dallas, TX
Info: www.nfpa.org

December 2-5, 2001
Symposium on Thermal Measurements:
The Foundation of Fire Standards
Dallas, TX
Info: www.astm.org

December 3-6, 2001
5th Asia-Oceania Symposium on Fire Science & Technology
Newcastle, Australia
Info: http://www.eng.newcastle.edu.au/cg/AOSFST5/welcome.html

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Melbourne, Australia
Info: www.sfpe.org

May 19-23, 2002
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Info: http://dialspace.dial.pipex.com/town/park/xzg98/interflamindex.htm

BRAINTEASER

Starting with the letter A, number the letters in the alphabet in order from 1 to 26. Using these values for the letters, find a word with the product of 69,888.

Thanks to Jane Lataille, P.E., for providing this issue's brainteaser.

Solution to last issue's brainteaser

Each letter below stands for only one other letter. Can you crack the code and figure out what all these fire protection words are?

PRIH = FIRE
MXEXIA = HAZARD
ROFRYRLF = IGNITION
HWGLUTIH = EXPOSURE
AHFURYS = DENSITY
HWYRFOTRUMHI = EXTINGUISHER
AHZXFA = DEMAND
UGIRFVCHI = SPRINKLER
FLEECH = NOZZLE
GILYHJYRLF = PROTECTION

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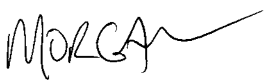
A Responsibility to Ourselves



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During the development of SFPE's White Paper on the roles of engineers and technicians,[1] a few anecdotes were brought up that illustrated situations where engineers did not perform their jobs properly. Examples included situations where engineers delegated engineering tasks to nonengineers or practiced outside of their expertise.

As engineers, if we become aware of a situation where another engineer has placed the public at risk, we have a responsibility to act. The public, our employers, and our clients depend on us to make decisions that provide them with appropriate fire safety. Because the public does not have an understanding of fire protection engineering principles, they are unable to judge when we do not fulfill our responsibilities. The public depends on us to police ourselves.

The SFPE Canons of Ethics for Fire Protection Engineers[2] identifies a hierarchy for the types of actions that should be taken when a fire protection engineer becomes aware of a hazardous condition: notification of an employer or client, and if such notification is not properly acted upon, notification of the appropriate pubic authority.

However, blowing the whistle on a colleague is serious matter, and lesser options may be warranted depending on the circumstances. Prior to notifying any outside authorities, an engineer who suspects that another engineer acted improperly should first verify that a breach has indeed occurred. This will typically involve searching for and analyzing additional information to gain insight into the context in which decisions were made that led to the perceived ethical breach.

Whitbeck[3] suggests that perceived ethical problems could be approached in a manner similar to design problems:

- Develop an understating of the unknowns. When a possible ethical wrongdoing becomes apparent, there will be many unknowns. These unknowns should be identified; however, it may not be necessary to resolve these unknowns, since resolving them may not be possible at this stage. Any ambiguities should be described with minimum interpretation.
- Define the ethical issues involved and consider courses of action. The ethical issues involved should be defined to the extent possible. Was it a case of an engineer practicing outside of their area of expertise? Is it a chronic problem? With a better understanding of the ethical issues involved, possible courses of action will become apparent.
- When there are multiple possible courses of action, they should be pursued simultaneously. Some possible courses of action may not be available indefinitely. Therefore, the evaluation of options should be conducted so that time-sensitive options are not excluded only because they were not considered in a timely fashion.
- Ethical issues have a dynamic character. As additional information is obtained, it is likely that the understanding of the ethical issues will change. If the understanding does change, the possible courses of action considered must evolve as well.

As kids, we were taught that it is wrong to "rat out" our peers. However, as adults, society depends on us to bring ethical wrongdoings to light. Failure to do so could result in consequences that reflect badly on the entire fire protection engineering profession.

1 "The Engineer and the Technician: Designing Fire Protection Systems," Society of Fire Protection Engineers, 1998. Available from http://www.sfpe.org/whatisfpe/final_white_paper.html.

2 Available from http://www.sfpe.org/whatisfpe/canon.html.

3 Whitbeck, C., *Ethics in Engineering Practice and Research*. Cambridge University Press, New York: 1998.