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Fire and Life Safety

Best practices for fire alarm notification design

As the functions and goals of fire alarm notification systems expand, the system layout must be effectively designed to provide a variety of vital signals.

Learning Objectives

- Examine fire alarm notification objectives, along with occupant behavior patterns in emergencies, to determine the best design for achieving system goals.
- Review visual notification devices and coverage areas based on device function and human perception of visual signals.
- Evaluate audible notification device types and functions, including calculations and placement methods for intelligible and nonintelligible coverage.

The buildings and areas within them that require fire alarm notification coverage are determined by the governing building codes or standards. The components of the notification system are required to conform to NFPA 72: National Fire Alarm and Signaling Code for compliant coverage. Full coverage notification is achieved when the required areas receive coverage for all required notification methods.

Systems provide coverage by four different methods listed within NFPA 72: textual, tactile, visual and audible. Textual notification, also called graphical notification, consists of static, scrolling or flashing visual signs with text. Tactile notification consists of auxiliary equipment used in very specific situations, typically to notify disabled occupants. A common example is a smoke alarm unit that attaches to an occupant's bedframe and vibrates the bed upon smoke detection, as a means of alerting sleeping deaf occupants of a fire.

Because the functions of textual and tactile devices are so specific, they typically are not included as required notification methods. Visual and audible notification are the most commonly applicable methods, both with distinct devices used for achieving code compliant coverage.

Public- and private-mode signaling

Before any notification devices can be located, a designer must determine the operations of the system that will best serve the area's usage, occupancy type and security requirements. NFPA 72 allows for public- and private-mode signaling to account for differing needs of notification systems.

Public-mode signaling refers to a fire alarm notification system that provides full coverage to all occupants in the areas protected by the system and is the more common operating mode. This is most effective in buildings where occupants are physically and mentally capable of self-evacuation. The majority of the general public fits into this category.

Public-mode signaling allows all occupants in the coverage area to independently react and self-evacuate.

Where occupants are not capable of taking these actions or if it would not be advisable to direct them to do so, private-mode signaling is more applicable. Private-mode signaling is defined as a fire alarm notification system that signals only the occupants directly concerned with initiating emergency action. Facilities operating in private-mode signaling rely on staff to evacuate, relocate or provide direction to occupants.

This method is commonly used in health care, detention and special education facilities — in areas where occupants are physically or mentally incapable of evacuating themselves. A correctional facility, for example, would rely on officers to evacuate inmates.

Private mode should be considered when the provision of total occupant coverage wouldn't benefit egress or life safety. There are cases where it may actually harm the occupants to receive notification signals. This is when it's important to consider typical human behavior in emergencies. Contrary to the common perception of panic or self-interest, occupants in emergencies have been consistently observed to act with altruism. They try to help others evacuate and act as a responsible party when in positions of perceived authority or greater physical health. Survivors of the 1980 MGM Grand fire in Las Vegas reported waiters and waitresses delaying their own egress to first guide the patrons from their assigned tables to safety. While admirable in many cases, it is ill-advised in other; some immobilized occupants need to be relocated in a specific way by trained staff.

A visiting family member in a hospital may try to move their relative upon notification and cause physical harm in doing so. Areas such as critical care units, operating rooms and neonatal intensive care units contain patients who may experience adverse health effects from an immediately located fire alarm device's signals. To avoid causing harm to occupants in these instances, only those trained to initiate emergency procedures should be notified. This still provides fully code-compliant notification coverage, it's simply provided via staff notification coverage instead of device coverage.

Strobe notification

Code–compliant visual notification is provided exclusively by synchronized flashing strobes, as part of either strobe-only visual devices or combination audible/visual devices. The device's coverage area is dependent on the strobe's intensity, measured by the listed candela (cd) rating or the luminance flux per solid angle omitted by the strobe.

The maximum coverage areas for strobes are listed in NFPA 72 Section18.5 and are based on commonly listed candela ratings. A standard, UL listed strobe typically has candela ratings of 15, 30, 75, 94, 95 and 110 cd. Extended coverage strobes typically have candela ratings of 177 and 185 cd.

The visual intensity perceived by the occupant varies by the occupant's viewing angle. At a 0-degree viewing angle, a strobe emits visual coverage at its full nominal candela rating. This angle occurs when an occupant is looking directly at the strobe, with a line of vision perpendicular to the strobe's mounting surface. As the occupant's viewing angle increases in either direction, the occupant receives sufficient but less intense visual notification.

In addition to the notification provided by viewing the strobe, notification also is provided by the viewing the strobe's effect. An occupant doesn't need to directly face a visual device from all possible orientations within a room at all times; NFPA 72 coverage requirements consider both direct and indirect notification. Direct coverage is provided when an occupant has a direct line of sight to a device, within its coverage area.

Indirect coverage is provided when the walls, floors, furniture and equipment within the strobe's coverage area are illuminated enough to notify occupants of an alarm signal. Occupants don't need to have a clear line of sight to a device at every possible orientation, but this direct line of sight is typically needed at no less than one orientation to achieve full visual coverage. The spacing requirements prescribed by NFPA 72 already have been designed to account for direct signaling, indirect signaling and loss in effectiveness by viewing angle. An understanding of the codes' origins, however, provides clarity of code language and intent and allows for the provision of better-quality designs.

The coverage area prescribed for wall-mounted devices extends a greater distance along the projection at the 0-degree viewing angle. Half of that distance is permitted in the perpendicular distance, along the mounting surface. The mounting height requirement of 80 to 96 inches above the finished floor is based on the typical occupant viewing height, to align the signals with the field of view projected by the human eye (see Figure 1 and Table 1).

Ceiling-mounted device coverage areas follow the same intent; the distances perpendicular to the 0-degree viewing angle are prescribed with the understanding that an increased viewing angle provides less effective coverage. Areas of coverage for ceiling–mounted strobes also have the added parameter of accounting for ceiling height. Increasing the mounting height of the strobe gradually decreases the candela visible at the typical occupant's eye level. Therefore, as mounting height increases, NFPA 72 increases the minimum compliant candela rating to provide coverage (see Figure 2 and Table 2).

Placing strobes

For the most effective visual coverage, both wall and ceiling-mounted strobes are best located using a fewer amount of strobes set to higher candela ratings. When beginning placement, the first consideration is obstruction to a strobe or its effects, from an occupant's line of vision. A room may be configured in a way such that one strobe, regardless of candela rating, can't clearly project visual notification to all occupiable spaces. One additional strobe should be added in each visually obstructed area until full, unobstructed coverage is feasible.

Candela rating should then be considered. The maximum wall-to-wall distance of the area or double the maximum device-to-wall distance, whichever is greater, should be used to select candela rating for each device. This value must be less than or equal to the maximum coverage distances listed in NFPA 72. Rooms too large to be covered by one device, even at a high candela rating, can be broken down into smaller squares, each treated as a separate room, to visualize device placement.

When placing multiple wall-mounted devices within the same room, devices should be arranged so that the most intense areas of visual coverage, nearest to the strobe and along the 0-degree viewing angle, are staggered apart from each other. Any overlap in coverage areas should be located at the outer coverage area boundaries, where the projected visual coverage is less intense. Multiple wall-mounted strobes within a room or corridor should thus not be placed directly facing each other. Devices also are best placed staggered apart on opposing walls wherever possible; this avoids having the majority of projected visual intensity all on one wall (see Figure 3).

Wall- or ceiling-mounted devices often will provide equal notification coverage in a typical room, though there are a few occasions where it's notably more effective to place one type of device over the other. Wall–mounted devices are preferred in areas with notably high ceilings, generally above 40 feet. Ceiling-mounted devices are not permitted by code to be mounted higher than 30 feet above the finished floor and suspending them more than 5 to 10 feet is less practical than providing wall–mounted devices instead.

In areas with rack– or wall–mounted storage, wall–mounted devices are either not feasible due to lack of open wall space or not practical due to the racks obstructing direct visual coverage. Ceiling–mounted strobes should be used to provide coverage between aisles, while also covering remaining areas of the room. They should be located to provide as much direct visual coverage as feasible within between aisles. Depending on the height of the racks, this may require strobes to be placed between each aisle.

Similarly obstructed rooms include libraries, large merchant stores and server rooms. Areas where the room usage would cause the walls to be crowded with mounted equipment — such as locker rooms, communal kitchens and mail or filing rooms — should be fitted with ceiling-mounted devices as well. Protruding wall–mounted equipment would disrupt a wall-mounted strobe's projection. For both mounting methods, best practice in visual notification device placement involves ensuring the occupant has a clear line of sight to the device itself from at least one orientation.

Strobes have slightly altered spacing requirements when located within corridors. In corridors with a maximum width of 20 feet, strobes are permitted to be 15 cd rated, spaced at a maximum of 100 feet between each strobe and located within 15 feet of all ends of the corridor. All changes in corridor direction should be treated as the end of one corridor and the beginning of another.

Like any other area with multiple strobes, wall-mounted strobes should be placed on opposing walls wherever possible. NFPA 72's spacing requirements for corridors are based on occupant behavior. Because occupants are upright, moving forward and looking ahead, designers can consider that they are more aware of their surroundings and would easily observe notification signals. Additionally, occupants are already up and moving, so the decision to evacuate requires less time to make.

Understanding the reasoning behind corridor spacing requirements allows the designer to recognize circumstances where they would not apply. A corridor that also contains seating areas, waiting areas, open lobbies or any similar usage would not meet the intent behind the spacing requirements. Applying corridor spacing in these areas would diminish the notification provided to the occupant, omitting necessary visual coverage.

Audible coverage

In addition to visual coverage, audible coverage is a frequently required and largely effective method of notification. Audible coverage detailed in NFPA 72 can be divided into categories of intelligible and nonintelligible signals. Audible devices providing nonintelligible signals include horns and chimes. Horns omit the characteristic "temporal three" tone, recognized by must occupants as a fire alarm sound. The requirements for this sound have become stricter over time to standardize it and make it more immediately identifiable to occupants. Studies on occupant behavior have indicated that the decision to take action in an emergency occurs faster when the notification signal is quickly and clearly recognized.

Chimes emits a lower volume signal, similar to a single-stroke bell. The chime sound is less recognizable to the general public as a fire alarm signal and is best applied in private-mode applications where only some occupants require audible notification.

Audible devices are required to produce nonintelligible signals at a specific decibel (db) to successfully alert occupants. This decibel level needs to be effectively higher than that of the average ambient sound, which is the average sound pressure level taken over a specific period of time. This accounts for all noises produced by normal operations of the facility.

Another significant measurement is the maximum sound, having a duration of at least 60 seconds, produced by normal operations. The former measurement can be taken from NFPA 72. Table A 18.4.3 in Annex A lists typical ambient sound levels of standard occupancies to use as estimates. This value, along with any anticipated maximum 60-second sounds, should be used to calculate the ambient decibel level the fire alarm audible signals need to overcome.

The requirements for audible device decibel output differ slightly for private and public mode. In public mode, all areas requiring coverage must receive an audible signal at least 15 db above the average ambient sound or 5 db above the maximum 60 second sound, whichever is greater. In private mode, required areas must receive an audible signal with the greater value of at least 10 db above the average ambient sound or 5 db above the maximum 60 second sound.

In both operation modes, devices can only be set to output signals at a maximum of 110 db. This requires that devices are located frequently enough to meet minimum coverage without having to be set above

110 db to do so. In areas requiring audible coverage with ambient sound levels above 105 db, a visual device is required by NFPA 72 as added notification.

A designer can confirm all points within the required area receive the required audible signals through decibel loss calculations. A device's audible signals undoubtedly lose decibel levels as distance from the device increases, but because sound travels in an expanding cone, the decibel loss per unit distance actually decreases as distance increases. A resulting and typically practiced approximation is that a fire alarm audible signal loses 6 db every time the distance from the device is doubled, beginning at a hearing distance of 10 feet from the device.

An audible signal also will decrease approximately 15 db each time it travels through a wall. Relying on coverage across walls is only recommended for small or low ambient sound level rooms such as storage closets or single person offices and can be considered only when the areas divided by the wall are within the same notification signaling zone.

As an example, consider a public-mode operating office building with an average ambient sound level of 55 db and possible maximum 60-second sound of 60 db from an air conditioning unit. Audible coverage would be required at the following decibel:

55 db + 15 db = 70 db

60 db + 5 db = 65 db

Greater value = 70 db

To provide effective coverage, the audible must deliver at least 70 db at all locations. If a room in the example office is 90-by-90 feet, one audible device located on a wall would need to be set to the following minimum decibel level:

x db measured at 10 feet = (x-6) db at 20 feet = (x-12) db at 40 feet = (x-18) db at 80 feet

(x-18) db at 80 feet = 70 db

x = 88 db

Based on this calculation, 88 db is well below the maximum allowed 110 db, so one device can provide audible coverage to the room. Should the calculated decibel value have been nearing 110 db, at least two devices need to be located in the room. When possible, providing more audible devices than minimally required is strongly preferred. More frequently located audible devices, tapped at a lower wattage, create a more even sound distribution.

Intelligibility

While nonintelligible audible signals notify occupants of an alarm condition, they don't provide any additional information. Mass notification systems and emergency communication systems have become more commonly integrated with fire alarm systems. These systems require intelligible voice messages to be able to signal for emergencies beyond fires, such as extreme weather events or active shooters.

Intelligible voice messages have the ability to provide clear and exact direction to occupants in situations where occupant behavior may be counterproductive to life safety. Many occupants, especially in the United States, have been trained to evacuate immediately upon fire alarm signals. This proves detrimental in a building in which the occupants are safest evacuating by zone or level.

In a building where evacuation procedures may be counterintuitive or complex, speakers are able to provide direct instructions to occupants. Fire alarm speakers are typically programed to emit both intelligible voice messages and nonintelligible signals, such as the "temporal three" tone, with microphone or pre-recorded voice message override. The speaker's nonintelligible signals still need to meet all the same audible requirements for those of a horn. However, the voice messages require certain areas to have full intelligibility, ensuring that occupants can feasibly understand the message. Areas requiring intelligibility need more frequently placed audible devices to achieve this.

The ability of occupants to perceive intelligible signals is dependent on the acoustical characteristics of the room, such as size, surface finishes, contents and average ambient noise level. A commonly practiced design constraint prescribes that speakers should be spaced with a distance of approximately double the finished-floor-to-ceiling height between them. A room with a 10-foot ceiling should have a speaker approximately every 20 feet, while a room with a 30-foot ceiling should have speakers located every 60 feet.

The increased spacing for higher ceilings is again due to audible sound traveling in an expanding cone; the farther the sound travels from a ceiling–mounted speaker, the more floor space it covers. That coverage, of course, is still required to meet minimum decibel levels, so it would need to output signals at a higher decibel than a device mounted on a lower ceiling.

Some areas are not able or required to have intelligibility, such as small storage rooms, mechanical rooms and unfinished shell areas. Intelligibility is also typically not achievable in areas with ambient sound levels above 85 db. Speakers in these areas can be located to meet the minimum decibel requirements of standard audible signals. The intent is that occupants receive audible notification and relocate to either an area that has full intelligibility or directly through an exit.

While intelligibility is not required in every area, the entire audible notification system should still consist exclusively of speakers. It's strongly discouraged and even a violation of some governing codes and standards to provide different audible device types within one notification signaling system.

Combining devices

Because visual and audible devices frequently are required in concurrent areas, combination devices, such as horn/strobes, chime/strobes and speaker/strobes, are commonly used. The designer needs to coincide the requirements and best practices of both audible and visual coverage with one shared device.

This is best accomplished by first locating the combination devices only by the requirements and recommendations of visual notification design. The areas should then be reviewed solely for audible coverage and intelligibility and be fitted with additional audible notification devices as needed. This minimizes the visual devices needed, while providing additional audible device coverage for more even sound distribution and intelligibility. Areas designed with combination devices should predominantly consist of combination devices mixed with audible-only devices, to give each method of notification the most effective coverage.

For any notification method, there are areas that require added attention and need to be more closely reviewed to provide proper coverage beyond the basic requirements. Areas intended for regular occupancy by deaf or blind occupants, as well as sleeping areas in some occupancies, have more tailored requirements for design in NFPA 72.

Beyond meeting prescriptive code minimums, systems should have devices and layouts that provide the most even and effective coverage achievable. They also must overcome any occupant behavior or assumptions detrimental to its life safety goals. As observed in reviewing notification requirements, there is a high degree of interconnection between system function and human behavior patterns.

Defend in place

This relationship becomes apparent in examination of the Grenfell Tower fire. Grenfell Tower, a high-rise residential apartment building in London, ignited June 14, 2017, killing 72 of its 293 present occupants. The high fatality rate is largely due to confusion among occupants about if and when to evacuate.

In a high-rise, fire alarm systems are not designed to notify all occupants at once or signal a mass evacuation. The design intent of the building is to contain the fire within its compartment of origin, so that only occupants within and directly around that compartment need to be notified and evacuate. Occupants outside this range don't need to immediately evacuate, so long as the fire is contained as intended. This practice is known in the U.K., and to the Grenfell Tower occupants, as the "stay–put policy."

The stay-put policy, though, is not universally effective. It is inherently and entirely dependent on the performance of the building's passive fire protection measures. If fire compartmentation fails, staying put should no longer be collectively advised. These constraints, however, were not considered in design, and the building was exempt from notification requirements based on intention to practice the stay-put policy.

The policy was so ingrained as universally practiced behavior that occupants and emergency personnel alike continued to rely on it for instruction up to an hour after fire compartmentation had failed. The fire breached beyond its compartment of origin and spread across the building exterior, re-entering the interior of the building at multiple levels. Occupants became increasingly endangered, but were left unsure of what action to take. Without notification of the advancing fire and need to evacuate, the original, unchanging instructions were held on to long after they were no longer applicable. By the time they attempted evacuation, many of the building's occupants were left with no survivable path to do so.

Fire alarm systems are designed to signal notification based on zone and building conditions, which can rapidly change in an emergency. These changing conditions are not always observable to occupants or emergency personal. Notification signaling, as part of an automatic fire alarm system, adapts to these changing conditions inherently to send the necessary occupants crucial signals and instructions.

Emergency voice communication systems, located with high intelligibility levels, most efficiently direct occupants in large or highly occupied buildings. The need for this system is compounded by the increasing reliance on it during other types of emergencies. Beyond meeting code compliance, the building's function, along with its typical occupants, needs to be carefully considered in fire alarm notification design. Automatic notification and clear instruction are vital to life safety in any emergency.

By

Keely Barrett, PE, EIT, Page, Austin, Texas

Keely Barrett is a graduate fire protection engineer at Page. She is a University of Maryland alumna.

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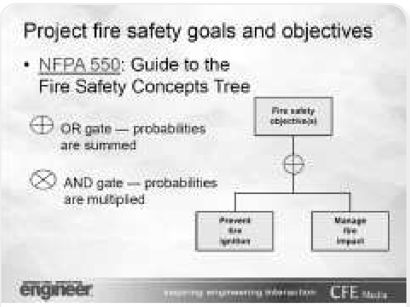

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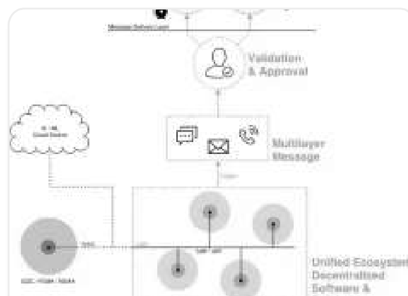

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