FIRE PROTECTION Engineering

SUMMER 2009 Issue No. 43

Fire Safety Concerns in Mercantile Occupancies

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From the TECHNICAL DIRECTOR

Fire Protection Engineering

Profession Weathering Economic Storm

The global economy is in its worst condition in decades. In most developed countries, the gross domestic products are very low, and the unemployment rates are very high. Unemployment is particularly high among people younger than 30; the unemployment rate in this demographic is in the double digits in the United States.

Most professional fields have been buffeted by the current economic conditions. However, the engineering profession is doing remarkably well. Manpower Inc., a global recruiting firm, states that engineering jobs are the toughest to fill in the United States.[1] Jonas Prising, president of the Americas for Manpower, said that "despite the current economic instability and high unemployment, there are still skills that the U.S. workforce seems to lack." Fire protection engineering is one of the skills that employers have a hard time finding.

The Society of Fire Protection Engineers conducts an annual survey of major employers of fire protection engineers to gauge employment trends. This year, 56 employers responded to the survey. Almost one-half of all respondents, 46%, indicated that the current economic slowdown has not affected their decision to hire additional fire protection engineers. Over the last year, 59% of the respondents attempted to hire a fire protection engineer. Similarly, half of the respondents anticipate hiring a fire protection engineer within the next year, and 88% foresee that they will need to hire additional fire protection engineers within the next five years.

Over one-half of the employers who tried to recruit fire protection engineers experienced difficulties finding a suitable candidate. The median length of time that it took to fill a fire protection engineering vacancy was four months, and many employers have been unsuccessful for over 12 months in finding someone suitable.

The top reason that employers cited for difficulty in filling a fire protection engineering vacancy was that there were no qualified applicants within their geographic area. A continuing challenge for all fire protection engineering employers is that there are a limited number of schools that teach fire protection engineering, and qualified candidates tend to be located near those schools.

Many fire protection engineering employers are resorting to a long-standing method of filling fire protection engineering positions: hiring engineers with degrees in other disciplines and teaching them on the job. Indeed, people with degrees in fire protection engineering are in the minority in the field, accounting for only about 40% of all fire protection engineers. The availability of distance-learning graduate programs makes teaching engineers from other disciplines easier.

A positive development is the potential to start a fire protection engineering program at California Polytechnic Institute. The school administration is keenly interested and has recently hired seasoned professor and past SFPE president Fred Mowrer on a part-time basis to help them get started. Since employers on the west coast of the U.S. have always had challenges finding fire protection engineers, the program at Cal Poly will be a boon to these employers once it is up and running.

That there are more fire protection engineering jobs than engineers to fill them has always been a blessing and a curse for the profession. It is a blessing in that individual engineers generally do not have a problem finding employment. The curse is that some employers hire people who are not qualified and do not make an effort to educate the engineers, and these unqualified engineers can create a negative impression of the profession.

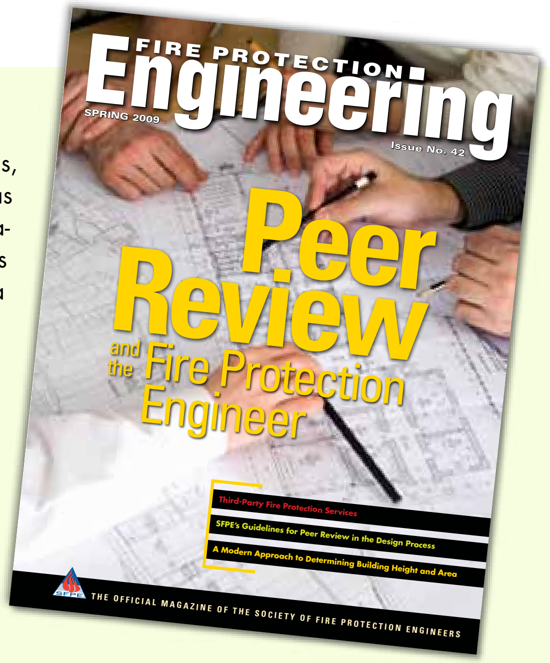
The Society of Fire Protection Engineers will continue to help bring more fire protection engineers into the field. The Chemistry of Fire teaching kit, which was sent to every high school in the U.S. and New Zealand, will expose many promising students to the field. SFPE's public awareness efforts will also expose people to the benefits of the profession. Additionally, SFPE will continue to promote fire protection engineering programs, such as the one starting at Cal Poly.

Reference:

1 Walker, D., "Engineering jobs tough to fill, Manpower finds," Milwaukee, *Wisconsin Journal Sentinel*, May 28, 2009.

Morgan J. Hurley, P.E.
Technical Director
Society of Fire Protection Engineers

Fire Protection Engineering welcomes letters to the editor. Please send correspondence to engineering@sfpe.org or by mail to *Fire Protection Engineering*, 7315 Wisconsin Ave., #620E, Bethesda, MD 20814.



Dear Editor,

I'm not of Academia, but I've had a great deal of experience using its products and, alas, I've often noted that peer review indicated that the reviewer had the same blind spots as the author. Once, I walked in on a fire marshal as he perused a journal article on evacuation times. "This guy," he uttered, "has never been at a fire. As soon as the first occupants reach the sidewalk, they stop to wait for their friends and the process slows down to a crawl." I've come across a peer reviewed megastudy on fire epidemiology to find that one of the component studies was about firemen who attended boilers. I could go on.

On the other hand, I've received valuable reviews from users without letters behind their names. A man who'd dropped out of high school at 16 to go to sea and ultimately became a chief stationary engineer knew things about pump stations no engineering professor ever thought about, e.g., would the operator be standing or sitting at the crucial time; i.e., at what height should that gage be installed?

Let's go beyond our comfy little circle when it comes to review; it could save lives.

Sincerely,
Gilbert G. Bendix, P.E.
Kensington, California

Dear Editor,

I wanted to address some misconceptions voiced in a letter to the editor (Spring 2009) by Dennis Kirson commenting on Mike Crowley's article in the prior issue. The NIST reports cited by Mr. Crowley were not critical of the Port Authority but rather were complimentary of their conscientious application of New York City building regulations over the life of the Twin Towers despite the fact that they were not legally obligated to do so. The NIST reports do, however, point out a few areas where the buildings were not consistent with the regulations, generally based on differences in the interpretation of regulations by the Port Authority compared to the manner in which those regulations were interpreted and applied by the building department. The detailed discussion of the issues below can be found in Chapters 10 and 11 of the NIST report NCSTAR 1-1.

One such issue that was discussed in correspondence over most of the buildings' life was the fact that the A and C stairways in both towers discharged at the mezzanine level. The building regulations require that egress stairs be continuous to a "public way." The Port Authority considered the Plaza (at the mezzanine level) a "public way." The building department definition of a public way is a level with fire department vehicle access, and no such access was possible from the Plaza. This issue was eventually resolved by an agreement between the Port Authority and NYC Department of Buildings that the Plaza was "like a public way."

The issue mentioned by Mr. Kirson was the NIST finding that the buildings required four egress stairs. This finding was not based on counterflow (the NIST report found that counterflow was not a problem on 9/11 for occupants) but rather resulted from the assembly occupancies on the 106th and 107th floors of both buildings (the Windows on the World restaurant and conference center in WTC 1 and the Top of the World observation deck in WTC 2). While the 390-person occupant load on the office floors were adequately served by the three stairs (and could have been served by two, wider stairs), the much higher occupant load factor for assembly spaces resulted in design occupant loads of over 1,000 for each of the two floors in each building. All U.S. model building codes and NYC building regulations require a third stair at an occupant load of 500 and four at 1,000.

Interestingly, this deficiency was apparently not noticed by anyone from the time the buildings first opened until the plans review for remodeling the restaurant after the 1993 bombing. At that time, a remediation plan was developed where the space was divided into three areas by horizontal exits, which allowed (under NYC building regulations) a tripling of the rated capacity of each stair. Once agreed to by Port Authority and building department officials for the restaurant, the plans were sent to the operators of the observation deck for a similar remediation.

In the NIST review of this accommodation, an additional condition was identified in the NYC building regulation (§27-367) that limited the application to cases where the assembly space "constituted less than 20% of the floor area occupied by the principal use." The Port Authority interpreted the solution as applicable since the assembly space was less than 20% of the office area of the buildings. However, in a response to a request for interpretation by NIST, the NYC Department of Buildings reported that the 20% rule does not apply to assembly spaces open to the public, as both the restaurant and observation deck were. Thus, both buildings required four stairs under NYC building regulations as applied by the NYC Department of Buildings to any building under their jurisdiction.

The NIST investigation found that these issues had no impact on the outcome on September 11, 2001, and that the issues derived from honest differences in the interpretation of the NYC building regulations (as opposed to some convenient interpretation intended to save money as some charged). The NIST investigation clearly disproved the accusations that the Port Authority took advantage of their exempt status to avoid doing what the regulations required. But Mr. Crowley's article in *Fire Protection Engineering* was accurate. And the new IBC requirement for a third stair in new buildings over 420 ft (130 m) is not based on a counterflow argument derived from any issue observed on September 11, 2001, but rather is to compensate for the fire department (high-rise firefighting) practice of taking one egress stairway out of service for use as an "attack stair" from which to advance their suppression activity. Thus the IBC requirement is for three stairs with the egress capacity requirement met by any two of the three.

Richard W. Bukowski, P.E., FSFPE
Rolf Jensen & Associates

Note: The writer is recently retired from NIST where he was co-author of the NIST report cited. The comments contained herein are his and do not necessarily represent the views of NIST or the federal government.

By David J. Thomas, P.E.

The first issue that needs to be considered when designing a mercantile occupancy is determining the scope of the hazard.

To determine the scope of the hazard, it is necessary to establish the type of sales that will occur. Will it be big box, strip center or portion thereof? Is the space or structure categorized as mercantile actually a portion of another use group? (e.g., first floor in a mixed-use retail/residential high-rise, etc). What, physically, is being sold?

All of the normal parameters for proper classification of commodities, e.g., storage heights, aisles, commodity type, packaging, unit types and handling methods, must be assessed by the designer before going into the codes of the local jurisdiction. The owner's needs as defined by the owner's procedures must be in hand, and checked by the designer, before proceeding to the code.

Assuming that the *International Building Code*®[1] or NFPA 5000®[2] is adopted, major problems can be avoided if the designer assesses the bid as follows:

All "M" uses: Do local amendments in the jurisdiction expand or contradict national model codes? If they do, do they apply to mercantile occupancies? Does the architect have specific areas delineated for processing (checkout, etc.) or handling (back of area, back of lot), and are those areas to be protected with different subsystems with different requirements from the main sales/storage area? Do particular corporate or insurance requirements that supersede or conflict with the locally adopted codes apply? Are fire alarms required, just sprinkler protection or no protection, or just fire separations required? Is there a corporate security/fire alarm interface that has code implications for special locks? If a fire alarm is required, are there code tradeoffs that permit omission of certain types of devices (e.g., manual stations)? Does the owner need certain fire alarm or sprinkler features for liability as well as code-compliance purposes? What types of central station connections are required in the jurisdiction? Are there exit issues, customer-access issues or accessibility requirements that will affect storage layouts?

Big-box or warehouse-type sales: How high will storage be? Are portions of the store to be set aside for specific products, or are shelves/racks to be moved, now or in future, depending on changes in demand? If storage over 12 ft (3.7 m) is necessary, can certain portions of Class IV or other challenging (flammable liquids, aerosols in bulk, etc.) goods be isolated if need be? Do current editions of the standards in force in the jurisdiction provide guidance for the future development of this owner? If the store is taking over an existing location, can the existing sprinkler system be easily modified or will complete rework or gutting be needed? For example, major code-compliance problems often occur when older designs set up for ordinary hazard group II or densities under 0.25 gpm/ft^2 (10 mm/min) need to be adapted to 100-sq-ft (9 m^2) spacing and higher densities.

Strip centers: Is the design for just mercantile use or for the usual mixed-use cases that will require checking of tenant separations, possible firewalls due to building height and area limits, high-hazard neighboring spaces, assembly neighboring spaces or the like? Are the exact building height and projected ceiling heights available so that it can be determined if the job can be met by ordinary hazard group I or II means, or will something with higher density be necessary? Are sprinkler tradeoffs available under mixed-use conditions? How much future flexibility (if any) does the owner want?

Spot mercantile locations: How will the mercantile use fit into the older part of the structure? What legacy codes apply to the structure overall? Must the design meet the old code, the new code or some combination of the two? Given the current wall types, finish types and interior partitioning of the structure, how much change does the client need to meet sales needs and the code? Many older structures that do not change use, if the hazard does not increase, need minimal change. If the hazard is increasing (e.g., putting a paint store in a strip center), are amounts and storage needs consistent with keeping alterations to a minimum and keeping the structure as close as possible to its prior code parameters?

One size doesn't fit all. It is possible to use the Web to try to check the published list of codes in force at the jurisdiction, set out the owner's sales/customer/goods needs before going to the code. The more detail, the sooner, the better.

David Thomas is with the Fire Prevention Division in Fairfax County, Virginia.

References:

1 *International Building Code®*, International Code Council, Washington, DC, 2009.

2 NFPA 5000®, *Building Construction and Safety Code®*, National Fire Protection Association, Quincy, MA, 2009.

Students to Converge on Capitol Hill for National Campus Fire Safety Month 2009

National Campus Fire Safety Month 2009 will be launched in Washington, D.C., on September 17, 2009. As part of this launch, college students will meet with Congress and encourage schools across the country to host fire safety courses for students.

Now in its fifth year, National Campus Fire Safety Month provides opportunities for schools and communities across the nation during September to educate students about the dangers of fire and their role in creating a fire-safe environment.

An estimated 18 million students currently attend colleges and universities nationwide. Since January 2000, 134 students have died in campus-related fires, according to statistics compiled by *Campus Firewatch*. Over 80% of those deaths were in off-campus housing. Four common factors in these deadly fires were a lack of automatic fire sprinklers, missing or disabled smoke alarms, careless disposal of smoking materials and impaired judgment from alcohol consumption.

"The value of National Campus Fire Safety Month comes from everyone joining together, both in Washington and across the nation, to make students, parents, schools and communities aware of the importance of fire safety on our campuses," says Ed Comeau, publisher of *Campus Firewatch*. "By working together, we can teach students what they need to protect themselves, not only for the time that they are in school but for the rest of their lives. As this year's motto says, 'Fire Safety – It's Part of Living.'"

For more information, go to *www.campusfiresafetymonth.org*.

Mowrer to Develop FPE Graduate Program on the West Coast

Cal Poly Continuing Education and University Outreach has retained Frederick W. Mowrer as a visiting professor to spearhead the establishment of a fire protection engineering graduate program.

"This unique program, a joint effort between our department and the College of Engineering, is desperately needed in our state," says Dennis Parks, Cal Poly Continuing Education Dean.

The program will be offered with both on-campus and distance-learning options. The current plan is to begin offering courses in the fall 2010 term, pending final approval at both the campus and California State University levels.

Mowrer received his doctorate in fire protection engineering and combustion science from UC Berkeley. He recently retired with emeritus status from the Department of Fire Protection Engineering at the University of Maryland after more than 20 years of service. Mowrer is thrilled by the opportunity and challenge of establishing a graduate program in fire protection engineering on the West Coast. "My goal is to produce graduates who can practice at a high level within this profession," he says. "With its educational philosophy, Cal Poly is an ideal fit for this goal."

Mowrer served on the board of directors of the Society of Fire Protection Engineers (SFPE) from 1995 to 2003, including a term as president of the Society in 2002. He currently serves as chair of the SFPE Technical Steering Committee, as chair of the Research Advisory Committee of the National Fire Protection Association's (NFPA's) Fire Protection Research Foundation and as a committee member of the International Association for Fire Safety Science. He is the author of various chapters of NFPA and SFPE handbooks, and more than 100 technical articles and reports.

For more information, contact *fmowrer@calpoly.edu*.

CORPORATE 100

The SFPE Corporate 100 Program was founded in 1976 to strengthen the relationship between industry and the fire protection engineering community. Membership in the program recognizes those who support the objectives of SFPE and have a genuine concern for the safety of life and property from fire.

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FIRE SAFETY CONCERNS IN MERCANTILE OCCUPANCIES: SHOPPING FOR SOLUTIONS

By Kenneth E. Bush, FSFPE

When one considers the modern definition for "mercantile occupancies," a wide variety of possible arrangements warrant attention. From small freestanding shops to large mega-mall projects; from simple store counters to huge bulk merchandising retail centers that take on the nature more of a warehouse than a merchandising center; any tenant which involves the display and sale of a product could be designated as a mercantile building.

In addition, new merchandising efforts have associated the sale of a variety of products with other-use spaces. It is not unusual to see a shopping mall which serves as an ancillary use to a hotel, an office complex or even a transportation terminal. The myriad of building heights, sizes, construction types and fuel loading, especially with a wide variety of product types and display means, have likewise presented a major concern to fire protection professionals to find a reasonable yet cost-effective means to protect these properties.

THE HISTORY FROM SHOPS TO STORES

In the past, small shops were constructed along the main business districts of towns and cities, often with stock stored in basements and with business offices or residential units located on the floors above. Due in many ways to zoning ordinances, the construction and operation of larger retail stores were limited to certain reserved areas designated exclusively to these types of occupancies. Medium-sized mercantile occupancies, including grocery stores and discount drug stores, did not become numerous until the mid- to late-1940s, when the local corner grocer or druggist could not compete with the prices offered by regional or national chains. These types of stores usually ranged in size from 1,000 m^2 to 4,000 m^2, were typically one-story freestanding structures of unprotected noncombustible construction and were not required by local building or life safety codes to be protected by automatic sprinklers until the mid-1970s.

From past designs to modern-day operations for most of these stores, the building is divided into two major spaces: one used for stock and storage space, and the other used for customer space and sales areas. Often, there are other spaces assigned for nonsales accessory uses, such as management activities. From a retailer's viewpoint, the distinction between stock and storage space is important, since employees enter the stock space frequently to transfer merchandise to the sales floor while storage areas are less frequently accessed because goods are set aside in these areas for extended periods of time.

The same principles cause concern for fire protection issues, as often the storage areas contain a much higher fuel loading requiring a higher level of protection. In addition, the less-frequent occupancy of true storage spaces by store employees could very likely allow a fire to begin and to grow undetected until the later stages of the event. This problem has become somewhat abated as new marketing concepts drive the operation of many stores by one corporation, and goods are typically stored in large central distribution warehouses, reducing the area needed for stock and storage areas in favor of enlarging the sales area to display merchandise. Frequently, items that are available for sale are distributed to the retailer on a limited basis and are stored directly on the sales floor.

THE MERCANTILE FIRE RECORD

With the consideration of the variation of the numbers of occupants who may be present in a mercantile occupancy, which can fluctuate widely with the time of day and seasons of the year, the life-loss statistics have been relatively low. The deadliest store fire in United States history occurred in 1968 in a Richmond, Ind., sporting goods store, resulting in 41 fatalities. During the four-year reporting period of 1999–2002, an estimated average of 17,200 structure fires per year was reported in stores and other mercantile properties in the United States.[1] These fires caused an annual average of only nine civilian deaths, 288 civilian fire injuries and $653 million in direct property damage. But even with the variables of seasonal occupant traffic, the lack of familiarity with means of egress and other building safety features by many transient occupants, and the levels and types of combustible contents, the control of fire and life loss in this occupancy classification has been relatively successful.

One-quarter of fires reported in mercantile-use groups occurred in grocery or convenience stores, and one-fifth occurred in service station properties or motor vehicle or boat sales or service facilities. The remaining 55% of these fires occurred in all other types of sales facilities, including general department stores and other specialty shops. It is interesting to note that these fires in mercantile occupancies accounted for only 3.3% of the 517,100 reported structure fires, 0.3% of the 3,140 civilian structure fire deaths, 1.6% of the 17,730 civilian structure fire injuries and 7.6% of the $8.6 billion in direct property loss.

The fire record in mercantile properties continues to improve, as fires in stores fell 56% from 37,500 in 1980 to 16,500 in 2002, the lowest number of reported incidents since data became available in 1980. From 2001 to 2002, these fires decreased by 7%. By comparison, structure fires of all types declined 51% from 1980 to 2002; however, from 2001 to 2002, all structure fires fell by less than 1%. For fires in stores, reports have indicated that electrical distribution or lighting equipment was involved in the ignition of 17% of all reported fires, and that another 14% of fires were intentionally set.

An examination of fire records also have indicated that the fire death rate and average estimated direct property damage were three times as high in buildings where no automatic suppression system was installed. This fact serves to emphasize the need for automatic fire protection in occupancies of this nature, especially considering the size, types, configuration and amounts of flammable and combustible materials that may be present; and considering the long periods of time that isolated mercantile properties are not occupied or monitored for fires or other hazards.

CONSIDERATIONS FOR FIRE PROTECTION PHILOSOPHIES

The basic protection features for these occupancies are relatively simple and routine. With the exception of some specialized properties, the most effective means to provide an adequate level of life safety and property protection involves the early detection of the incipient fire; adequate warning to the occupants of the building; means of sufficient size, nature and location to provide for timely evacuation or relocation of occupants to areas of safety; and the activation of automatic suppression equipment to control and confine the fire and its associated products. Actual occupant loads for stores vary with the sales seasons and locations, and most design codes take these factors into consideration when establishing egress requirements. These are basic approaches which are employed by all of the modern building and life safety codes in the U.S., including those published by the International Code Council[2] and National Fire Protection Association.[3, 4]

The fire record in mercantile properties continues to improve, as fires in stores fell 56% from 37,500 in 1980 to 16,500 in 2002, the lowest number of reported incidents since data became available in 1980.

Additional factors which are employed in the design of egress patterns also include the habits and convenience characteristics of the public. Most people favor the convenience of shopping on the ground floor of the building, and the model codes[2, 3, 4, 5, 6] consider that possibility by assigning a higher occupant load to any ground floor of the building.

Factors for occupant loads are based upon an expected customer flow into and out of the mercantile spaces, especially large mercantile spaces, considering merchandisers frequently place higher-volume sales items on the main level to accommodate and benefit from the higher customer flow. Some building designs have main entrances on more than one floor level. In those cases, the customer flow is projected to be less than in those stores with a single ground-level story. Therefore, the design occupant load must be adjusted once again to address these basic marketing principles. Some areas of the mercantile occupancy are not accessible to the public and warrant even further consideration when calculating occupant population, depending on the particular use of any assigned space.

The general operation and philosophies of the retail industry also present a variety of egress issues that require the attention of the building designers and fire protection professionals. As with many other occupancy classifications, security becomes as important a concern as routine customer access. Store owners and operators need the visibility and access to products, yet find it essential to arrange a rather high level of prevention against theft. It is for those reasons that U.S. building and fire codes permit special arrangements to provide for a high level of security while maintaining an adequate level of safety for egress. Often, mercantile designs will incorporate specialized locking arrangements, such as delay egress locks and access-controlled egress doors, to address these special needs.

In order to utilize these special locking features, particular attention must be paid to the specific code requirements regulating their use. These code requirements include limiting key-operated locks to only the main entrance with the recognition that such doors must remain unlocked in order to conduct routine sales and requiring extra levels of fire protection, including complete automatic sprinkler or detection systems, visible markings and posted instructions, and adequate lighting for protection of all building occupants.

The operational aspects of egress components, especially doors, may have a direct impact on the ability to safely and quickly use these egress components in the event of fire or other emergency. Power-operated or power-assisted doors are frequently installed at the main entrance of stores where consumers routinely carry purchased merchandise out of the building. Other features may incorporate revolving doors or gates to control the effects of outside weather and conserve the costs of conditioning the interior of the building, and like means, especially checkout stands, to enhance security measures. In similar fashion, stores will also often offer the use of carts or buggies for customer convenience, posing an additional need to provide for the adequate placement and storage of these devices out of the clear egress path from the interior of the building.

As in other occupancies where large populations of transient occupants may be present, there is a need to address the egress characteristics of the building's population. It is for this reason that, for most mercantile occupancies, the building is designed such that at least one-half of the required egress width is provided in the wall which contains the only means of customer access. The general public will frequently attempt to leave a building along the same path of their entrance.[7] However, U.S. building codes permit a safe path of travel to be arranged through a storeroom, often located at the rear of the store, as an acceptable alternate egress arrangement, provided adequate precautions are in place. These precautions include limitations on the size of the store and associated number of patrons, the presence of supplemental means of egress, the presence of localized fire protection measures and the maintenance of a clear, unobstructed and designated access to the exit.

Another option offered for customer convenience and sales promotions is the arrangement to permit open stairs between the first floor and one adjacent story. With the higher levels of fire protection, particularly automatic sprinkler protection to confine the effects of a fire present in these larger buildings, an adequate level of safety can be afforded to an ambulatory, aware population of store occupants, even with unprotected vertical openings between floors.

CONTENTS CONTROL AND PROTECTION

The contents of a mercantile occupancy present the major fire hazard. Automatic sprinkler protection has proven to be an effective means to combat fires, as evident from the decrease in loss history after the introduction of required sprinkler protection in the 1970s.

Modern model codes recognize the cost benefit of these levels of protection and base protection levels on building heights and areas, and upon the hazardous nature of building contents. While many smaller shops do not require automatic sprinkler protection, the effectiveness of these systems in larger stores has mandated their installation in these buildings.

Warranting further consideration is the attention to higher-hazard contents. The introduction of common household products, such as paints and thinners, petroleum products for lubricants and cooking activities, and specialized chemicals for a variety of reasons can pose an even higher challenge, particularly as these products are regularly displayed and stored in racks or in bins that are located directly in sales areas. Where such materials are present, more-stringent requirements may need to be included by the project designer and fire protection professional. These added fire protection features may include additional exits to reduce travel distance and eliminate common paths of travel, dedicated fire detection and warning systems to provide for timely reaction by building occupants, and specialized extinguishing systems, sometimes involving unique suppression agents.

SHOPPING FOR CONVENIENCE AND MARKETABILITY

For many years, the shopping concept of grouping stores in one commercial area proved to be convenient for the consumer as well as an advantage for the building owners and sales associates. The public was afforded the opportunity to complete purchases from a variety of stores at one location. Often, these buildings consisted of a grouping of various types of stores that were separated from one another by rated wall assemblies, but with exterior access from parking and public transportation means.

Later, the public desired to travel from store to store without being subject to weather. This led to the design and construction of large mall buildings which incorporated a number of retail establishments under a common covered or roofed interior area used as a pedestrian way. Mall buildings became very popular in a very short period of time, and today most large shopping centers either planned or under construction are of this type. Additionally, many mall buildings are now being built in urban areas as multiuse projects in conjunction with parking decks, office buildings, recreational facilities and transportation systems.

With this new mall building concept came a variety of fire protection issues that were unique to projects of this design. Most U.S. model codes, especially the NFPA 101: *Life Safety Code®*,[3] permit the mall to be considered in one of two basic concepts. The first is to regard the mall complex as one very large, single mercantile occupancy with the mall being an extension of the retail sales areas. In terms of exit access, the mall is an aisle common to the various tenant stores that extends exit access aisles of tenant spaces. This concept is rarely used, since travel distance and other related egress issues cannot usually be met in a single building of this size.

Most likely, the covered mall is considered as a climate-controlled pedestrian way, permitting the increase in the distance of travel from each of the tenant stores to a mall exit. This arrangement employs a systems approach, which may offer a higher degree of safety than a typical aisle serving as an exit access, if certain minimum conditions and systems are provided.

One of the main concepts of this design is to provide for a large open space to ensure adequate egress capacities for the large expected building population. Egress, leading either to designated exit passageways or to exterior exit doors, is permitted through covered mall areas. Particular attention is needed to such passageways as they often serve as staging areas for stock deliveries and trash removal, both of which violate the overall egress concept and introduce additional hazards to the design use of these areas.

These large mall spaces are also significant in terms of protecting occupants from direct exposure to a fire within a tenant space, especially to serve as a large volume to dissipate smoke during extended evacuation periods. Where a new mall has more than three connected levels, introducing hazards similar to open atrium spaces, specialized smoke control systems must be employed.

Open storefronts between the mall and tenant shops are critical since swinging doors can not only make exiting more difficult but also inhibit the ability for customers to enter the store without "threshold resistance," citing the reluctance to push, pull or slide doors. Since the temperature is controlled throughout the entire building, grates or grilles are typically employed for security, and no protection for the opening to the covered mall is provided.

Therefore, the control of fire spread in these buildings is limited by the construction of tenant separation walls rather than by separating stores from the mall pedestrian way. Since this pedestrian way serves as the primary means of egress, smoke management, either by mechanical or passive means, is critical to the overall life safety system.

A basic concept of mall protection also includes the installation of adequate fire protection and control systems. In the United States, due to the size and arrangement of the fundamental mall structure, supervised automatic sprinkler protection is required throughout the building. With the constant changes in construction and tenant arrangements in these buildings, special considerations to permit the control of certain sections of the building sprinkler system are necessary, and required, to permit tenant fitouts and renovations without affecting large portions of the remaining system.

In addition, the size and lack of fire department access to all interior portions of these structures mandate the installation of means for interior firefighting. And while most modern codes do not require a full standpipe system, they do require hose outlets for fire department use in certain locations throughout the building.

Fire warning systems should be designed to properly notify and provide clear direction to those persons in immediate danger from a fire or other emergency, yet not require the unnecessary disruption to other unaffected spaces within these large covered mall buildings.

Another complicating factor introduced by current mall designs involves the variety of occupancy types that may be incorporated into the overall concept. Often, the exact nature of mall tenants remains unknown at the time of construction and could frequently change during the lifespan of the mall building.

Not only do modern malls include merchandising areas, either in the form of small specialty shops or large anchor stores, the mall may also include ancillary occupancies, such as movie theaters, restaurants, recreational facilities, apartments, hotels, transportation terminals, amusement areas, business offices, daycare centers and even ambulatory healthcare centers. There is even a growing trend to combine the mall concept with the feel of the town center design, and tenant spaces are being constructed to open directly to uncovered parking areas or roadways that were the basic design concept popular in the 1940s.

It is important for the fire protection professional to consider the nature and hazard, and associated levels of protection which may be required, for each expected occupancy type. The classification of a mall as a mercantile occupancy often now does not address the issues necessary for complete and adequate protection of conditions and occupants that may be found in these buildings.

PROTECTION FOR MEGA-STORE VS. WAREHOUSE

Over the past 20 years, bulk retail merchandising stores have come into existence, combining the operations of a warehouse and retail store. These facilities utilize pallet or rack storage in a large portion of the building, with other areas designed in the more traditional retail display using fixtures and low-level racks or shelves to display merchandise.

The construction of bulk merchandising retail stores generally adds little to the overall fuel load, with designs similar to warehouse buildings having exposed concrete floors, masonry exterior walls, steel columns and roof structures, and very limited interior finish issues. However, it is not unusual to have rack storage to a height of 6 m, with retail merchandise displayed on the lower levels and stock stored directly above, eliminating the need for separate storage spaces typically found in retail operations.

This mode, amount and variety of product display pose some unique fire protection issues. Products which represent a special fire hazard may be combined or mixed for consumer convenience in quantities and locations that may not be consistent. Special circumstances may include the relocation of certain products or conditions for unique marketing techniques that place special products in areas of the store where such higher-hazard commodities are not normally located or adequately protected.

The properties of the modern bulk merchandising center present a fire problem that is sufficiently challenging in size and fuel load that may require a specific engineering analysis to design and confirm the adequacy of built-in fire protection features. There have been several examples of fires which grew quickly in intensity and volume to fully overwhelm the benefits of a complete sprinkler system. In an effort to address this protection problem, several research reports, including some by the Fire Protection Research Foundation, have been conducted to deal with these specialized hazards, especially concerning the storage of flammable and combustible liquids.[8, 9]

In late 1999, the retail trade approached the fire sprinkler industry with a challenge to develop a ceiling-only sprinkler design for storage and display of Class I through Class IV commodities, cartoned nonexpanded Group A plastics and nonexpanded exposed Group A plastics in retail outlets. Adding to that question was a debate over the shelving types used by the retail industry that challenged the solid-shelf gondolas and slatted wood rack shelving that would otherwise require in-rack sprinklers at every level.

After extensive fire testing and product evaluation, a K25.2 EC sprinkler to meet the needs of the retail industry was developed. The use of this new sprinkler was coupled with specific design criteria stated in the latest edition of the NFPA 13, *Standard for the Installation of Sprinkler Systems*,[10] to solve the fire problem in a way that is acceptable for both retailing operations and adequate fire protection levels.

Each of these designs utilizes the K25.2 sprinkler and addresses other associated conditions with shelf construction, maximum building roof height, maximum storage height, rack lengths, aisle widths, minimum flue dimensions and ancillary storage or product display locations. By varying some specific details, particularly with regard to the density of automatic sprinkler protection and water supply duration, the product display and storage of many popular retailers, including Home Depot, Sam's Club, Walmart, Best Buy, Target, Office Depot and Bed Bath & Beyond can be adequately protected.

The common factors for adequate sprinkler protection for these occupancy types includes a very high water flow density which ranges from 15 mm/min (0.38 gpm/ft^2) over 190 m^2 (2,000 ft^2) and 18 mm/min (0.45 gpm/ft^2) for the four hydraulically least demanding sprinklers to 24 mm/min (0.6 gpm/ft^2) over 190 m^2 (2,000 ft^2) and 28 mm/min (0.7 gpm/ft^2) for the four hydraulically most demanding sprinklers. Test results have indicated that the only means to effectively control a fire originating in these types of consumer-driven marketing arrangements is to provide large quantities of water very quickly, with operational considerations of shelf construction, aisle width and commodity types, configuration and amounts in mind.[11]

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Human Behavior in

MERCANTILE OCCUPANCIES

By Karen Boyce, Ph.D.

"We shape our buildings; thereafter, our buildings shape us" – this famous maxim, attributed to Sir Winston Churchill, has perhaps never been as appropriate as when applied to mercantile premises. Mercantile premises can be simple corner shops or part of complex built environments where retailing is not necessarily the primary function, e.g., airport terminals. They can be in city centers or out of town, specialty shops (e.g., food, textiles) or department stores selling many different products; consequently customer profiles differ from store to store.

However, mercantile occupancies all have one thing in common: The entire ethos of mercantile premises is to convert those who enter the store from casual onlookers to avid shoppers.

Retailers use visual merchandising such as the use of color, lighting, sensory engagement, digital and/or interactive displays to encourage people to buy goods. The whole experience revolves around encouraging the individual to enter the store, engage with the goods and linger until they have made a purchase. This notion of lingering and engaging with the merchandise is of course completely at odds with what is desirable in the event of a fire emergency, which is to ensure that customers leave the store as quickly as possible. The commitment of staff to sell, and of customers to buy, is something which must be overcome to achieve a successful, safe evacuation of the premises.

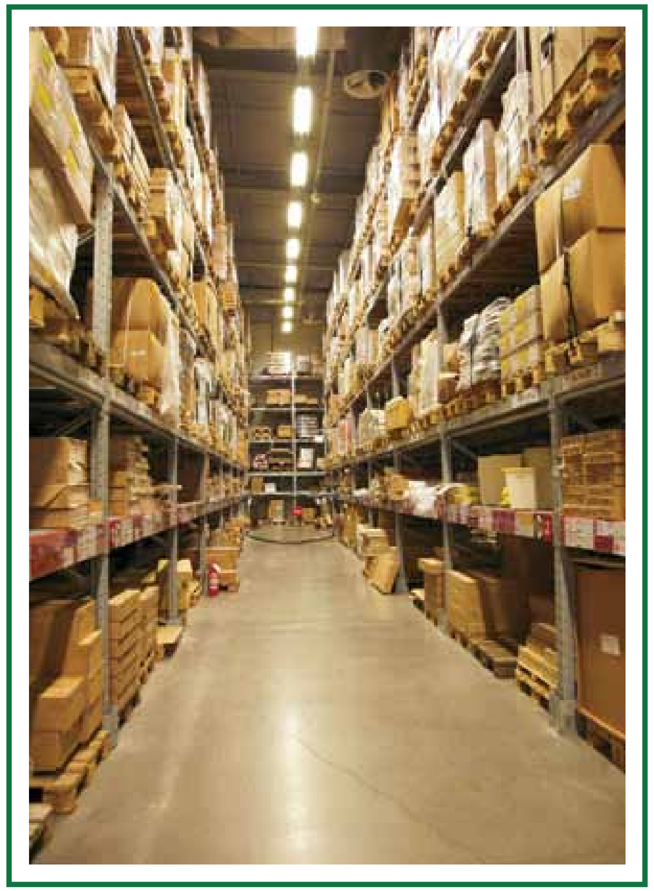
Although the deaths from fire in mercantile premises in the United States has been relatively low in recent years (an estimated 9 deaths and 288 casualties from 1999–2002),[1] such premises do attract large numbers of people on a daily basis and have the potential for multiple fire fatalities and casualties. The deadliest store fire in U.S. history was in a sports goods store in Richmond, Ind., killing 41 people.[1] A supermarket fire in Ascuncion, Paraguay, in 2004 claimed over 400 lives, and a fire at the L'Innovation store in Brussels, Belgium, in 1962 claimed 325.[2]

The understanding of human behavior in fires in mercantile occupancies has been gained from both well-documented real fires and research evacuation studies that have been conducted in such occupancies. Two of the most well-documented fires in retail premises are the Littlewood's department store, Liverpool, UK, in 1960[3] (11 fatalities) and the Woolworth's store, Manchester, UK, in 1979 (10 fatalities).[4] Research studies[5,6,7,8] have added to the understanding of the potential evacuation behavior of occupants and staff in a fire emergency.

RESPONSE OF STAFF AND OCCUPANTS

Consideration of the circumstances surrounding documented fires suggests that the principal reason for the occurrence of fatalities was, as in many other premises, the delay in commencement of evacuation of the occupants. In the Woolworth's fire,[9,10] poor communications between staff, delayed call to the fire brigade and delayed sounding of the alarm were evident. Both the Woolworth's and Littlewood's store fires involved occupants in restaurants which were close to sales areas and the delays in raising a general fire alarm. These factors, combined with rapid fire spread, meant that occupants did not know there was a fire until it was virtually too late.

The premovement time, the time from warning of the fire until occupants start to move towards an exit, is crucial to their ultimate safety. Following the Woolworth's fire, it was suggested that occupants were slow to leave food that they had bought and that this was a factor in their being trapped, suggesting that commitment to activity is something that might be an issue in retail premises. An example might be the individual who has spent considerable time choosing item(s) to purchase – can they be expected to abandon these items at the checkout to leave?



There is evidence to suggest, however, that the evacuation inertia of customers can be overcome in the presence of trained staff. Video evidence of unannounced evacuations of four large mercantile stores[5] suggests that customers' initial reaction in response to the alarm was simply to ignore it, with the majority continuing to browse or choose goods to purchase.

In contrast, the majority of staff responded quickly to the alarm by initiating positive evacuation activities,[11] e.g., closing down tills, directing customers to leave and directing them to exits (mean response time, 18 seconds). This resulted in a fairly rapid evacuation across all stores, with the mean customer premovement times across the stores ranging from 25 to 37 seconds and the maximum premovement time in any store of 100 seconds.

In these evacuations, staff played a crucial role in encouraging customers to leave. Fifty percent of customers noted (in questionnaires distributed after the event) that their first indication of the emergency came from staff, compared to only 33% who indicated that their initial indication came from the alarm. This emphasizes the relative effectiveness of personal involvement of staff.

In these evacuations, it was suggested that almost 80% of staff[11] had a direct beneficial influence on customer behavior. This was particularly evident where staff had direct contact with customers, for instance at tills or in changing rooms. In the large majority of cases, customers did not evacuate until they were told to do so by staff. This shows that considerable dependence needs to be placed on staff to overcome customer evacuation inertia.

These positive actions of staff are in direct contrast to inappropriate staff behaviors in real fires in retail stores where staff wasted time trying to fight a fire instead of initiating the evacuation of customers.

Inappropriate behavior of staff was also evident in a clothing store fire involving 20–30 customers.[6] In this fire, although a customer quickly alerted staff, staff attempted, but failed, to fight the fire. There were reports of people entering the shop, passing the fire and waiting to pay up to 3.5 minutes after ignition. Although all successfully left safely, the delays by staff in closing down tills and initiating the evacuation of the store could have had serious consequences.

Staff clearly has a crucial role to play. Additionally, there is also evidence of the positive influence of a voice alarm system in such environments. In an unannounced evacuation of a restaurant within a shopping center, 11 persons caught on camera all started moving towards the exit within 15 seconds of completion of the voice communication message without any obvious instruction or guidance from staff.

INFLUENCE OF SETTING

There is a tendency in some stores to display goods on units which are much higher than the height of the average person using the store. This sometimes means that those browsing or choosing goods in these areas have little view of the rest of the store. In an emergency, this means that occupants have less potential to obtain visual information about what is happening in other parts of the store.

There is evidence to suggest that this may result in longer premovement times in these areas. For example, the longest premovement times occurred in the food halls, where high refrigeration units limited customers' view beyond their immediate area.

In an emergency and in developing emergency plans, it should be recognized that the ability of staff to respond might vary with the setting in which they are located. For example, it has been shown[11] that, although staff generally responded quickly, staff working on the shop floor responded significantly faster to the alarm than those on tills.

The main factor delaying the response of staff on the tills was that they were serving customers and couldn't cancel their activity immediately. In contrast, staff on the shop floor had no well-defined responsibilities for customers. The differing responses of staff in different settings is consistent with the theory of "occupancy"[11] which suggests that different social, organizational and physical environments afford different possibilities for action but also impose different constraints on individuals.

EXIT CHOICE BEHAVIOR

An important aspect of store design is the objective of the retailer to move the customer through the entire store and expose them to as many products as possible. This often results in predefined pathways throughout the store with lines of sight to enhance the customer experience and draw them to the next set of goods on display/promotion. These sight lines, however, will not necessarily assist the customers in finding the nearest available exit in the event of an emergency.

The concept of "movement towards the familiar"[12] predicts that persons will be drawn in an emergency to familiar persons and places. With respect to exit choice, this means to those routes with which they are familiar – normally those by which they accessed the building. Analysis of exit choice behavior among a sample of customers on the fire floor in the Woolworth's fire[13] determined that 71% used a staircase which was used to enter the floor directly from street level and 22% used the escalator to move between floors, i.e., 93% used routes which were familiar to them. Studies of individuals in an Ikea store also found preference of the familiar route, even when the distance to the familiar exit was double the distance to the emergency exit.

In the store evacuations, differences in patterns of exit use were evident. In the multistory stores, approximately 55% of occupants used their usual access route. The reasons for what might (in contrast to previous evidence) be a relatively high use of emergency exits can mainly be attributed to the influence of staff. Over 30% of occupants in these stores indicated that they chose an exit because they were directed by staff. In the single-story stores, occupants actually made good use of the emergency exits (over 75% in one store) – this may have been due to the increased visibility of the emergency exits in this store and the fact that shoppers, although not familiar with the routes, would have known where they led.

In the same evacuation studies, two contrasting examples of the use of emergency exits arose. In the first case, the emergency exit was positioned at a focal point covering a strategic area and opened automatically on alarm. This, together with the induced natural flows past till stations, succeeded in attracting many evacuees, even though it wasn't their normal access/egress route. In the second case, occupants in a basement queued past an emergency exit while waiting to evacuate by an escalator – the same bank of escalators that they had used to access the basement.

These examples illustrate how the natural flows of customer traffic, created by the design of internal spaces, can work both advantageously and to the potential detriment of evacuating occupants, respectively. The first also shows the attraction that an open door can have to evacuating customers and is consistent with findings of other studies.

Exit-choice behavior of occupants is a complex issue and is likely to depend not only on issues such as proximity and whether or not the exit is via a normal route, but also on whether it is attractive to the evacuee and whether they have knowledge of where it leads. The latter may be of particular significance in a mall environment where the natural tendency of customers may be to leave a store by a route which is convenient to lead them to continue their shopping or return to their parked car.

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CHALLENGES in Mercantile Occupancies

By Edward Goldhammer, P.E.

Mercantile occupancies are those that involve the display and sale of merchandise and are accessible to the public. Mercantile occupancies range from small "mom and pop" operations to much larger big-box retailers. Mercantile occupancies often present complex fire protection and life safety issues, and require special consideration when developing fire and life safety solutions.

Fire challenges in mercantile occupancies may arise from:

- Varying products and display/storage configurations;
- Conflicting safety and security objectives; and
- Occupants who are generally unfamiliar with their surroundings.

Typical combustible merchandise may include flammable and combustible liquids, hazardous materials, plastic, aerosols, rubber tires and many other high-hazard commodities displayed in various solid piled, shelving and racking arrangements. Inherently, mercantile occupancies are sales-driven and require flexibility to adapt to changing market conditions and fluctuations in seasons.

Fire and life safety design professionals must consider all of the special life safety challenges facing the mercantile industry and incorporate these into an integrated approach with both active and passive systems which accomplish a well-thought-out design solution. Passive systems include compartmentalization, fire-rated construction and physical separation. Active systems include fire alarm, fire sprinkler and smoke-management systems.

HAZARD CLASSIFICATION

Proper hazard classification is crucial to a successful fire protection strategy. One important characteristic in defining hazard severity is understanding the heat release rate for the product. Heat release rate is a function of both heat of combustion and burning rate. An increase in heat release rate may lead to an increase in hazard. The heat release rate is critical information when determining fire size, sprinkler effectiveness, detection adequacy, smoke production and available safe egress times.

Today, the use of plastics in goods and products is prevalent in the retail industry. In accordance with NFPA 13,[1] Class IV commodities are allowed up to 15% by weight or 25% by volume of Group A plastic.

Traditional design approaches to protect Class I–IV commodities may be inadequate for the ever-increasing presence of Group A plastics. This is especially true for big-box stores; however, even with smaller retail operations, the overall design approach is based on the hazard class. NFPA 13 addressed this in the latest edition confirming the use of Ordinary Hazard Group 2 for mercantile occupancies that are arranged in stockpiles. For example, if the store has Class I–IV commodities, the stockpile height is allowed to 12 ft (3.7 m); however, for Group A plastic commodities the stockpile height is reduced to 8 ft (2.4 m).

When there will be Group A plastics, it is important to properly apply the requirements of NFPA 13. For example, NFPA 13 permits "mixed commodities" to contain up to five pallets of higher-hazard group A plastic; however, the Group A plastic must be randomly dispersed with no adjacent loads.

Classifying commodities is a unique challenge, and utmost consideration should be given to the retailer to allow for greater merchandising flexibility and future changes. A thorough investigation of the retail commodity, including hazardous materials classifications, flammable and combustible liquids, aerosols and any other high-hazard commodities, is necessary prior to developing any fire protection strategy.

DISPLAY AND FIXTURE ARRANGEMENTS

Retail display and storage arrangement play an important role in the severity of a fire. The display arrangement can affect the rate at which materials burn. This burning rate is dependent on many factors, including storage height, flue space, shelving, aisles, display depth and storage density.

NFPA 13 defines various types of storage arrangements, including solid piled, shelf and rack storage. Mercantile occupancies might include one or a combination of all three configurations. Many of the prescriptive requirements have been developed based on warehouse storage. However, many display arrangements do not fit neatly into the prescriptive requirements.

For example, shelf systems may exceed the 30 in. (750 mm) required by NFPA to be classified as shelf storage, although the arrangement may also not fall into the traditional rack storage criteria. Various high-shelf storage arrangements may also be outside the limits of the prescriptive code. It should be noted that the NFPA 13 committee is addressing some of these difficulties, with a proposed new definition of back-to-back shelf storage in the 2010 edition.

The use of solid shelves within the display storage array can create a shielded fire. NFPA 13 defines solid shelving as anything over 20 sq ft (1.9 m^2). In mercantile rack storage arrays, it is common practice to provide displays within the storage array that could be considered solid shelves. In addition, solid display shelves in excess of 30 in. (750 mm) could be considered rack storage with solid shelves.

Storage density can also be affected by the retail display. In many cases, retail display storage within the sales floor is significantly less dense than a typical rack storage array in a warehouse. Product is displayed out of the cartons in retail display shelves as opposed to closely packed products in cartons on racks. In other cases, such as big-box home improvement, retail display is similar to a traditional warehouse storage rack.

RETAIL AND HIGH-PILED STORAGE

Certainly, the determination of whether a retail occupancy falls within the prescriptive high-piled storage provisions of the *International Fire Code® (IFC)*[2] can be quite challenging. The high-piled storage provisions incorporate enhanced features into the building design to account for an expected higher fire severity. These features typically impact larger retail occupancies, especially the big-box retailers. Building enhancements may include smoke management, sprinklers, detection, access, storage restrictions and small hose stations.

The *International Fire Code* defines high-piled storage as combustible material storage within a building in closely packed piles or on pallets, in racks or on shelves where the top of storage is greater than 12 ft (3.6 m) in height. Also, high-piled combustible storage may include certain high-hazard commodities such as Group A plastic, aerosols, etc., exceeding 6 ft (1.8 m) in height.

Retailers using storage racks might fall into the provisions for high-piled storage. Retailers using display shelving and not warehouse storage racks are typically not considered high-piled storage, even when there are limited amounts of high-hazard commodities exceeding 6 ft (1.8 m) in storage height.

High-piled combustible storage has several distinct features not common to display shelving, such as storage in a compact arrangement, quantities of types of products stored and storage heights.

Among these factors, compact arrangement should be evaluated as the sales floor display may be significantly less dense than in warehouse storage. Products are displayed out of the cartons in retail shelves versus closely packed on warehouse racks.

SPRINKLER DESIGN

The type of commodity and complexity of the storage arrangement must be thoroughly evaluated when designing fire sprinkler systems. One of the greatest challenges that might be encountered is integrating the protection strategy into a program which allows merchandising flexibility to the end-user without compromising adequacy.

Sprinkler design must include an analysis of expected hazards and the various merchandising display arrangements. Special consideration is given to grated and solid mezzanines, shelf systems, solid shelves, slatted shelves, racks, displays in racks, solid piles, aisles, flue spaces, storage heights and ceiling heights.

The technology behind automatic sprinkler protection has come a long way, especially since the early '90s. The use of larger-orifice sprinklers, extended coverage and suppression-mode technology has tremendously helped to protect a large variety of products and storage configurations. Larger orifice size equates to larger K-factors and greater flows at minimum pressures. These contributing factors aid in the overall effectiveness of sprinklers in storage fires.

Retailers have also utilized full-scale fire testing to provide design solutions for their display storage arrangements. One example is the Retail Fire Research Coalition, a partnership of government agencies, retailers, insurance companies, consultants and testing laboratories. The coalition developed standards specific to their display storage and racking arrangement, and incorporated these into NFPA 13. Another example is retailers displaying flammable liquids, combustible liquids and aerosols developing protection standards specific to suppression-mode technology. One retailer conducted several full-scale fire tests to develop protection guidelines for their display storage of aerosols within a rack array. The design approach was to incorporate a combination of rack sprinklers, overhead ESFR sprinklers and a horizontal barrier to trap heat and allow activation of the rack sprinklers. These guidelines were later incorporated into NFPA 30B under "Mercantile Occupancy Special Protection Design."[3]

SMOKE MANAGEMENT

Today, there are mercantile operations in all types of specialized areas, such as high-rises, atriums, covered mall buildings and high-piled storage areas. The requirements for smoke management are driven by these special occupancies and not necessarily the mercantile operations. Integrating smoke management into the building design requires special consideration and should include an evaluation of the mercantile use and operations.

There are many approaches to a properly engineered smoke-management system. High spaces in malls and atria may be used as smoke reservoirs, which mitigate effects on the occupants' egress through the mall. High-piled storage areas may utilize mechanical exhaust in lieu of traditional smoke and heat vents.

If a retailer falls under the provisions of high-piled storage, then a smoke-management system may be required.[2] This is frequently accomplished through use of smoke and heat vents using a prescriptive vent area to floor area ratio of 1:50 or 1:100.

While smoke and heat vents may provide value, their presence in sprinklered buildings has long been an issue of debate. With today's technology, in lieu of these prescriptive ratios, a design approach can incorporate design fire, smoke production and smoke exhaust to design a performance-based alternative. This performance approach can utilize exhaust fans or reduced smoke and heat vent ratios. Developing the methodology for the smoke-management system is quite complex and requires a plume analysis to determine design smoke conditions. The design professional should take into consideration the retail display arrangement including the commodity analysis and heat release rate.

The codes recognize that the quantity of smoke produced is a direct effect on the ability of fire sprinkler systems to detect and suppress a fire. As an alternative, the *IFC* allows the use of suppression mode technology (Early Suppression Fast Response sprinklers – ESFR) without smoke and heat vents. This is based on the performance of these types of sprinkler systems. By activating sooner and suppressing the fire, the ESFR sprinkler system minimizes smoke and heat development.

FIRE ALARM

Mercantile occupancies might contain people who are unfamiliar with their surroundings. Display fixtures can confuse the path of egress. As such, the prescriptive code provisions for fire alarm systems in mercantile occupancies have recognized these challenges for the wide range retail operations.

Prescriptive codes require fire alarm systems for most mercantile occupancies.[2, 4, 5, 6] In the past, a fire alarm system in mercantile locations included sprinkler monitoring with limited notification unless it was required as part of another occupancy. Today, especially in big-box stores, full notification coverage is typically provided.

Placement of notification devices should be integrated with the display and fixture layouts. In high-rack areas, notification appliances should be located within aisles for greater visibility. Placing notification on the racks should be avoided due to inherent damage to the equipment from merchandising operations. In some jurisdictions, wall-mounted devices are considered inappropriate and only ceiling-mounted devices over the aisles are permitted. As fixtures are modified and relocated as part of the merchandising program, the notification appliances should be re-evaluated for compliance.

Detection is typically handled through the automatic sprinkler system. If a smoke-detection system is desired as an alternate means or required as part of delayed egress in a high-rack arrangement, the design professional must consider rack configuration and commodity classification. Location of detectors can be at the ceiling level above each aisle and/or intermediate levels in the racks. If beam-type detectors are used, consideration should be given for low-hanging signage.

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RETAIL and RESTAURANT FIRE PROTECTION CHALLENGES in the Venetian Macau-Resort-Hotel and Casino

By Nicholas J. Williams, P.E., and Robert J. Keough, P.E.

The Venetian Macau-Resort-Hotel and Casino is massive by anyone's standards. Presently, it's the third-largest building by area in the world, and it is the largest casino on the planet. At its opening in August 2008, the Venetian Macau-Resort-Hotel would consist of a casino, 3,000-room hotel, convention center, 15,000+ seat sports arena, 1,800+ seat Cirque du Soleil theatre, and 300+ retail shops and 50+ food and beverage shops under one roof containing over one million square meters. This one facility contains more floor space than both World Trade Center Towers as well as two Pentagons.

Rolf Jensen and Associates, Inc., (RJA) provided third-party fire-protection services for this mega-project. It was imperative that the project challenges be met by enforcing all fire and life safety requirements set forth in the fire protection report. In addition, it was necessary to continue to enforce these measures as additions, alterations and tenant fitouts occurred.

The twists and turns of this adventure began when Macau reverted to Chinese control in 1999. Before then, Macau was known as a sleepy Portuguese colony that offered gambling under the monopoly of Stanley Ho. In 2002, the government of Macau granted concessions to a variety of casino operators that ended the historic Stanley Ho monopoly.

The new foreign operators wanted to bring Las Vegas-style concepts to Macau, including mega-casinos with hotels, convention centers, theaters, event centers and many retail shops under one roof.

One of the major concerns was the ability of the local building codes to address the multiple architectural and fire protection concerns associated with a mega-resort with retail. The Las Vegas Sands Corporation was the first operator to build a casino under the new concessions in Macau. They negotiated with the local government to build this and other mega-projects based upon the *International Building Code® (IBC)*, which is used in Las Vegas and has the provisions and flexibility needed for projects of this magnitude. Due to the overwhelming success of the Sands Macau-Hotel and Casino which opened in 2004, the Venetian Macau-Resort-Hotel and Casino was put on a fast-track construction schedule that was accomplished in three years.

The Venetian Macau-Resort-Hotel and Casino involved hundreds of separate tenant fitout projects underway at the same time. This was compounded by the statutory needs of a very competent overseas local authority without previous *IBC* experience, hundreds of separate architects and contractors who did not have *IBC* design and installation experience, and trying to meet everyone's needs while ensuring fire and life safety remained a top priority.

One of the major obstacles faced was simple communication. Trying to communicate technical concepts with inexperienced architects, engineering firms and contractors that use English as a second language led to countless challenges. To their credit, the Venetian recognized that this was going to be a major issue and set up a Retail Coordination Team consisting of 78 design/project managers at its peak. Also, Arup Fire was brought on by the Venetian to provide guidance to the design teams. With everyone on board, one of the first tasks was to develop the design criteria for all tenant design teams to follow. RJA, as the third-party reviewer, had to maintain its independence from the design team, but it was recognized that everyone was looking to them for guidance on what was needed to achieve a compliant design development submittal. As such, RJA worked with the Venetian Retail Coordination Team in defining the submittal criteria for a tenant fitout package.

Each submittal package was provided in a binder containing a tab for each discipline. An introduction was provided giving general information about the new tenant, the codes applicable to the design and a drawing showing the tenant's location in reference to this massive structure. The architectural, MEP and life safety and fire protection disciplines were individually tabbed and had a narrative providing general information on what was to be installed and its impact on any existing systems.

Each discipline contained drawings that were identically folded so that their A1 size (comparable to "D" size) fit easily into the binder. The binders themselves fit in a neat and organized manner on reference shelves with the hundreds of other binders that comprised the project. Instead of hundreds of rolls of indistinguishable drawings gathered into a pile, an orderly library was created where existing conditions could be easily referenced.

The life-safety and fire-protection services section of the submittal provided substantiation that the system modifications could be supported by the existing systems. Whether it was a revised layout of the egress plan, sprinkler system, the relocation/addition of fire alarm device(s) or appliance(s), or the addition of a kitchen hood suppression system, the submittal's information had to clearly provide and support the proposed modification. Each system submittal began with its narrative and was followed by a drawing showing the system as a whole with changes highlighted on the section involved. This was followed by a "superimposed" drawing that had a color overlay showing the change in relation to the existing conditions. Although there were complaints about the need for all of these drawings for a small shop, the approach has proven effective in keeping as-builts and system design calculations current, which translates into maintaining system performance for the longevity of building.

The submittals were separated into two categories: retail, and food and beverage (F&B) shop units. By categorizing the submittals, the level of information needed to submit for review was more clearly defined.

The difference was strictly dependent upon whether the shop unit utilized kitchen appliances that produced grease-laden vapors. If so, per the applicable code for this project, the tenant was required to install a Type I exhaust hood in conjunction with a kitchen hood suppression system to protect the applicable hazard.

The Venetian recognized that due to the large number of F&B shop units to be opened in the project (50+), they needed to standardize the type of kitchen hood suppression system to be purchased by the tenants. Along with mandating that the tenants use the same sprinkler and fire alarm contractor, this decision proved to be instrumental in maintaining the consistency and quality of the installations.

This also alleviated unneeded complication by mandating all tenants use a common system, and therefore allowed the local contractors to master the requirements of that specific system. Again, while maintaining its independence from the design team, RJA provided guidance on the fire alarm, sprinkler and kitchen hood suppression system submittal requirements. This was very crucial in helping the Retail Coordination Team gather the required information for the submittal package.

Providing the extent and level of information required to ensure the integrity of the fire protection systems for this mega-facility was not a familiar concept or practice in Macau. The Venetian Retail Coordination Team assigned specific tenants to individual project managers, and it was their responsibility to spearhead the collection of all the separate design disciplines into the single submittal. The intent of the panel team was to fast-track the design process in order to meet their ambitious schedule for so many projects. The panel format allowed for the multiple consultants to sit around a "roundtable" on a daily basis to review the multiple submittal packages and resolve inter discipline conflicts. Upon signoff by the panel team, the package was then forwarded to RJA for third-party review. Although there was feeling to the contrary, RJA was adamant that it would not be part of the panel team.

In order to maintain independence as the third party, it was not prudent to be part of the design process. However, it was recognized that there were participants of the team that never dealt with the fire protection and life safety requirements mandated by the *IBC*. Therefore, to assist the Retail Coordination Team in providing design team members with guidance, RJA provided presentations as well as workshops and discussions on basic *IBC* requirements for life safety and fire protection system requirements.

Without these careful checks and balances, the systems' performance would quickly fall into a questionable state from which it is nearly impossible to recover.

Topics presented included occupant load calculations, travel distance, common path of travel, dead-end corridors, and sprinkler system and fire alarm requirements. This proved to be very beneficial in giving the project managers a basic knowledge to help them understand essential design parameters that could ultimately affect the approval of the design development submittal package.

Upon RJA's approval of the design development submittal, a set of shop drawings had to be developed and submitted for review. At this point, it was determined how the integration of the new system(s) would affect the existing systems. If the current design was to affect the overall performance of a specific system, design changes would be made to meet the intended design of the overall integration of systems. This ensured the reliability and integrity of the system.

The final step of the process was the most complicated – commissioning of fire protection systems throughout a building that operates 24 hours a day. The main concern was ensuring the modifications did not affect the performance of the system's operation in occupied spaces. Careful craftsmanship and timing of the installation were needed to maintain the systems' operability during crucial occupied hours in the retail spaces.

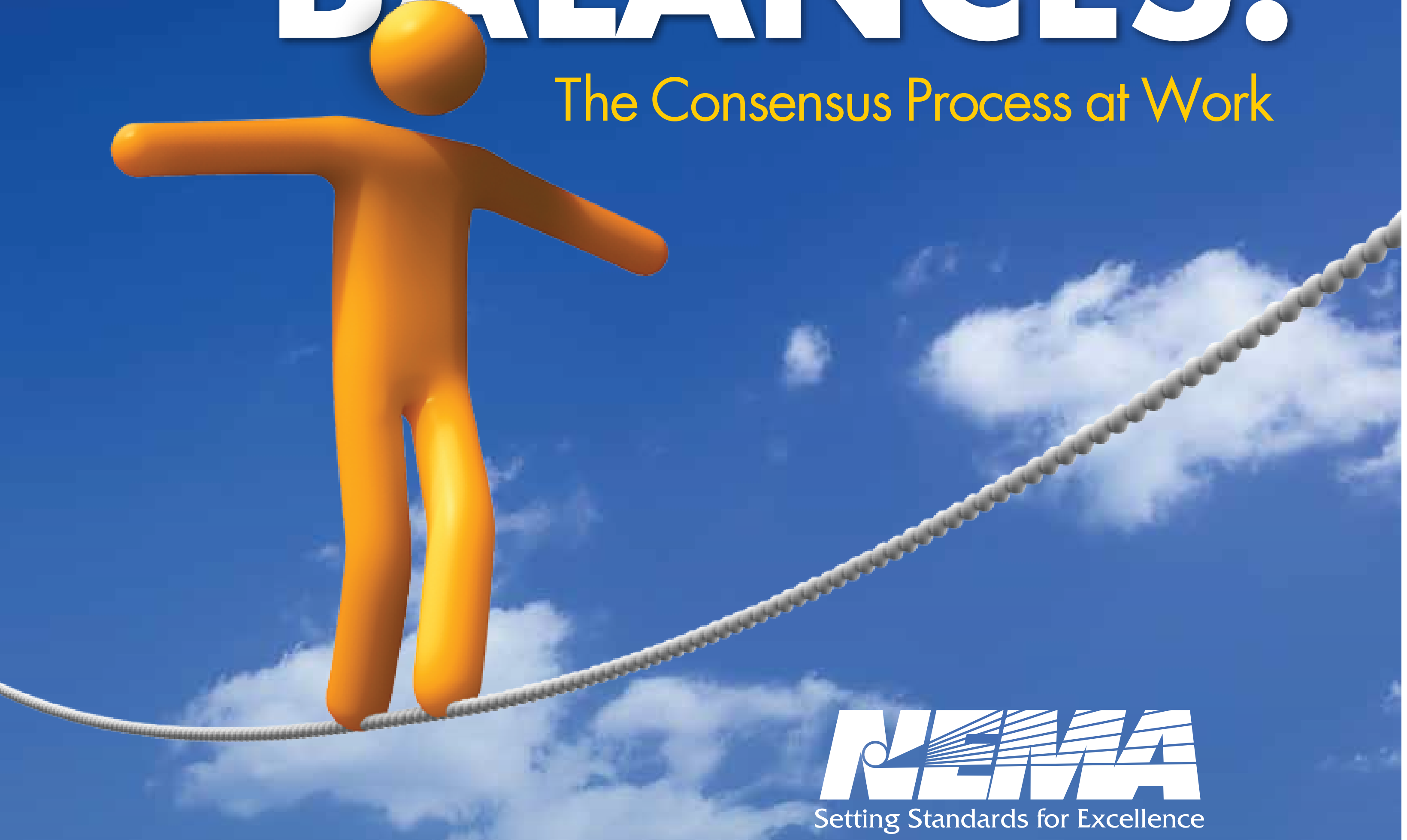
Disruption to casino operations also played a critical role during the commissioning process; therefore, testing was conducted in the early-morning hours due to minimal building occupancy of the retail and casino areas. This time presented the final opportunity to make sure all the systems were installed as shown on the approved shop drawings. This was critical to ensuring that the as-builts showed an updated system design.

Without these careful checks and balances, the systems' performance would quickly fall into a questionable state from which it is nearly impossible to recover. Although the process may seem tedious, each step was critical in attempting to maintain the systems' integrity over the life-cycle of its operation.

Nicholas J. Williams and Robert J. Keough are with Rolf Jensen & Associates.

CHECKS AND BALANCES:

The Consensus Process at Work



NEMA Setting Standards for Excellence

The successful development, adoption and use of codes and standards depend, in a large part, on an open and fair development process. However, there are several key checks and balances of this "consensus" process of which many users and participants are unaware and that are not formalized.

Codes for the construction of buildings have evolved tremendously since Hammurabi first had his "code" of 282 "laws" chiseled onto stone tablets in Babylon sometime in the 17th century BC. Much of Hammurabi's code is written in what is now called "performance based" language.

For example:[1]

No. 229: If a builder build a house for someone, and does not construct it properly, and the house which he built fall in and kill its owner, then that builder shall be put to death.

and

No. 233: If a builder build a house for someone, even though he has not yet completed it; if then the walls seem toppling, the builder must make the walls solid from his own means.

The evolution of codes to contain more prescriptive content made standardization of systems more uniform and also made the resolution of construction disputes easier. Today, whether one uses a prescriptive code or a performance objective for the design and construction of a building or a fire protection system in a building, a triad of codes and standards form the foundation for the final work product.

With respect to fire protection, laws, regulations or codes require certain fire prevention and fire protection objectives to be met. Certain system standards address the application, design, installation and location of the fire protection systems used to meet the objectives of the laws, regulations or codes. Finally, product standards address safety and performance of the components used to make up the fire protection systems. (See Figure 1.) For additional discussion on the development and interdependency of codes and standards, see "Codes & Standards & AHJs – Oh My" in the Spring 2007 edition of this magazine.[2]

Although the triad shown in Figure 1 looks to have three independent components, there is some overlap or discretion of where specific requirements may lie. For example, the environmental or power ranges within which a piece of equipment must perform may reside in either the product standard or in the system standard, or in both.

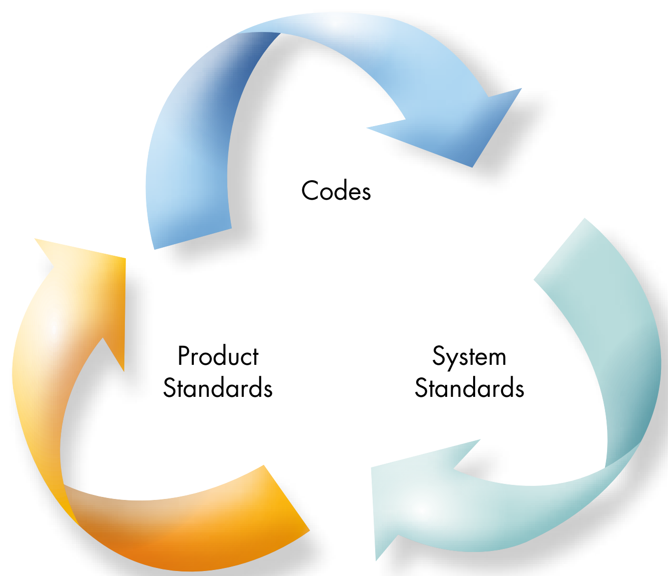


Figure 1. Relationships

In the United States, the American National Standards Institute (ANSI) has developed procedures for coordinating standards development among different organizations.[3] ANSI also has procedures for the accreditation of standards developers. A key element necessary for ANSI accreditation is "due process" where any person or organization with an interest in the subject has a right to participate. The development process must also be open, lack dominance by any particular interest category and must be balanced to ensure a diverse input during the development process. These requirements are the backbone of the "consensus" process.

The word consensus means that there is a general agreement among a majority of those involved. This differs from unanimity where all agree on the subject. However, the best consensus occurs when all, or nearly all, accept the objective and the specific wording of a paragraph or section of a code or standard. This does not mean that each person, entity or interest group has gotten exactly what they want. But they at least generally accept, endorse and support the final negotiated product.

When each element of the triad shown Figure 1 is developed using the consensus process, each has the best opportunity to incorporate fair and balanced objectives, requirements, methods and systems. However, unless the three elements shown in Figure 1 are coordinated and cross-checked for balance, there is room for error.

For example, a building code might require a smoke-detection system for a certain occupancy. As the system standard, NFPA 72, *National Fire Alarm Code*®, requires a certain spacing of the smoke detectors forming a smoke detection system. The product standard, UL 268,[4] requires certain performance characteristics for the individual smoke detectors. If the product standard changes the allowable sensitivity of the individual smoke detectors, the response time of the smoke-detection system might be affected, which would then affect the available safe egress time for the building. Similarly, the sensitivity can remain fixed, while a change in the allowable spacing would affect response time. Also, the building code could change to require smoke detection for situations where the existing product and systems standards cannot produce the desired results. To prevent these types of errors, it is important that individuals, entities and interest groups work in two or more of the triad categories to provide overlap, checks and balances.

Another example involves recent research that demonstrates that low-frequency signals with certain characteristics can awaken and alert persons with hearing loss and persons who are impaired by alcohol.[5, 6] NFPA 72 is in the process of developing requirements for the use of this type of signal.[7] However, there is no product standard for the specific signal content at this time – the research has not yet been incorporated into any such product standard. Therefore, since the objective of requiring such a signal can be compromised if the signal is not specified in detail, until such a product standard exists, it is necessary that the signal characteristics be specified in the system standard. In this example, the NFPA Technical Committee undertook the responsibility to check and provide the needed balance by specifying the characteristics of the low-frequency signal.

Third-party oversight is often used on fire protection projects. There are three common forms of independent oversight. The first and most common example of third-party oversight is the review of plans for projects.

A second example of third-party oversight is where an authority having jurisdiction might require that an independent third party perform on-site surveys and tests of a fire protection system in a building or on a property to verify that the system meets the intended requirements.

A third example of an oversight program involves product and service listings. When a product is listed, it is tested for safety and its intended performance using a product standard. But that is not the end of the listing process. The listing organization must perform periodic reviews and tests of samples from the production of the listed products to ensure that they meet the product standard to which they have been listed.

Similarly, some organizations provide a listing for alarm service companies. The listing organization will evaluate the service company for their "ability to manage the installation and maintenance of systems for compliance with NFPA 72."[8] If a company meets all of the requirements, they will be "listed" as an alarm service company, which then permits that company to install, test and inspect systems in buildings and issue certificates for the particular NFPA 72 category of the alarm system. As with products, the listing organization has a follow-up service to periodically check the work of listed alarm service companies.

The consensus process for codes and standards development and the oversight process for independent reviews must remain transparent and be subject to the scrutiny of all involved in the process.

All oversight programs are reliant on the independence and quality of the organization and persons performing the services. The Federal Aviation Administration has recently been the subject of hearings concerning their oversight of maintenance performed on commercial airliners. The Inspector General of the Transportation Department testified that the FAA inspection office had "developed an overly collaborative relationship" with an airline.[9] FAA inspectors testified that their agency was treating the airlines as their customers rather than as companies to be regulated.

The consensus process for codes and standards development and the oversight process for independent reviews must remain transparent and be subject to the scrutiny of all involved in the process. Using Figure 1 as an analogy, the process is circular, not linear. Having reviewers of the reviewers of the reviewers is more

costly and may be less effective than having all of the principal parties scrutinizing each other. Owners should not assume that their contractors are performing properly; they should require documentation and ask questions. They may not have the expertise to understand all that is involved, but they might recognize when something does not seem right. Code officials should not accept plans without doing or requiring a thorough review. Similarly, it should not be assumed that company is performing the proper inspection, testing and maintenance of a fire protection system. Officials responsible for assuring compliance should have a quality-control program that uses statistical sampling and checking to verify compliance. They might do this themselves, or they might use an independent third party to check for compliance. The system is compromised when the fox is permitted to write the specifications for the construction of the hen house and its fence, and then also do the test and inspection.

In any endeavor as complex as the construction, use and maintenance of a building and its fire protection systems, there will be problems. However, these are minimized and mitigated when all of the stakeholders work together and make an effort to understand and check each others' roles. Checks and balances. "Doveryai, no Proveryai" – Russian for "Trust, but verify."

References:

1 The Code of Hammurabi, Translated by L.W. King (1910), Edited by Richard Hooker, World Civilizations, *http://www.wsu.edu/~dee/meso/code.htm*, 1996.

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5 Bruck, D., and Thomas, I., "Waking effectiveness of alarms (auditory, visual and tactile) for adults who are hard of hearing," Fire Protection Research Foundation, Quincy, MA, 2007.

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8 Underwriters Laboratories, Fire Alarm System Certification-Listing Process, *http://www.ul.com/alarmsystems/fire.html*.

9 Caterinicchia, D., "FAA Inspectors Say Concerns Ignored," *The Associated Press*, Washington, DC, April 4, 2008.

UPCOMING EVENTS

July 13–15, 2009
Human Behavior in Fire
4th International Symposium –
Fire Safety – Putting People First
Cambridge, England
Info: www.intercomm.dial.pipex.com/html/events/hb09a.htm

September 24–25, 2009
Euro Fire 2009
Belgium
Info: www.eurofire2009.eu

October 15–17, 2009
Fire Protection and Life Safety in
Buildings and Transportation Systems
Advanced Research Workshop
Santander, Spain
Info: grupos.unican.es/gidai/

October 19–23, 2009
The Annual Meeting –
SFPE Professional Development
Conference & Expo
Scottsdale, AZ, USA
Info: www.sfpe.org

June 2–4, 2010
Structures in Fire
East Lansing, MI, USA
Info: www.egr.msu.edu/sif2010

BRAINTEASER > Problem/Solution

Problem

Using the digit "5" the number of times listed below, no other digits, and no addition ("+") signs, write a mathematical formula that calculates an answer of 110.

These problems have many solutions. For example, a formula for making 110 from (6) fives would be 5 × 5 × 5 – 5 – 5 – 5 (using 5 symbols). We will publish the formulas using the least number of symbols for each case below.

(3)
(4)
(5)
(6)
(7)
(8)

Thanks to Jane Lataille for submitting this month's brainteaser.

Solution to Last Issue's Brainteaser

The first terms of a series are: **1, 2, -1, -2, 5, 26, 67**

What are the next 3 terms?

One can check to see if the series is represented by a polynomial equation by calculating the differences between terms, differences of differences, differences of differences of differences and so on, until all of the differences are equal. The number of times that subtractions are performed before all of the results are equal provides the order of the polynomial. In the case of the following polynomial, three subtractions must be performed.

After the order of the polynomial is found, then a series of simultaneous equations can be defined, i.e.:

$an^3 + bn^2 + cn + d = n^{th}$ term, where *a*, *b*, *c* and *d* are coefficients, and *n* is the number of the term in the series. Setting up at least four equations for unique terms in the series and solving them provides:

$n^3 - 8n^2 + 18n - 10 = n^{th}$ term.

CASE STUDY

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The Chicago Temple Building has been home to the First United Methodist Church of Chicago since 1924. A unique composition of worship sanctuaries, the pastoral residence and several floors of offices makeup this 568-foot tall, multi-use building.

Due to recent changes in local codes and extensive construction within the Chicago Temple, its owners were required to bring its 50-year old alarm up to current fire code.

The replacement system chosen was that of the E3 Series® Expandable Emergency Evacuation system, manufactured by Gamewell-FCI. Its modular design enabled Fire & Security Specialists of Alsip, Illinois to build the system as large or small as needed while allowing for easy expansion or reconfiguration down the road.

Utilizing a minimum number of conductors, the selected system accommodates an almost limitless number of sensors, amplifiers and relays, greatly reducing the E3 Series' physical footprint across the facility.

The system's network utilizes digital signaling technology, requiring only one UTP (unshielded twisted-pair) of conductors for network communication up to 3,000 feet between nodes. One pair of fiber optic cables can also be used – a benefit for difficult radio frequency interference (RFI)-prone environments. This single pair of wires is capable of integrating virtually every facet of the system in the Temple–firefighter phones to elevator control–detection to notification.

The E3 Series system features ARCnet™, a high-speed data network over which control and sensor data, as well as bi-directional audio communications, are transmitted. It supports up to 25,000 devices with up to 64 nodes of modules, including power supplies, voice controllers, addressable relays and even control panels.

"We installed automatic smoke detection, elevator recall, fireman's phone, sprinkler supervisory and voice evacuation," says Ken Creed, President of Fire & Security Specialists. "The ability to use a few pairs of wire for sensor data as well as voice and other communications is what makes the E3 Series system so attractive, especially in large, high-rise situations like the Chicago Temple Building."

Silent Knight Ad

1

Fire/Smoke Dampers

Ruskin's FSDR25, true round fire/smoke damper, is now available with the optional DTS, Damper Test Switch. Features include factory-supplied cinch plates, an integral sleeve, fewer parts at the job site and an optional "momentary" push-button test switch that gives maintenance personnel the ability to cycle-test the fire/smoke damper locally at the damper, which makes cycling the damper a one-person job versus two or more.

www.ruskin.com
—Ruskin

2

Analog/Addressable Fire Panel

The PFC-9000 Series Analog/Addressable Fire Panel comes with one loop, expandable to three, each capable of supporting 127 analog sensors and addressable modules for a total of 381 smoke sensors or modules. The PFC-9000 uses a 12-Amp power supply with four class A/B (Style Z/Y) Notification Circuits rated at 1.7 Amps each. The 9000 series also has four alarm queues with selector switches and LEDs, three-level password protection with field-programmable definitions and RS-232 output for remote system printer or CRT.

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3

Free Applications Tools/Resources

Honeywell Power Products has created a new library of materials to assist specifiers, dealers and distributors in the application of power supplies for video, intrusion, access control and fire alarm installations. An all-new Applications Guide, Product Catalog and Resource CD are now available free of charge. The CD includes an "HPP-Calc" voltage-drop calculations program, an interactive graphics tool designed to determine voltage parameters of a specific fire alarm's notification appliance circuit (NAC). To request materials, call 877.477.7697 or visit the Web site below.

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—Honeywell Power Products

4

Clean Agent Systems

The Flex family of clean agent systems produced by SEVO utilizes 3M™ Novec™ 1230 Fire Protection Fluid. Currently, Flex Systems range in size from 3 lbs to 30 lbs, with coverage areas ranging from less than 50 cubic feet to 750 cubic feet. Flex Systems, which are offered in two configurations, require no electric power source to activate and can be accessorized with a pressure switch for process shut-down, a self-contained audible device, a manual release and/or an electronic solenoid.

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