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COMPLEX CURTAIN WALLS
GEOMETRY AND MATERIAL SELECTION FOR PASSIVE FIRE PROTECTION

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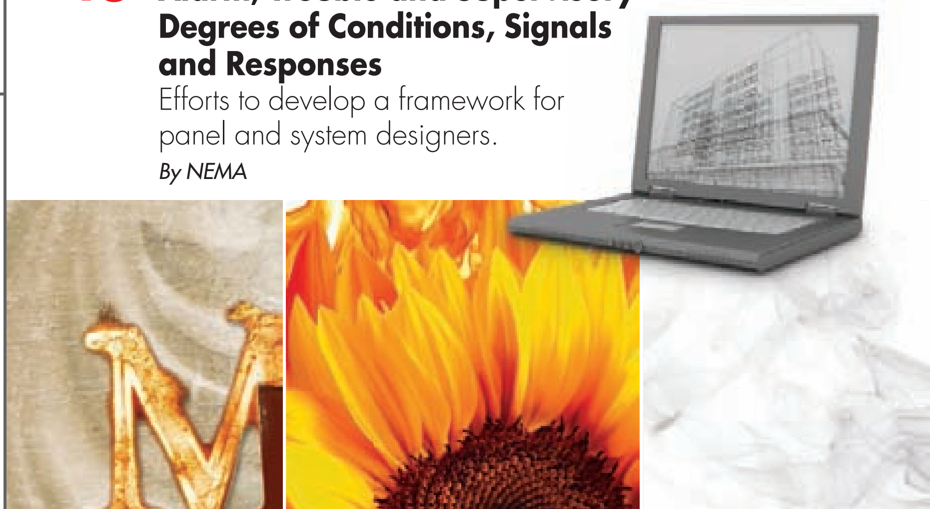

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From the TECHNICAL DIRECTOR

Uncertainty and Fire Models

Fire models, as representations of reality, are approximations of what might happen in a fire. As approximations, fire models are not intended to provide predictions that are exact. The amount by which model predictions might differ from what might occur in a fire is referred to as "uncertainty."

Whenever a fire model is used in a manner that could impact public health, safety or welfare, it is important that the model is appropriate for the intended application. Model validation is part of the process of determining whether a model is suitable for a specific application. Model validations generally take the form of comparisons of model predictions with fire test data. When conducting a model validation, a fire test is simulated using the model, and the model results are compared to the data from the fire test.

The *SFPE Engineering Guide to Substantiating a Fire Model for a Given Application*[1] notes that there is no single, widely accepted definition for model "validation." For example, ASTM E-1355[2] identifies three methods of conducting model validations: blind, specified and open.

In blind calculations, the modeler is only given a basic description of the experiment that will be modeled. In a specified calculation, the modeler is provided with complete and detailed model inputs for the experiment that will be modeled. In an open calculation, the modeler is provided with both a description of the experiment that will be modeled and the results of the experiment. Blind calculations are also called *a priori* ("prior to"), and open calculations are also called *a posteriori* ("posterior to," or more simply, "after"). Both approaches have advantages and disadvantages.

Uncertainty in model use comes from a variety of sources, e.g., inaccuracies in the model itself, inaccuracy in the input data that is used, and how the model user represents the space that is modeled (this last source of uncertainty is also called "user effects"). Because model uncertainty will have to be compensated when the results of the model are used, it is desirable to quantify the model uncertainty. However, quantifying all these sources of uncertainty can be non-trivial.

Blind validations treat all sources of uncertainty collectively. An advantage of treating all uncertainty collectively is that the uncertainty analysis is simplified. A disadvantage is that if the uncertainty from the various sources were offsetting, then the user might conclude that the total uncertainty is lower than it really is.

In fire protection engineering applications, most model validation exercises are open calculations; the modeler has access to the results of the experiments that are used for the validation. Recognizing this, the *SFPE Engineering Guide to Substantiating a Fire Model for a Given Application* recommends conducting the model validation separately from deciding how to treat uncertainty introduced by using the model.

Recently, a study was conducted where modelers from around the world modeled a fire in an apartment.[3] The modeling was conducted on a blind basis, and the modelers were given the geometry and dimensions, layout of the furnishings, the materials and dimensions of each furniture item, and the location of the fire ignition. Supporting photographs were also provided.

Participants in the study could choose the models that they used, although only two different models were used: a zone model or a field model. There was a tremendous amount of scatter in the model results. For example, the predicted time to flashover varied by a factor of 10.

Modelers used a wide variety of approaches to simulate the apartment fires: some specified the heat release rate, while others allowed the models to predict it; some modeled the entire apartment, while others only modeled a portion of it. Therefore, the study affirms that there are multiple possible sources of uncertainty associated with fire modeling.

It is important that fire model users understand the degree to which model predictions might differ from what might actually occur. The *SFPE Engineering Guide to Substantiating a Fire Model for a Given Application*[1] provides a process for determining if a model is appropriate and estimating and treating the uncertainty associated with the use of the model.

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

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2 ASTM E-1355, Standard Guide for Evaluating the Predictive Capability of Deterministic Fire Models, ASTM International, West Conshohocken, PA, 2011.

3 Rein, G., et al. "Round-robin Study of *A Priori* Modelling Predictions of the Dalmarnock Fire Test One," *Fire Safety Journal*, 44, 2009. pp. 590-602.

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Dear Editor:

I just read the article by Morgan Hurley titled "A Huge Step Forward in Fire Protection Engineering Education". It was an informative article about academic programs in the United States that offer degrees in fire protection engineering. It talked about schools in the east and west and how there are few programs in FPE. As I started to read the section where the author talks about schools out east that offer the program, I soon realized that he left out The University of New Haven.

Mr. Hurley talks about The University of Maryland and WPI and how they are the only schools on the East Coast offering degrees in FPE, which is actually not true. I am a recent graduate of the FPE program at The University of New Haven, and I have had instructors ranging from chiefs of local fire departments to graduates of the Ph.D. program from The University of Maryland. The University of New Haven even has a SFPE chapter, of which I was president from 2009-2011.

I understand that our program is not accredited, but our other engineering programs are. Even though the FPE program is small, it is structured well.

I hope that my response to your article was informative and hopefully next time The University of New Haven will get some recognition in the SFPE magazine.

Sincerely,
Patrick J. Cox

PUBLICATION AVAILABLE FROM SFPE

SFPE has just completed the *Engineering Guide to Substantiating a Fire Model for a Given Application.*

The *Engineering Guide to Substantiating a Fire Model for a Given Application* provides a framework for determining and documenting the suitability of a fire model for use in a specific application. The framework in the guide is applicable to all types of fire models, ranging from algebraic calculations to zone or lumped parameter models to CFD or field models.

The guide addresses:

- Definition of the problem that is intended to be solved using modeling
- Selection of a candidate model
- Model verification and validation
- Uncertainty analysis

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By Daniel J. O'Connor P.E., FSFPE

A general principle of building design is that vertical fire spread should be resisted so that smoke and flames are contained to the floor of fire origin. Today's explosion of creative green energy-saving design solutions for the exterior wall and exterior façade of buildings sometimes overwhelms and outpaces concerns for fire safety.

Meeting building objectives for energy savings and sustainability has building designers and architects implementing any one of a variety of methods to accomplish the goals for a green-certified structure. Such methods include, among others, double-skin façade systems, enhanced insulation techniques, high performance insulating glass assemblies and landscaped roofs and alternative power source systems (e.g., photovoltaic solar panels).

In recent years, the green building/sustainability movement has resulted in the development of new concepts in façade or curtain wall design that intended to enhance the energy efficiency of building façades. Double-skin façades are a key development in this area that offers solutions to heating, cooling, sound control and lighting efficiency. The basic components of double skin façade systems involve the use of an outer, glazed curtain wall, usually with ventilation openings; a cavity (usually ventilated) with dimensions of centimeters to meters in depth; and a second inner curtain wall with insulated glazed units.

There are wide variations possible for the design of these double skin façades. Design variables include the ventilation scheme (passive or active), use of louvers, motor operated openings or fans, shading devices, horizontal or vertical partitions within the cavity and operable windows on the inner skin of the double façade.

Depending on local climate, the double façade concept may be used in different ways. For example, in winter climates, the air cavity is closed and the system is used as a triple glazed system with the air in the cavity acting as a transparent insulator. The temperature of the internal glazing is effectively raised, reducing heating costs and increasing comfort at vicinities close to the glazing. In hot climates, air inlets and outlets may be opened to develop a stack effect (hot air rises) allowing hot air to be released at the top of the cavity and replaced by fresh air from the lower regions of the cavity. Within the air cavity, sun shades can be used to absorb and reflect solar heat energy, which can promote an even higher temperature differential for the stack effect to take place within the cavity. As a result, cooling cost for inhabited areas is reduced and comfort is increased.

The double-skin façade concept poses conditions impacting fire spread that previously were not encountered with single-skin or more common curtain wall designs. The risk of fire spread through such double-skinned façades introduces concerns arising from the fact that should flame break through the inner façade it would then be confined within a long tall shaft-like space. The dynamics of the flame and radiant heat exposure for this case are potentially more severe than with a flame freely flowing to the open atmosphere.

Other types of double-skinned façades may reduce the risk of fire spread, particularly those using a partitioning scheme within the cavity of the double-skinned façade. The cavity can act as a shaft for fire and smoke spread, but depending on the cavity design and ventilation scheme, the result may be either an increase or decrease in flame extension and risk of fire spread.

In addition to this, a naturally ventilated building can challenge the operational aspects of mechanical smoke control systems and pressurized stair systems that generally rely on tightly closed façades in order to develop the pressure differentials and appropriate air flow patterns necessary to manage or resist the movement of smoke and fire within a tall building.

The materials used to construct an exterior wall can be an important consideration in the relative risk that the façade poses to fire spread vertically up or down the building face. Façades are often constructed primarily of masonry, metal and glass materials, but it is also common to find façades that use architectural cladding systems comprised, in part, of combustible materials. Examples are aluminum-faced sandwich panels with a polyethylene core or combustible and Exterior Insulation and Finish Systems (EIFS), among numerous others.

Exterior wall designs are tending towards more effective continuous insulating assemblies using polystyrene or polyurethane foam insulation. While many exterior façades using combustible assemblies meet applicable fire standards, the use of the insulating products are being applied in creative ways to better serve the needs for energy conservation. However, the fire performance capabilities (good or bad) of many new applications and configurations have yet to be fully explored.

As the "evolution of green" continues, designers will continue to develop new applications and concepts that may be counter to the traditional principles of fire-safe building construction and may require some level of testing and evaluation to prove adequate fire safety performance. The challenge for fire protection engineers will be to successfully identify the quickly evolving new applications and design concepts before their widespread use poses undue risks in the built environment.

Daniel J. O'Connor is with AON Fire Protection Engineering.

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Cal Poly Fire Protection Engineering Program Receives Nearly $1 Million Federal Grant

Cal Poly's fire protection engineering program has been awarded a $940,571 federal grant to evaluate methods for fighting wildland fires that have spread to urban areas.

The fire protection engineering graduate program is the first of its kind on the West Coast.

"This is great news for Cal Poly's budding fire protection engineering program. In California, we face the constant threat of wildfires, and this new program at Cal Poly will help meet our demand for fire protection engineers so we can better cope with fire season and other threats. I appreciate the efforts of our students and teachers at Cal Poly for their efforts to improve fire safety in our communities," Capps said.

The grant will test the effectiveness of compressed air foam systems in suppressing structural fires at wildland-urban interfaces as well as whether the systems are safe for firefighters. It will enable the researchers to perform and analyze various fire tests using both the foam technology and plain water systems, working with the Cambria and Santa Barbara fire departments and at the National Institute of Standards and Technology's National Fire Research Laboratory in Gaithersburg, MD.

"This grant is very important on several levels," said Susan Opava, Cal Poly's dean of research and graduate programs. "It enables testing of a very promising technology. It also enables our faculty to utilize and expand their considerable knowledge and experience in fire management and protection, and it creates a rich 'learn by doing' experience for our master students."

For more information, go to *www.calpoly.edu*

NIST Launches Online Disaster and Failure Events Data Repository

A new website offers easy access to National Institute of Standards and Technology (NIST) disaster and failure study data.

The Disaster and Failure Events Data Repository is organized and maintained to enable study, analysis and comparison with future severe disaster events. It also will serve as a national archival database where other organizations can store the research, findings and outcomes of their disaster and failure studies.

As the database grows, it will include data on significant hazard events; how buildings and other structures performed during those events; associated emergency response and evacuation procedures; and the technical, social and economic factors that affect pre-disaster mitigation activities and post-disaster response efforts.

The repository is being established in two phases. The first phase, which is complete, includes data from NIST's six-year investigation of the collapse of the three World Trade Center buildings. Phase two will include a larger collection of information on hazard events such as earthquakes, hurricanes, tornadoes, windstorms, community-scale fires in the wildland-urban interface, structural fires, storm surges, floods and tsunamis, and man-made hazards (accidental, criminal or terrorist).

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GEOMETRY AND MATERIAL SELECTION FOR PASSIVE FIRE PROTECTION

By Ajla Aksamija, Ph.D., and Bruce Toman

OVERVIEW OF PASSIVE AND ACTIVE FIRE PROTECTION SYSTEMS

Fire protection for buildings relies on both passive and active measures. Active measures include fire detection and suppression systems, such as smoke detectors, fire alarms, sprinklers and building management systems.

Active measures are used to detect fire occurrence, to notify building occupants of the potential danger, to extinguish fires and minimize their dispersal within a building. Passive measures are used to minimize the potential for fire occurrence and to slow the spread of fire throughout a building.

Passive measures include use of fire-resistant walls, floors and materials, and rely on compartmentalizing the overall building. Organization of a building into smaller compartments, consisting of one or more rooms or floors, slows the spread of fire from the area of origin to other building spaces, thus limiting damage to the building and providing building occupants time for evacuation. Especially important is the separation between floors and protection of the joint system between the exterior wall and slab edge.

Exterior Wall Perimeter Fire Barrier Systems

The mechanisms of floor-to-floor fire spread at the exterior walls have been established by the work of fire researchers and fire engineers dating back to the 1960s.[1] Testing efforts of product manufacturers and testing laboratories during the 1990s have indicated that flames emitting from an exterior window can extend higher than 16.5 ft. (5 m) above the top of the window; therefore, fire-stops must be included in the design.[2]

In multi-story construction, prevention of fire spreading from floor to floor is achieved by including a fire-stop in the space between the floor slab and a curtain wall. If the void between the floor and the curtain wall is not properly sealed, the fire can spread from the lower to the upper floors. Therefore, perimeter fire barrier systems are used to provide fire resistance and prevent passage of fire from floor to floor within the building.

During the 1970s and 1980s, perimeter fire barrier systems usually consisted of fire-rated insulation, supported by Z-shaped galvanized sheet metal impaling clips, which held the insulation in place between the slab edge and the back of the curtain wall, sealing off any opening between floors and walls. The width of these spaces was limited to 7 in. (180 mm). But, several unfortunate events during this time have shown that a more robust system is required to produce an intact seal between curtain walls and the vertical face of the floor slab.

For example, the fire at the First Interstate Bank Building originated in an open-plan office on the 12th floor of the building and extended to the 16th floor — primarily through the outer wall of the building. Windows broke and flames penetrated behind the spandrel panels around the edges of the floor slab and the exterior curtain wall. The curtain walls, including windows, spandrel panels and mullions, were almost completely destroyed by the fire. This event showed that vertical fire spread can be rapid in buildings without adequate compartmentation, and buildings must be designed to reduce the risk of vertical flame spread.[3]

A similar occurrence at the office building at One Meridian Plaza resulted in fire spread from the 22nd to 30th floors through exterior walls.[4]

Following the January 1994 earthquake in Northridge, Calif., inspectors reviewing buildings for damage to the superstructure observed that fire-rated insulation shifted during the earthquake, and was on top of the ceiling systems at the perimeter of the buildings. It became apparent that a more robust system was needed to keep the insulation in place.[5] Code requirements and testing criteria were revisited and improved systems were developed to be more versatile in their retention and to more effectively resist the passage of heat and smoke.

It should be noted that fire protection material alone will not provide perimeter containment; a joint system is needed to prevent the passage of flame and hot gasses. The perimeter joint must be sealed with a material or system that extends the fire rating of the floor to the exterior wall surface. Secure connection of the insulation material to the spandrel is important in order to keep it in place and to prevent it from moving or falling out, and sealant may be needed at the top of the insulation.

Five basic features are needed for a successful perimeter fire containment system:[6]

1. Installation of a reinforcement member at the area behind the spandrel insulation to keep it from bending due to the compression fit of the insulation.
2. Mechanical attachment of the mineral wool spandrel insulation to hold it in place.
3. Curtain wall mullion protection with mineral wool mullion covers.
4. Compressive fitting of the insulation between the slab edge and the interior face of the spandrel insulation.
5. Application of smoke sealant material at the top of the insulation to provide a barrier. UL lists approved perimeter fire containment systems for standard curtain wall designs, and the above features apply to all of the tested systems.

BUILDING CODES AND TESTING PROCEDURES

Review of Building Code Requirements for Fire Protection of Curtain Walls

When a curtain wall is constructed on a building, a gap or void is created at the intersection of the floor and the interior face of the curtain wall. The International Building Code[7] (IBC) requires the sealing of these voids along the perimeter of the building with an approved system, thus creating perimeter fire containment. The material used to fill the void must be:

- Approved material, tested in accordance with the ASTM E 119[8] testing procedure;
- Securely fastened to the interior face of the curtain wall; and
- Capable of preventing the passage of flame and hot gasses.

Section 714.4 of the IBC addresses fire protection for curtain wall and floor intersections. It specifies that a curtain wall and fire-resistant floor intersection must be sealed with an approved system to prevent the interior spread of fire, and it must be tested in accordance with a recently adopted two-story fire test ASTM E 2307[9] procedure, which partly conforms to the ASTM E 119 standard.

Standard Testing Procedures for Fire Tests

The ASTM E 2307 test method measures the performance of perimeter fire barriers and their ability to prevent fire spread during the deflection and deformation of the exterior wall and floor assemblies. The main objective is to measure the ability of the fire barrier system to maintain its integrity to prevent fire spread. Exposure conditions and temperatures are specified by this standard for the first 30 minutes of exposure, and then conform to the ASTM E 119 time-temperature curve for the remainder of the test. The temperature ranges for the first 30 minutes of the test are slightly higher than the ASTM E 119 requirements. This test method does not provide quantitative information about the perimeter fire barrier relative to the rate of leakage of smoke. It indicates whether the system can last as long as the floors, and whether the protection scheme can adequately protect wall framing and attachments.

UL listings are available for some of the standard curtain wall types that indicate fire resistance ratings for tested systems. They are available for curtain walls where the maximum distance between the curtain wall and perimeter floor is 12 in. (300 mm), but more unique and complex curtain walls may require testing to ensure that the perimeter fire barrier systems are

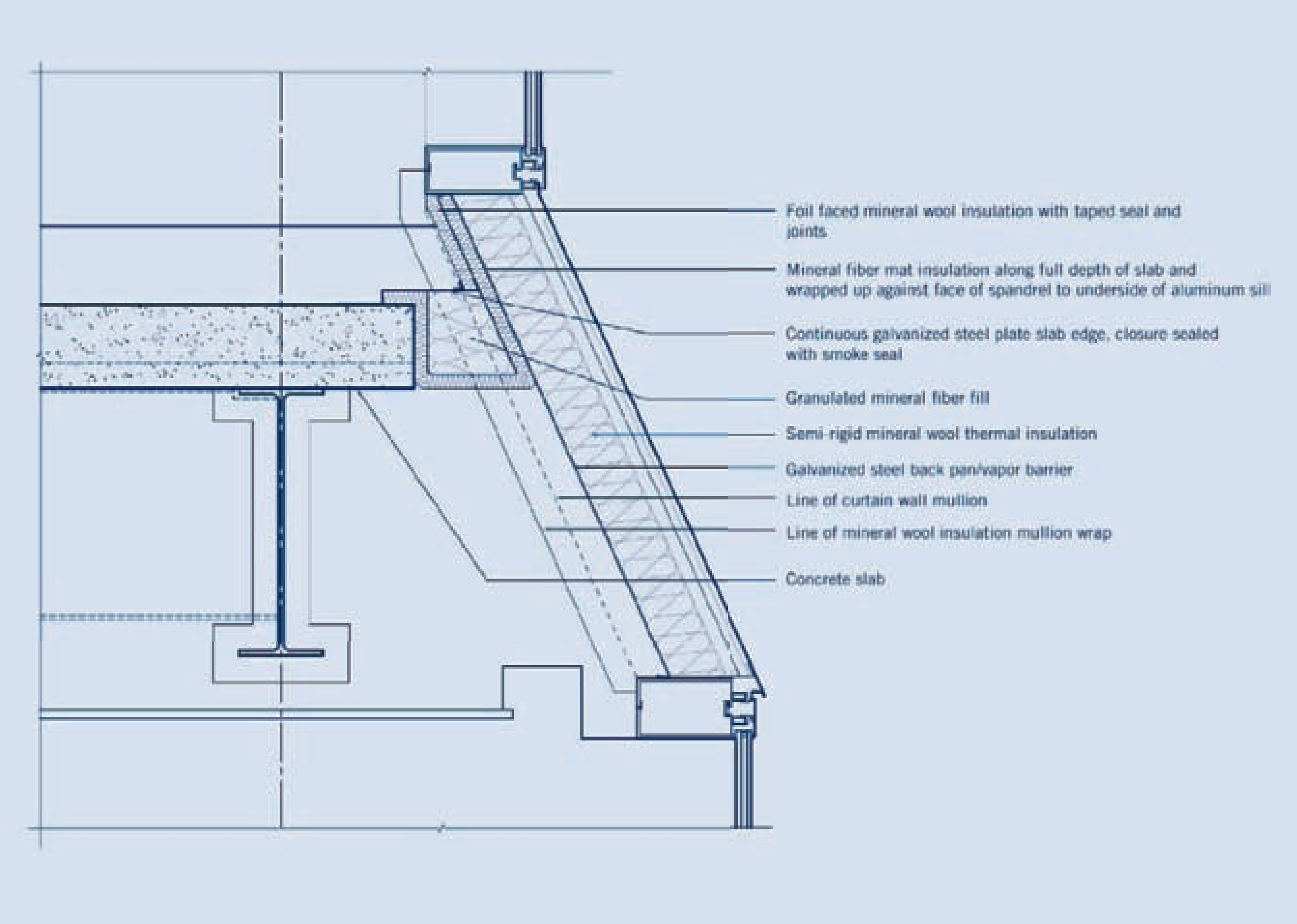

Figure 1. Perimeter fire containment concept for the twisting spandrel conditions

adequate and conform to building code requirements.

COMPLEX GEOMETRY AND JOINT CONDITIONS

Curtain wall systems have evolved to more complex and customized solutions, driven by architectural design aspirations and technical capabilities. Unique façade designs, twisting geometries, curved surfaces and rotated floor plates are now being developed by architects to express innovative building forms, but they also impose new challenges in terms of facade structural stability, fire protection and material selection compared to traditional flat facades and standard curtain walls.

A recent residential tall building design illustrates in detail how complex curtain wall geometry influences material selection for perimeter fire containment and fosters development of new design concepts for curtain walls. The twisting tower geometry resulted in irregular spandrel transitions, which would require a flexible perimeter system to adapt to the curvature of the façade. Moreover, the twisting geometry resulted in gaps between the curtain wall and edge of slab that exceed 12 in. (300 mm); therefore, listed systems were not available.

Detail Development and Mock-Ups

The detailing was developed in conjunction with a manufacturer who performed preliminary constructability mock-ups, detail and specification review, and performed a small-scale furnace test to verify that the design concept and materials would achieve desired fire rating. Figure 1 shows a detailed section of the perimeter fire containment concept and the location of insulation.

An initial wood profile constructability mock-up was built to test how the insulation would be installed and adhered to the back pan of the spandrel, since the twisting conditions and the changing relationship of slab edge to spandrel required that this material be flexible and able to adapt to the geometry. First, the mock-up was constructed using 3-1/2 in. (89 mm) of mineral wool spandrel insulation.

The preliminary mock-up confirmed that the curving and twisting spandrels would not facilitate the installation and retention of insulation.


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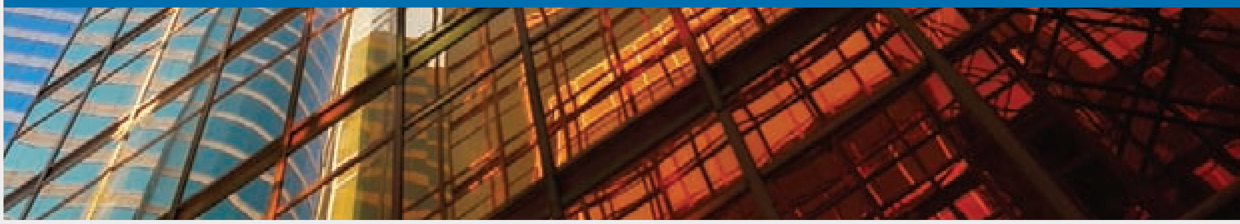

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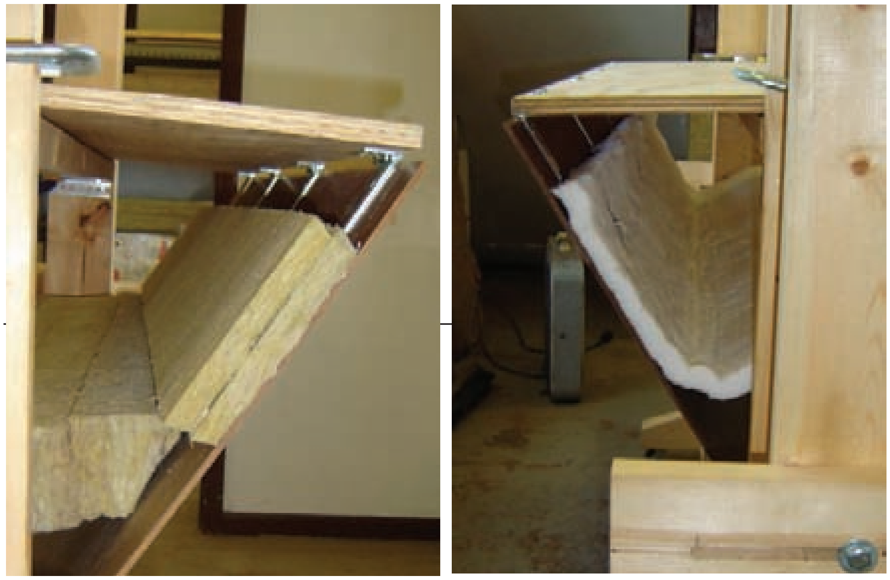

Figure 2. (Left) Detailed mock-up using mineral wool installed along the 30° inclined spandrel back pan. (Right) Detailed mock-up using needled mineral wool blanket also installed along the 30° inclined spandrel back pan. (Both figures are used with permission from Thermafiber Inc.)

A second mock-up was constructed using 1 in. (25 mm) needled mineral wool blanket insulation, which would be able to twist and adapt to the geometry of the twisting spandrels. It was mechanically fastened to the top of the floor slab and the interior face of the spandrel. Figure 2 shows the comparison between the mock-ups using mineral wool and needled mineral wool blanket insulation.

Testing Procedure and Results

A small-scale furnace test of the perimeter fire containment system was performed at Underwriters Laboratories. The purpose of the test was to confirm that the proposed building perimeter fire barrier system offered a concept capable of achieving the specified ratings. The test consisted of placing the

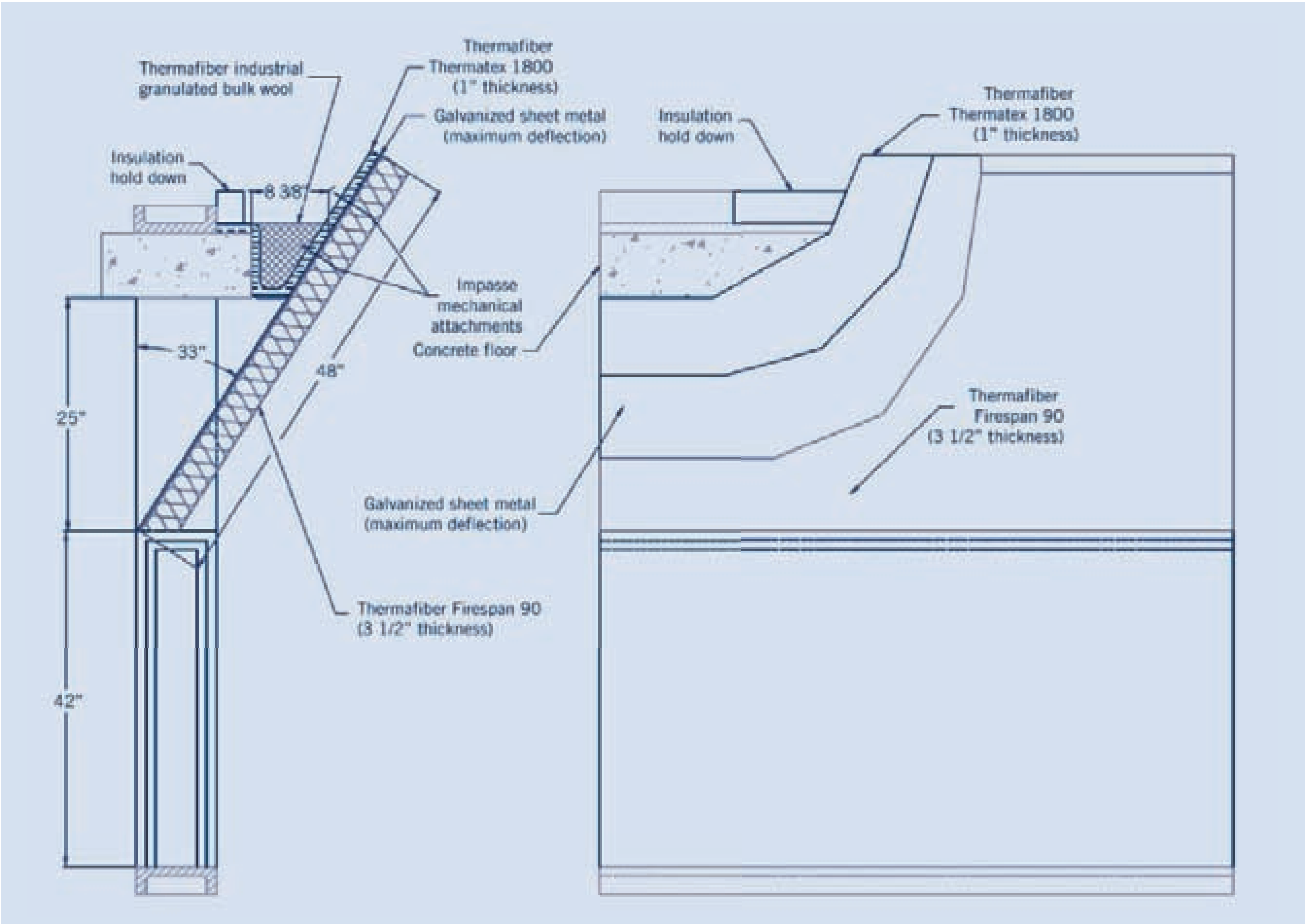

Figure 3. Drawing of the small-scale furnace test set-up (used with permission from Thermafiber Inc.)

Figure 4. Photographs of the small-scale furnace test set-up (used with permission from Thermafiber Inc.)

spandrel and insulation mock-up of the proposed materials in a small-scale vertical furnace and applying the flame to the interior side of the assembly for a period of two hours following the ASTM E119 time-temperature curve.

Two thermocouples were located on the exterior side of the mock-up — one on top of the insulation and one attached to the face of the steel attachment clip. They were used to monitor temperature rise on the non-fire side of the assembly. The furnace frame was adapted and configured with a 30-degree inclined angle on the metal back pan with a perimeter void of 8-3/8 in. (213 mm). The back pan had a 3-1/2 in. (89 mm) thick layer of mineral wool insulation, which was mechanically attached to the exterior face, as can be seen in Figure 3. The interior face that was exposed to the testing equipment was covered with needled mineral wool blanket and mechanically attached.

The cavity created at the perimeter void was filled with wool insulation. It successfully sustained a 2-hour rating, indicating that it would be able to withstand temperatures up to 1,800°F (982°C). This perimeter joint successfully prevented flame and hot gasses from breaching through the perimeter void, which is required by ASTM E 2307 and building code requirements. Figure 4 shows photographs of the testing set-up.

This case study shows that a few key elements are necessary for fire protection of innovative and complex façade designs:

1. Integrated design approach with early involvement of all involved stakeholders, including architects, engineers, manufacturers and fire protection engineers;
2. Concept design and constructability exploration through mock-ups; and
3. Development and verification of concepts through testing.

ACKNOWLEDGEMENTS

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Ajla Aksamija and Bruce Toman are with Perkins + Will.

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THE MONTE CARLO EXTERIOR FAÇADE FIRE

By Jesse J. Beitel and Douglas H. Evans, P.E., FSFPE

Image provided by MGM Resorts International

Fire spread along the upper portions of the southwest facing exterior façade(s) of the 32-story Monte Carlo Hotel and Casino in Las Vegas, Nevada. The flames and heat caused several windows to break, but automatic sprinklers kept the fire from entering the building. It took the determined suppression crews to stop the fire's progression. This article addresses the ensuing forensics investigation, contributing aspects, lessons learned and whether these combustible exterior façades should continue to be allowed.

Just before 11 a.m. on Friday, Jan. 25, 2008, the Clark County Fire Department was notified that the exterior façade of the Monte Carlo Hotel tower was burning. For more than an hour, the fire continued to propagate across the exterior, both horizontally and vertically. The fire also spread downward in some areas due to burning material falling down from the area of origin, landing on horizontal ledges below.

Heat from the flames broke out several windows and the fire attempted to gain access into the interior of the high-rise tower guestrooms, but automatic sprinklers halted its interior spread (Figure 1). In all, 17 sprinklers activated.

In addition to the Clark County Fire Department, other local jurisdictions provided mutual aid. Approximately 100 suppression personnel responded. It took the determined emergency responders using hose lines from window openings and the roof to halt the fire's propagation and extinguish the burning exterior façade.

Ignition of the exterior wall was attributed to welding on a catwalk on the roof parapet wall – a 30 ft. (9 m) high screen wall. While a cause and origin investigation was begun, the results were never summarized and published. The exterior cladding materials first ignited on the left side (as viewed from the exterior) of the central core area. The fire then progressed laterally. The adjacent materials on the right side of central core façade began to burn and the fire continued to propagate laterally over these decorative materials. The fire also moved to the left along the upper portion of the west tower and began to involve the cladding materials. Over time, the fire on the west tower moved laterally approximately 80 ft. (24 m).

Once the fire progressed away from the central core area, it appeared that the decorative band at the top of the 32nd floor, the medallions between the windows on the 32nd floor and the decorative band at the top of the wall were the primary mode of lateral flame propagation. Not only did these areas exhibit their own flame-spread, the resultant flames caused the flat area of the wall above to ignite.

Figure 1. View of façade fire

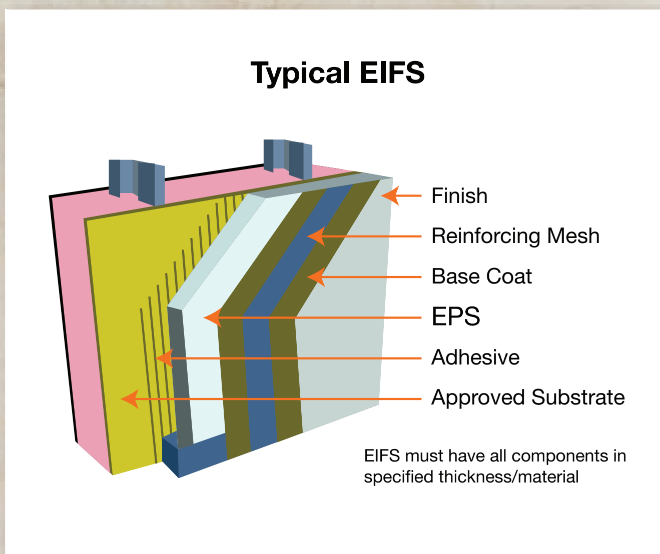

Figure 2. Components of an Exterior Insulation and Finish System (EIFS)

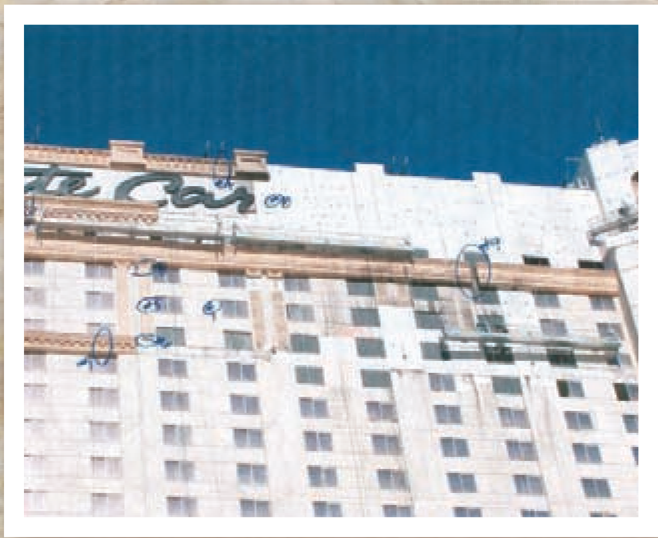

Figure 3. Locations of removed samples

Figure 4. Sample taken from the horizontal band at the 29th floor

The fire on the exterior façade was extinguished by the emergency responders at approximately 12:15 p.m.

THE BUILDING

The 32-story Monte Carlo Hotel and Casino was constructed in 1994 and 1995. The code of record was the 1991 Edition of the Uniform Building Code (UBC).[1]

The plan layout of the hotel was a center tower from which three wings, each approximately 240 ft. (73 m) long, extended.

The code of record required Type I noncombustible construction. The UBC required that, for this type of building construction, the exterior walls be of noncombustible construction.

Based on information obtained by Clark County Department of Development Services, the exterior wall cladding of the Monte Carlo was an Exterior Insulation and Finish System (EIFS) that was installed at the time of construction. Additionally, it appeared that several decorative architectural details were also installed on the exterior wall at the time of construction.

UBC Section 1713 (e) 2.B allowed EIFS to be applied as exterior wall cladding. Other types of foam plastic materials would be allowed, provided they also met Section 1713 (e) 2.B.

EIFS, when applied as an exterior wall cladding, has the following components (Figure 2):

- Substrate wall system,
- Adhesive that attaches the expanded polystyrene foam plastic insulation (EPS) to the substrate wall,
- EPS insulation board,
- Glass fiber reinforcing mesh,
- Base coat on the face of the EPS that embeds the mesh and
- Finish coat.

All of these components must be present for the wall cladding to be considered a properly installed EIFS. Each component must be installed per the manufacturer's recommendations and their evaluation report for the specific system.

After the fire, several questions were raised concerning the construction of the exterior façade. Hughes Associates (HAI) was asked to assist CCBD during the investigation. The primary questions concerned the installation of the EIFS, as well as potential non-EIFS materials. The questions included:

- Were the materials installed in accordance with code, the tested assemblies and the manufacturer's guidelines?
- If so, were the code requirements, associated tests and manufacturer's guidelines adequate?
- If not, to what extent do these need to be revised?

THE INVESTIGATION

A few days after the fire, CCBD personnel obtained undamaged samples from the west wing of the exterior façade. Figure 3 shows the approximate locations where the various samples were removed. Samples included portions of the:

- Horizontal band at the top of the exterior wall,
- Horizontal band above the uppermost guestrooms (32nd floor),
- Horizontal band at the 32nd floor,
- Horizontal band at the 29th floor (Figure 4),
- Decorative column pop-outs that extended from the 29th floor to the 32nd floor,
- Base wall assembly of the upper screen wall, and
- Base wall assembly intended to represent the primary exterior wall covering.

The samples were inspected and descriptions were developed by CCBD and HAI personnel. During inspection of the materials removed from the Monte Carlo, smaller samples were removed and subsequently sent by CCBD to a laboratory for qualitative characterization.

It should be noted that the samples taken were taken from the west façade, near the burned area. Samples were not taken from

other areas of the building and the sampling did not necessarily evaluate construction methods.

SAMPLED MATERIALS

The following summary of the various materials installed on the exterior façade is based on visual observations and the laboratory analysis:

1. The horizontal band at the top of the exterior wall was over 5 ft. (1.5 m) high and contained an expanded polystyrene (EPS) foam plastic core covered with a rigid non-EIFS coating.
2. The horizontal band above the uppermost guestrooms (32nd floor) was approximately 6 ft. (1.8 m) high and contained up to 3 ft. (0.9 m) thick EPS foam plastic at the upper portion covered with a polyurethane encapsulant.
3. The horizontal band at the 32nd floor was primarily hollow with a ½ in. (13 mm) thick outer shell comprised of fiberglass and a gypsum-plaster binder.
4. The horizontal band at the 29th floor was approximately 3 ft. (0.9 m) high and contained 2 ft. (0.6 m) thick EPS foam plastic at the top covered with a rigid non-EIFS encapsulant.
5. The decorative columns between the 29th and 32nd floors were approximately 2 ft. 4 in. (0.7 m) wide and 6 in. (150 mm) thick with an EPS foam plastic core and an EIFS coating (thinner than required).
6. Each of the two base wall assemblies sampled contained 5/8 in. (16 mm) thick gypsum wall board covered with one inch of EPS foam. The primary difference between the two was that the EIFS coating from the upper sample was noticeably thinner but in both samples, the EIFS coating was thinner than required.

INVESTIGATION FINDINGS

Based on the information obtained, the following findings were developed:

1. The Monte Carlo had, as its exterior wall cladding in the fire area, had the following two components:
   a. An EIFS system that was installed in the flat areas of the building and on the decorative column pop-outs that extended from the 29th floor to the 32nd floor – the analysis indicated that these EIFS areas had a non-complying thickness of lamina (the exterior encapsulant).

b. Decorative non-EIFS materials used for ornamentation – These items included the horizontal band at the 29th floor, the horizontal band at the top of the 32nd floor, the railing at the top of the parapet wall and are believed to include the medallions between the windows on the 32nd floor.

2. It appears that the EIFS, when properly applied, did meet the requirements of the 1991 UBC.
3. Based on the analysis of the samples, it appears that the EIFS lamina did not have the correct thickness. The actual lamina varied in thickness from approximately 28 to 69 percent less than the nominal minimum thickness.
4. The EIFS had additional decorative components applied to it. These were large shapes that contained significant thicknesses of EPS and these components were not covered with EIFS lamina. The analysis concluded that they did not meet the requirements of the 1991 UBC.
5. The primary contributor to the progression of the fire was the combination of materials in the decorative band at the top of the wall, the decorative band at the top of the 32nd floor (EPS with a polyurethane resin coating) and the undetermined materials in the medallions.
6. Flaming droplets and burning pieces of EPS and/or polyurethane caused ignition of the large decorative band at the 29th floor. This decorative band was composed of EPS and had a non-EIFS coating.
7. EIFS in the flat portion of the parapet wall was involved in the fire but was not the primary contributor to the lateral propagation of the fire, even though it appears to have a non-complying thickness of lamina. It did burn in the immediate area of fire exposure, as would be expected based on testing, but did not significantly propagate beyond the area of fire exposure caused by the burning of the decorative band at the top of the wall, the decorative band at the top of the 32nd floor and the medallions. As the fire progressed along these materials, it continued to involve the EIFS, but the EIFS was not the primary cause of the continued progression of the fire.

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LESSONS LEARNED

The primary lesson learned was:

Exterior wall systems are frequently pre-manufactured off-site and shipped to the job site. Since construction sites typically do not contain sufficient space to stage curtain walls, they are frequently installed near the time of delivery. It is virtually impossible to confirm compliance of such systems when already installed on the building. In addition, the foam plastic is encapsulated and cannot be verified to comply with applicable code requirements. As such, the third party inspections required during fabrication is a fundamental part of the assurance process.

Other lessons learned include:

Exterior insulation and finish systems are just that – they are systems. The installation must include all constituent components in accordance with the tested assemblies to provide a system that meets applicable code requirements and provides the level of protection intended.

Other similar looking, yet untested materials/assemblies may constitute an unacceptable hazard.

Jesse J. Beitel is with Hughes Associates, Inc. Douglas H. Evans is with Clark County, Nevada.

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1 International Conference of Building Officials, Uniform Building Code, Whittier, CA, 1991.

BUILDING INFORMATION MODELING for Fire Protection

By Stephen A. Jones

Building Information Modeling (BIM) is rapidly changing the ways companies work together to design, build and operate projects. About half of the owners, design professionals and construction companies in North America are involved to some degree with BIM, and that number could pass three-quarters by 2015.[1] Increasingly, fire protection engineers and trades are being asked to work in a BIM environment.

GETTING STARTED IN BIM FOR FIRE PROTECTION

Many fire protection companies began working in BIM by adapting their existing technology tools to try to fit the new way of working.

For example, add-on software is available for AutoCAD that can turn a 2D line into a 3D solid. This enables drawings where everything is elevated to the right height. This approach is not ideal, but it's workable. Another is a specialized fire protection software program called Autosprink that draws everything in 3D, calculates hydraulics and prepares a printout list or a file for fabricators.

Software also is available that can reference 2D drawings and trace them into BIM. The software SprinkCAD permits a direct integration into BIM that saves time and improves efficiency.

CURRENT LEVEL OF BIM USAGE FOR FIRE PROTECTION

Most fire protection companies are seeing an increase in BIM requests. Unfortunately, the economic downturn has reduced new construction and generated more renovations and upgrades, where BIM is not as prevalent. Anecdotally, BIM projects represent 15 percent of current work, up from about 3 percent three years ago.

HOW BIM IS USED FOR FIRE PROTECTION

The powerful spatial coordination capability of BIM (also known as 'clash detection') is the primary way projects involving multiple trades are taking advantage of BIM. Conventional coordination, done with transparent drawings on light tables and between crews in the field, yields mixed results. On a BIM project, the discipline-specific models produced by engineers and trades can be evaluated together as if they were in a single model by uploading them into specialized software programs, such as NavisWorks, Solibri or BIM Sight, that can read multiple file formats concurrently. This way, geometric conflicts between the models can be resolved virtually by the project participants before they create physical problems in the field. *(see illustrations as an example)*

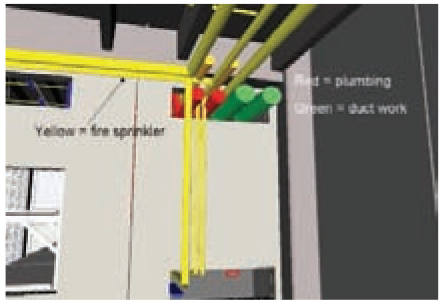
This model-based approach to spatial coordination is quickly becoming standard practice. The trend is starting to create a disadvantage for trades that are not modeling their work. Some contractors have adopted the position that if any trades are not doing 3D modeling with the others, then the non-modeling trades will have to coordinate around the ones that do. This represents a potentially major change in the traditional pattern, which has always been 'sprinklers go around everybody else', because now if sprinklers have a layout that goes in the building model and HVAC doesn't, sprinklers take precedence.

As a result, fire protection contractors are being careful to implement software that works in the leading clash-detection programs. This software includes Autosprink, NavisWorks and the HydroCAD programs.

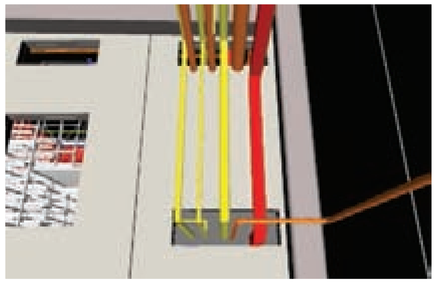
The use of BIM also is expanding beyond piping to include fire alarm control panels, pull stations, smoke detectors and many other elements of the total fire protection package.

SPATIAL COORDINATION IN BIM

Project teams using BIM can analyze models produced by multiple companies in different file formats by uploading them into clash-detection software that reads them all concurrently and identifies geometric conflicts.



The Clash:
Clash detection discovered a conflict between plumbing (shown in red), duct work (shown in green) and the fire sprinkler (shown in yellow).



Fire alarm manufacturer Notifier got involved in creating BIM-compliant information about its products in response to demand from the marketplace for product information that could work in BIM.

The Notifier catalog of BIM content has been available for several months and appears to be getting attention from specifiers. This manufacturer is seeing double-digit monthly

downloads from the various places they are making it available, which include Sweets.com, Autodesk Seek and the notifier.com website. The company also has conducted presentations to more than 1,000 A/Es around the country to explain how BIM content helps the project process.

There is a growing demand for manufacturers to create content to support the full range of fire protection in BIM.

BIM is impacting design and craft labor as well. While 3D BIM is more design-intensive because it requires more steps, the extra work during design is more than compensated in the field benefits. For example, locating anchors in precast concrete that has been modeled can quickly recoup the cost of modeling through fewer field adjustments.

Increased prefabrication is one of the major reasons BIM is gaining such popularity among trade contractors across the United States, especially structural and MEP. Interestingly, this particular benefit has not impacted fire protection trades to the same degree because they have been extensively prefabricating for years.

As more construction industry firms begin adopting BIM, cultural challenges as well as technical ones present themselves. In general, people who started out in 2D have a harder time shifting to BIM because they are used to interpreting what they see in their mind's eye into 2D views on paper. For people with less experience using 2D views, the shift to BIM seems to be easier because they don't have to change an ingrained practice.

This gap creates opportunities for a growing number of outsourcing BIM service companies, many of whom routinely create comprehensive BIM models for project teams from a variety of 2D and BIM source materials. Often, existing staff do not have the time or expertise to shift quickly to BIM, so they find consultants who offer a more efficient way to make the transition.

Different owners also are implementing BIM to varying degrees, which impacts its effectiveness for fire protection contractors. Some building owners require all trades to extensively model, coordinate and prefabricate their work. Others are less stringent in their demands, so sometimes just a few of the trades model because the others do not have the capability. This reality limits the benefits of BIM because not all of the information is available in a BIM format for optimal coordination.

THE FUTURE OF BIM IN FIRE PROTECTION

BIM is deployed on some healthcare projects because of the critical requirement for trade coordination. For example, a new form of agreement called an Integrated Project Delivery (IPD) contract calls for the owner,

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This approach to fire protection in BIM is very comprehensive. Everything from sprinkler pipes, valves and fittings all the way down to fire alarms, dampers, sealants and caulking will be modeled in BIM. This will ultimately tie to the owner's facility management model.

For example, firewalls are very critical to track in a healthcare project. So, in the field, penetrations in fire walls can each be bar-coded, providing the owner a statement of conditions and an understanding of where all penetrations are located. That serves as an immediate indicator of the location along that fire wall, and allows the user to pull up what penetrations are in that area, pop a ceiling tile and then scan the penetration. The system will tell the user who installed it, when it was installed and what system it is.

After construction is complete, when a trade contractor comes in, the system will produce a work order before raising a ceiling tile and making a penetration. The contractor will take before-and-after photos and then scan them in so the owner will always know who, when and what assembly was installed. The benefit of this approach is expected to pay off in the many years of modifications that will take place above the ceiling in a facility.

Stephen A. Jones is with McGraw-Hill Construction.

Reference:

1 "The Business Value of BIM," McGraw Hill Construction SmartMarket Report, McGraw Hill, New York: 2009.

FIRE SAFETY:

AN INTEGRAL PART OF SUSTAINABILITY

By Christopher J. Wieczorek, Ph.D.

INTRODUCTION

A long history of fire safety advances has been shown to save lives, protect property and minimize business interruption losses; however, in today's corporate culture, risk improvement efforts may be cast aside in favor of sustainability efforts. Property risk managers want to earmark money for risk improvement and loss mitigation, while other corporate objectives may drive executives to dedicate resources to sustainability initiatives to improve the corporation's image and reduce operating costs. The matter is further complicated by building certification processes, such as Leadership in Energy and Environmental Design (LEED) developed by the U.S. Green Building Council (USGBC) and other international certification organizations. For example, credit for green certification may be given for items that are difficult to connect with sustainability (such as a bicycle rack), but no benefit is accrued from fire safety measures such as automatic fire sprinkler protection systems and the use of materials certified for their limited flammability characteristics, which may prevent a total loss of resources invested in building construction.

Recent studies show that risk management measures and sustainability efforts are not necessarily mutually exclusive.[1, 2] In fact, current research demonstrates that, if a building is not properly designed and constructed to withstand potentially catastrophic events due to risk factors posed by fires, floods, earthquakes or hurricanes, such disasters can nullify the benefits gained from green construction. Efforts to improve sustainability solely by increasing energy efficiency (without consideration of risk) have the potential to increase the magnitude of risk factors by a factor of three. Incorporating risk mitigation measures – including construction methods and building materials that can improve a building's survivability as an integral part of reducing lifecycle environmental impact – represents the next step in making buildings durable, and thus sustainable.

UNINTENDED CONSEQUENCES

Thus far, the focus of green building research and development has been on reducing the impact on the environment; to that end, green regulations and rating systems that recognize high-performance buildings from an environmental perspective have driven the progress. The USGBC has developed the LEED certification process as a "green" building certification system, providing third-party verification that a building was designed and built using strategies aimed at improving performance across key metrics: energy savings, water efficiency, CO_2 emissions reduction, improved indoor environmental quality, and stewardship of resources and sensitivity to their impacts throughout the world.

> Focusing only on improving sustainable aspects of a building under normal operation, without any consideration for off-normal conditions that pose risks to property, can result in unintended consequences and even tragedy.

One common aspect of most of these certification systems is a lack of consideration for the impact of risks such as fire and natural hazards on sustainability. This approach could result in the selection of materials for their insulating properties but that are deficient in their flammability characteristics.[3] Focusing only on improving sustainable aspects of a building under normal operation, without any consideration for off-normal conditions that pose risks to property, can result in unintended consequences and even tragedy.

RISK FACTORS

Gritzo *et al.*[1] supplemented the traditional lifecycle carbon assessments of buildings, taking into account risk factors of events such as fire, wind and flood as well as the use of mitigating technologies such as sprinklers. The impact of risk factors on lifecycle carbon emission is illustrated in Figure 1. The plot indicates the carbon emission of a building as a function of time. The lower curve may be considered the carbon emissions under normal conditions and the upper curve shows the deviation from that due to a fire.

The carbon emission cycle can be divided into three portions: 1) construction, including manufacture of material, transportation and equipment usage; 2) normal operation over the lifetime of the occupancy, *i.e.*, primarily power consumption, utilities and maintenance if applicable; and 3) decommissioning, including equipment usage for demolition and transportation for disposal. Figure 1 reflects additional carbon emissions resulting from the fire and subsequent reconstruction.

Gritzo *et al.*[1] defined a risk fraction, indicating the relative importance of carbon emissions due to risk events, such as fire, compared to normal operation over the building's lifetime. The risk fraction, therefore, represents the increase that risk factors pose to the sustainability posture of a building over its lifetime. A reduction in the risk fraction can be achieved through effective risk management strategies, which can serve to reduce the fire frequency and/or the extent of damage produced and reconstruction required.

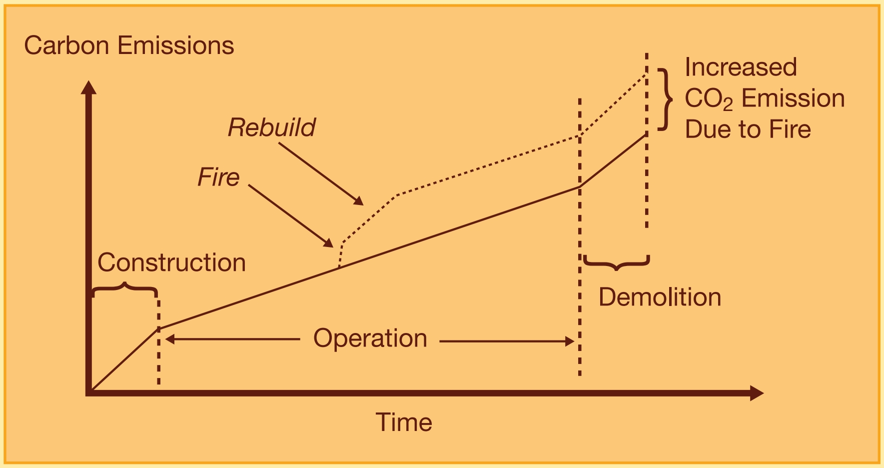

Figure 1. Contribution of risk factors to total lifecycle carbon emissions

This analysis was carried out for four different occupancies: a standard office building, an office building with reduced operating emissions (*i.e.*, a "green" building), a manufacturing facility (where the frequency and severity of fires are greater) and a residential single-family home. The results illustrate that risk factors increase the lifecycle carbon emissions of a standard office building on the order of 1 to 2 percent and as much as 14 percent for light manufacturing facilities.[1] For single-family residential homes, the contribution of fire risk to the total lifecycle carbon emission is between 0.4 and 3.7 percent.[2]

For the standard office building with an improved sustainability posture achieved by reducing operating emissions, the influence of risk factors increases nominally to 4 percent over the lifetime of the facility. The importance of risk factors will gain increased significance as future efforts progress to reduce the carbon footprint of operating facilities. The impact of a fire in a more "sustainable" building without consideration of risk factors, and the need for risk management, can result in lifetime carbon emissions that are greater than they would be if sustainability had never been considered in the design. This difference is attributed to the higher embodied carbon emission associated with more material and process-intensive components used to achieve energy efficiency.

In all cases, the use of automatic fire sprinkler systems provides an order of magnitude reduction in the fire risk factor contribution to lifecycle emissions.

ENVIRONMENTAL IMPACT OF AUTOMATIC FIRE PROTECTION SPRINKLER SYSTEMS

In addition to reducing the risk factor contribution to lifecycle emissions of a building, automatic fire sprinklers have environmental benefits by reducing the levels of air and water pollution, water usage and overall fire damage. To quantify these environmental impacts, large-scale fire tests were conducted using identically constructed and furnished residential living rooms.[2] In the non-sprinklered test, fire extinguishment was achieved only by fire service intervention, while in the sprinklered test, a single residential sprinkler was used to control the fire until final extinguishment was achieved by the fire service. In the tests, the fire service initiated water application 10 minutes after the fire was detected.

Quantification of the environmental benefit was based on comparisons between the two tests, including total greenhouse gas production, quantity of water required to extinguish the fire, quality of water runoff, potential impact of wastewater runoff on groundwater and surface water, and mass of materials requiring disposal.

The use of automatic fire sprinklers reduced the peak heat release rate from 13,200 kW to 300 kW and reduced total energy generated by a factor of 76. The amount of combustible material consumed in the fire was less than 3 percent in the sprinklered test and between 62 and 95 percent in the non-sprinklered test.

The total air emissions generated from the sprinklered test were lower than those from the non-sprinklered test. Of the 123 species analyzed in the air emissions, only 76 were detected in either the sprinklered or non-sprinklered tests. Of the species detected, the ratio of non-sprinklered to sprinklered levels for 24 of the species was in excess of 10:1. Eleven were detected at a ratio in excess of 50:1, and of those, six were detected at a ratio in excess of 100:1. The remaining species were detected at the same order of magnitude. The use of automatic fire sprinklers reduced the greenhouse gas emissions – consisting of carbon dioxide, methane and nitrous oxide – reported as equivalent mass of carbon dioxide, by 97.8 percent.

Comparing the water usage between the two tests, it was found that, in order to extinguish the fire, the combination of sprinkler and hose stream discharge from the firefighters for final extinguishment was 50 percent less than the hose stream alone. Extrapolation to a full-size house indicated that the reduction in water usage achieved by using sprinklers could be as much as 91 percent.

A new study independently confirmed this result, stating that the increase in water usage in full-size homes without sprinkler protection can be as much as 1,200 percent.[4] Furthermore, fewer persistent pollutants, such as heavy metals, and fewer solids were detected in the wastewater sample from the sprinklered test compared to that of the non-sprinklered test. The pH value of the non-sprinklered test wastewater exceeded the allowable discharge range of 5.5 to 9.0 required

by most environmental agencies and was four orders of magnitude higher in alkalinity than the wastewater from the sprinklered test. The non-sprinklered test wastewater represents a serious environmental concern.[5]

Analysis of the solid waste samples indicated that the ash/charred materials from neither the sprinklered nor the non-sprinklered test would be considered "hazardous waste," and that the wastes are not anticipated to significantly leach once disposed of in landfills.

In the sprinklered room, flashover never occurred; however, in the non-sprinklered test, flashover occurred at approximately five minutes after ignition. The occurrence of flashover prior to fire service intervention is an indication that the fire would have propagated to adjacent rooms, resulting in greater production of greenhouse gases, greater water demand to extinguish the fire, and additional materials to be disposed of in landfills. However, in the sprinklered test where the fire was confined to the area of origin, the damage, greenhouse gas production and water consumption represent maximum values independent of additional rooms.

The greater fire damage in the non-sprinklered test has a direct impact on the carbon emissions of the building. This is due to the embodied carbon associated with the building materials necessary for reconstruction and that associated with the manufacture of furnishings and contents.

CARBON FOOTPRINT OF AUTOMATIC FIRE PROTECTION SYSTEMS

The manufacture and installation of an automatic fire protection system is not a "carbon zero" process and thus a potential concern regarding sprinklers being considered sustainable. Although, to date, no cradle-to-grave analysis of an automatic fire sprinkler system has been conducted, an order-of-magnitude evaluation can be made by noting that the major carbon emission contribution is associated with the steel pipe. The carbon dioxide emissions associated with the manufacture of steel pipe is known. Buchanan and Honey state that, for steel pipes, the carbon dioxide emissions incorporate "the energy required to make the machines that make the machines."[6] For steel pipes, the carbon emissions are reported as 1.96 *kg C/kg steel*; the equivalent carbon dioxide value would be 7.2 $kg\ CO_2/kg$ *steel*.[5]

Making the assumption that for an industrial occupancy the typical sprinkler system consists of a 3 in. (80 mm), schedule 10 (3 mm thick) steel pipe, the weight per unit length is 6.44 *kg/m*.[7,8] A 3 m (10 ft.) length of pipe is necessary for a 9.29 m^2 (100 $ft.^2$) coverage area; thus, there would be 2.11 kg steel per square meter protected. Based on these values, the carbon emission contribution of a sprinkler system in an industrial occupancy is 15.2 $kg\ CO_2/m^2$. For office buildings and manufacturing facilities, the total carbon emission of the building, over a 40- to 60-year lifetime, can range between 2,000 and 4,500 $kg\ CO_2/m^2$;[1] therefore, the installation of a sprinkler system would result in a 0.34 to 0.76 percent increase in total carbon emissions.

Although this analysis neglects the carbon emissions associated with the sprinklers, sprinkler risers, pumps, fittings, etc., the analysis was based on the partially offsetting assumption that the steel pipe manufacturing was achieved with machines operating only on fossil fuels.[5] This is a conservative assumption, since many current manufacturing processes use sustainable practices that reduce reliance on fossil fuels.

For residential occupancies, a similar analysis can be conducted assuming a 1 in. (25 mm) diameter, schedule 10 (2.8 mm thick) pipe and would result in a carbon emission contribution from the sprinkler system of 4.91 $kg\ CO_2/m^2$.[9] Based on 1998 and 2008 U.S. census data, the average single-family home was 164 m^2 (1,765 $ft.^2$); thus, for a typical home, the sprinkler system will add 806 $kg\ CO_2$. This would result in an increase of 0.29 percent to total carbon emission over the building's lifetime, *i.e.*, 278,000 $kg\ CO_2$.[2]

It should be noted that for residential homes, plastic pipe would be more typical than steel pipe. A recent study indicates that the carbon dioxide emission of a plastic pipe is between 63 and 80 percent lower than that of a steel pipe.[10] Therefore, the carbon emission of a residential sprinkler system is equivalent to the carbon dioxide emission from the combustion of 18 to 33 gallons (68 to 125 liters) of gasoline.

Christopher Wieczorek is with FM Global.

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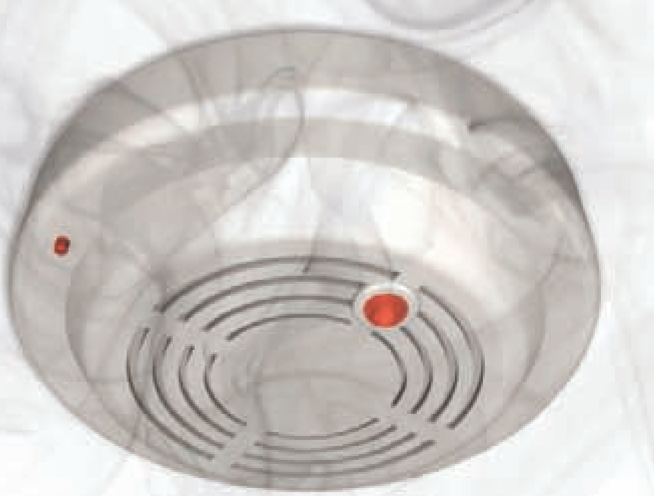

ALARM, TROUBLE AND SUPERVISORY– Degrees of conditions, signals and responses

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Should a carbon monoxide condition result in an alarm signal or in a supervisory signal? The answer is: It depends.

Combined, NFPA 72[1] and NFPA 720[2] address a full range of signaling systems, from simple smoke or carbon monoxide alarms, to basic fire alarm systems, to complex emergency communications systems for many types of hazards and risks. System designers and authorities having jurisdiction often question whether a certain event should trigger an "alarm" or a "supervisory" signal. Too often, users of NFPA 72 and NFPA 720 get caught up in trying to categorize a signal rather than focusing on what needs to be done with that signal.

In the past, fire alarm terminology was fairly simple. An alarm meant "a warning of fire danger."[3] A trouble signal was an indication that some part of the fire alarm system was broken or off-normal. A supervisory signal was used to indicate that some other protection system, monitored by the fire alarm system, was off-normal. Supervisory signals were used to indicate when sprinkler valves were closed or when a suppression system releasing panel was disabled. At a protected premise, a fire alarm almost always resulted in occupant notification and the intended evacuation of the building or area.

Some fire alarm systems monitor sprinkler systems in large storage occupancies where those systems may have few or no other common fire alarm system features. For a variety of reasons, many of these systems do not require in-building, general occupant notification. They may only signal at an on-site control unit or annunciator and at an off-premises supervising station or fire department dispatcher. This type of signaling was one of the first recognitions that there are degrees of "danger" conditions requiring different responses.[4]

In the 2007 edition of NFPA 72, the definition of "alarm" was changed by dropping the word "fire" so that it reads: "a warning of danger."[5] This was done as the code began to branch out to address signaling system use for many different types of hazards. In 2007, a new annex was added to address emergency communications systems, including mass notification systems. In 2010, the emergency communications systems annex evolved into Chapter 24 of NFPA 72.

The development of the first edition of NFPA 720, released in 1998 as a recommended practice, brought about a new type of alarm signal: "A signal indicating a concentration of carbon monoxide that could pose a risk to the life safety of the occupants in the family living unit, requiring immediate action." NFPA 720 did not define a carbon monoxide supervisory signal and did not formally define any degrees of response other than "immediate action." However, paragraph 1-2.1 did note that the purpose was to provide a warning of the presence of carbon monoxide to "allow occupants to either escape or take other appropriate action." The 2009 edition added a definition for supervisory signal: "A signal indicating the need for action in connection with a pre-alarm condition, or in connection with the supervision of protected premises carbon monoxide safety functions or equipment, or the maintenance features of related systems."

The changes to NFPA 72 and NFPA 720 are recognitions that there are varying degrees of "conditions" that require varying degrees of "response" that are initiated by various types of "signals."

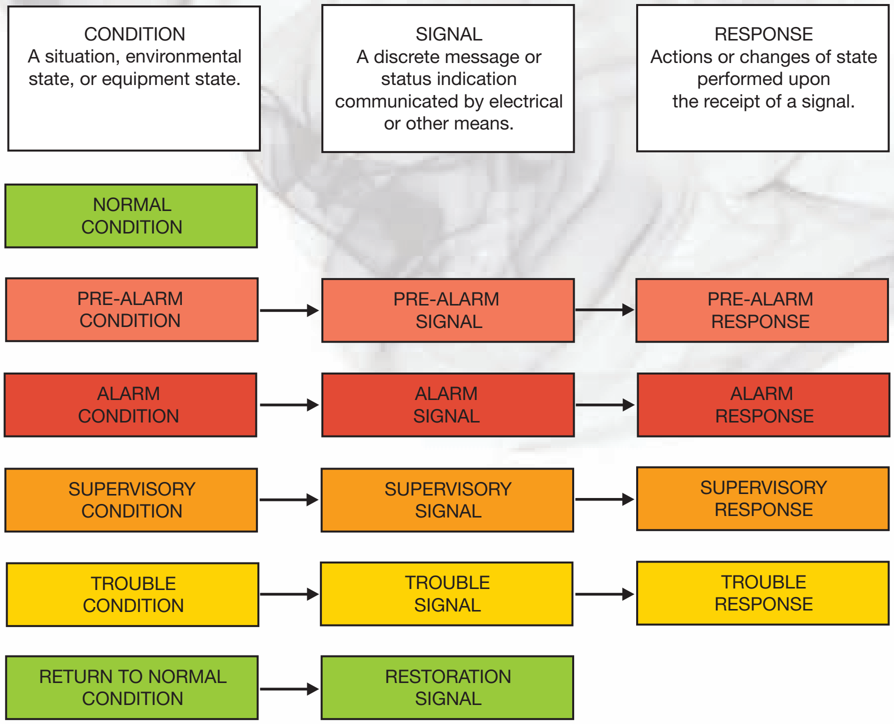

Figure 1. Condition – Signal – Response Model

NFPA 72 and NFPA 720 do not dictate specific responses. Instead, they are standards that facilitate the gathering of information about conditions and the communication of that information in a way that can be used to affect the needed response. The response, action or service that is needed for a given condition must be specified by the system designer in consultation with all stakeholders. Under the simplest circumstances, the response may be pre-defined by other governing laws, codes or standards.

Proposals have been processed for the 2013 edition of NFPA 72 that would formally define condition, signal and response, along with several sub-definitions. Though still in the development process, Figure 1 shows a working model.[6]

In addition to the sub-definitions shown in Figure 1, there might be additional defined terms such as "Fire Alarm Signal," "Evacuation Signal," "Guard's Tour Signal," "Delinquency Signal" and "Carbon Monoxide Alarm Signal." Introduction of this model into NFPA 72 is intended to help focus designers and users on the response that is needed for a given condition and to demonstrate that there are a variety of ways that signaling systems can be used to convey meaningful information to the correct target audiences. In fact, NFPA 72 will not define all possible conditions, signals and responses that a signaling system might manage. For example, a runaway chemical reaction might produce a detectable overheat condition. There is no need to define an overheat condition, signal and response. Similarly, is it necessary to define a sprinkler waterflow condition, signal and response?

The need for this model, and the need for several discrete categories of condition, signal and response, also is driven by product ergonomics, development and listing. Currently, system control units are designed and listed to produce alarm, trouble and supervisory signals. Every attached initiating device must trigger one of these three standard responses at the control unit interface. If an initiating device is intended to result in an alarm signal, the panel response must include a unique audible alert signal.

As of the 2010 edition of NFPA 72, the audible alert signal can be the same used to indicate trouble conditions and supervisory conditions, provided that the signals are distinguishable by some other means, such as visual indicators (LEDs). (Prior to the 2010 edition, the panel would have to have an audible alarm alert signal that was distinct, while trouble and supervisory conditions could trigger a different, but common audible signal.) The code was changed, in part, because the intent is to get someone to pay attention to the control unit and to investigate the signal.

As different types of alarm, trouble and supervisory conditions, signals and responses are being introduced, it is not practical or ergonomic to require unique audible alerts for each. If a control unit experiences a fault, the control unit may signal trouble by sounding the common local audible attention signal and by lighting a yellow LED labeled "trouble." A separate LED (yellow or amber) is commonly used for supervisory signals along with the common audible alert signal.

While most control units use the "three LED" method for signal distinction – along with green for normal – it is not required. Some have a pre-alarm LED or two or more alarm level LEDs. A unit could use a text display to provide the visual information in lieu of LEDs. The use of text displays creates greater opportunity for distinction of the various types of conditions, signals and responses. However, the use of three to five LEDs on a display has the advantage of providing a quick visual indication of the potential importance of the incoming signal. This can be very important during the management of actual emergencies.

For example, during a fire, as smoke and heat spread (conditions), additional initiating devices activate and cause the audible alert on the panel to resound, even if it had been silenced. It will also resound as new faults are introduced by circuits being attacked by the fire and for incoming supervisory signals from fire pumps starting and valves being operated to control water. In a fire emergency, this resound might happen hundreds of times, which causes the person at the panel to be nearly continuously assaulted by the audible alert signal. While a text display can convey a richer message, having a simple three to five LED display indicating the level of an incoming signal can be an important ergonomic simplification.

> There have been cases where signals have been ignored or missed because of complex and confusing interface ergonomics.

So, should a carbon monoxide condition result in an alarm signal or in a supervisory signal? The answer still is: it depends. For example, in a residential home or apartment where occupants might be sleeping, if a carbon monoxide condition is detected, the desired response is to immediately alert the occupants so that they can take appropriate actions – evacuate or ventilate the space and correct whatever caused the condition. In that case, the signal should be classified as an alarm signal as it is intended to indicate that a dangerous condition exists. If a carbon monoxide condition is detected in a parking garage, the required response might only be to activate a ventilation system. There might be no other signal.

If the condition is not corrected or worsens, a signal might be used to alert maintenance staff that repairs are needed to the ventilation system or to investigate why the CO levels were not reduced by the ventilation system. The conditions being used to trigger these signals and responses are levels of CO that are not an immediate threat to occupants. Therefore, these signals might be categorized as either supervisory or as pre-alarm. Less emphasis needs to be placed on the category and more emphasis needs to be placed on ensuring the correct response.

There have been cases where signals have been ignored or missed because of complex and confusing interface ergonomics. The proposed condition, signal or response model does not dictate any new control unit interface or means for alerting users or occupants. However, it does define a framework for panel designers, system designers and even for the NFPA 72 technical committees to use as systems evolve and increase in complexity.

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UPCOMING EVENTS

November 14–17, 2011
Exploring the Mega-fire Reality 2011, A Forest Ecology and Management Conference
Tallahassee, FL, USA
Info: www.megafirereality.com

March 6-9, 2012
Suppression, Detection and Signaling Research and Applications – A Technical Working Conference (SUPDET 2012)
Phoenix, AZ, USA
Info: www.nfpa.org/Foundation

March 14–16, 2012
5th International Symposium on Tunnel Safety and Security
New York, NY, USA
Info: www.istss.se

May 13–16, 2012
7th International Conference on Wood and Fire Safety
Štrbské Pleso, Slovakia
Info: michaela.colonova@fsi.uniza.sk

June 6–8, 2012
7th International Conference on Structures in Fire (SiF'12)
Zurich, Switzerland
Info: http://www.structuresinfire.com/

June 11–14, 2012
2012 NFPA Conference & Expo
Las Vegas, NV, USA
Info: www.nfpa.org

September 19–21, 2012
Human Behaviour in Fire 2012 – 5th International Symposium
Cambridge, England
Info: www.intersciencecomms.co.uk

September 27–28, 2012
2nd International Conference on Fires in Vehicles (FIVE)
Chicago, IL, USA
Info: www.firesinvehicles.com

October 14–19, 2012
2012 Annual Meeting: Professional Development Conference and Exposition
Savannah, GA, USA
Info: www.sfpe.org/Education.aspx

June 24–26, 2013
Interflam 2013
London, England
Info: www.intersciencecomms.co.uk

BRAINTEASER > Problem/Solution

Problem

Two cars are drag racing. The track length is 0.5 km. The first car accelerates to a speed of 100 km/hr in six seconds and maintains this speed until the conclusion of the race. The second car accelerates to a speed of 120 km/hr in 10 seconds, then maintains this speed until the end of the race. Which car won the race?

Solution to Last Issue's Brainteaser

Iodine-131 has a half-life of 8.0 days. If someone has one gram of Iodine-131, how long will it take before the mass decreases to 0.33 grams?

For radioactive decay, the relationship of the quantity at time t and the initial quantity is as follows:

$$N(t)=N_0 e^{-t\ln(2)/t_{1/2}}$$

Where $t_{1/2}$ is the half-life, $N(t)$ is the quantity at time t, and N_0 is the initial quantity. Substituting:

$$0.33g=1g \times e^{-t \times 0.69/8}$$

Solving for t, it will take 12.9 days before the one gram mass of Iodine-131 decays to 0.33 grams.

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Protectowire's distributed temperature measurement is based on the proven Raman-Optical Time-Domain-Reflectometry (OTDR) technique. An optical laser pulse propagating through the sensor fiber gets scattered light back to the transmitting end, where it is analyzed using a patented code sequence measurement concept. The backscattered light is spread across a range of wavelengths. Some of these wavelengths are affected by temperature changes, while others are immune. By very accurately measuring the difference in the signal intensity of the backscattered light, an accurate temperature measurement can be made. This enables the FiberSystem PTS Controller to provide an exact location of a fire or hot spot anywhere along the sensor's length. Temperatures are recorded as a continuous profile. The system is also capable of providing graphical representation of the fire size and direction of fire spread based upon the length of sensor in alarm mode.

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For additional information, contact The Protectowire Co., Inc., 40 Grissom Road, Plymouth, MA, USA 02360 Ph. 781.826.3878 Fax: 781.826.2045 or *sales@protectowire.com*.

Firefighter Telephone System

Silent Knight has expanded its portfolio of Farenhyt fire alarm systems with the release of a new high-capacity firefighter telephone system. The IFP-FFT can support up to 72 telephone connections with as many as 10 phones in use at one time, and has been designed to operate on a single loop of standard wire to reduce expenses and simplify installation. Ideal for high-rise buildings and large facilities in regions that require firefighter telephone systems.

www.farenhyt.com

—Silent Knight

Voltage Sensing Relay and Timer

The Voltage Sensing Relay and Timer (VSRT), a new product in the FlexMod™ line, helps prevent dead batteries in emergency vehicles. The VSRT conserves the starting power of a vehicle battery by shutting off auxiliary loads when either starting voltage drops to a low level, or a pre-set timer times out; it alerts the vehicle operator when starting voltage is low and then cuts off any non-essential loads, such as air conditioning or exterior lighting, thus conserving power to start.

www.colehersee.com

—Cole Hersee Co.

Corrosion Inhibiting System

Potter Electric Signal Company, LLC, and General Air Products have teamed up to offer a nitrogen generator specifically designed for use in fire protection sprinkler systems to slow the oxygen corrosion process by filling system piping with 95% to 99% pure, dry nitrogen. The Potter Nitrogen Generator is a pre-engineered, turnkey system ready to connect to a new or existing system and includes everything needed to operate at peak efficiency.

www.pottersignal.com

—Potter Electric Signal Co., LLC

Water Mist Fire Protection

The HI-FOG System with a SPU-6 Sprinkler Pump Unit has passed a seismic qualifying test. The test demonstrated that the 7,500-pound system can withstand the effects of an earthquake of up to 1G of force and continue operating. HI-FOG water mist fire protection uses high pressure to force pure, potable water through specially designed and patented sprinklers. The small droplets vaporize fast, absorbing heat efficiently and facilitating a safe evacuation of occupants.

www.marioff.com

—Marioff North America

LOC Emergency Communications

Gamewell-FCI has expanded its emergency communications systems capabilities with a second version of its Local Operator Console (LOC) used to remotely control emergency messaging and system operation. The new LOC-TEL version offers a lower-cost alternative that also meets the mass notification requirements of LOCs as mandated by the U.S. Department of Defense in its Unified Facilities Criteria (UFC) document 4-021-1. A telephone and 16 programmable switches allow this LOC-TEL to direct pre-recorded and live voice messages to any designated area within a facility.

www.gamewell-fci.com

—Gamewell-FCI

Industrial Inspection Camera

The SeeSnake nanoReel N85S industrial inspection camera system is used for ultra-small diameter lines ranging from ¾ to 2 inches, and has the ability to make tight turns for specialized applications. The lightweight, compact drain inspection camera system allows users to push cable distances of up to 85 feet. At 9½ pounds, the portable nanoReel inspection camera system can be transported to and from jobsites, making it suitable for inspecting boiler tubes, supply lines, sprinkler systems and a wide array of specialty applications.

www.ridgid.com

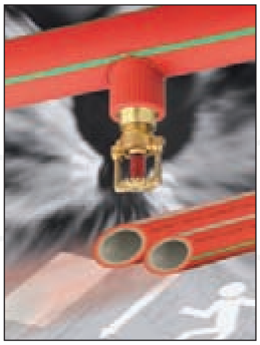
—Ridgid

Combo Fire/CO Detection

The new Advanced Multi-Criteria Fire/CO Detector (AMCF/CO) provides a cost-effective solution for the growing commercial market that requires carbon monoxide (CO) detection in addition to traditional fire detection. The AMCF/CO works with the new System Sensor B200S addressable sounder base. The B200S produces both Temp 3 and Temp 4 patterns for fire and CO alarms – which are synchronized across all sounder bases. And, for evacuation signaling, the sounder base can act as part of the system – fully synchronized to other System Sensor horns and horn strobes in the facility.

www.systemsensor.com
—System Sensor

Aquatherm Red Pipe



Recognized internationally for years, and formally known as Aquatherm FireStop Fusiolen® PP-R, Aquatherm Red Pipe is now available in the North American market through Red Pipe Industries. The fire protection product has been approved by FM Global for use in wet pipe automatic sprinkler systems in light hazard occupancies. The highly engineered polypropylene-random (PP-R) pressure pipe has FM approval in the FM 1635 class (No. 3036285) and belongs to the Aquatherm family of PP-R piping systems.

www.rpi-na.com
—Red Pipe Industries

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Model RV-1 Relief Valves are factory-assembled and fully trimmed valve arrangements. Pilot-controlled, the Model RV-1 Valve maintains a relatively constant system pressure at the pump discharge as flow demands change. UL Listed and FM Approved, Model RV-1 Relief Valves feature stainless steel trim tubing and a ceramic enamel-coated valve interior. They use a single-moving part in the diaphragm chamber and are available in sizes 2 through 8 inch in both globe and angle configurations.

www.tycofsbp.com
—Tyco Fire Protection Products

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www.simplexgrinnell.com
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www.acafsystems.net
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www.vikinggroupinc.com
—Viking Corp.

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