Fire Prevention

Lessons Learned

A review of published investigation reports from the Charleston Sofa Super Store fire

By Frank J. Baker

BUILDING OWNERS, OCCUPANTS and the fire service play important roles in the outcome of any fire emergency. The fire at the Charleston Sofa Super Store is one of the most tragic single event outcomes in history for firefighters. The outcome was attributed to actions, inactions and conditions before and during the event itself.

This article presents a review of existing investigative reports and highlights those items identified as critical to the overall outcome. Most of the available information was assembled by an independent team of respected fire service professionals from across the U.S. that was appointed by the city of Charleston, SC. The team's mission was to conduct an exhaustive review of the incident and develop strategies for the city to implement to improve the fire department, as well as to benefit all fire departments. The information also includes lessons that can be used by building owners and occupants to avoid similar situations.

The Incident

At 7:09 p.m. on June 18, 2007, the first call reporting a fire behind the Sofa Super Store on Savannah Highway in Charleston, SC, was received by the 9-1-1 dispatch center. The first due battalion chief and crew from the dispatched apparatus of Fire Station 11 observed visible smoke as they left the station and arrived on the scene less than 3 minutes later.

The evening would end in tragedy. Nine firefighters would die in an incident that would later be determined to have been entirely preventable—from the fire itself to the loss of life. Preexisting conditions inside the building and inadequately managed fireground operations caused the conditions inside the structure to degrade rapidly.

Many hose lines would be stretched into the building in an effort to combat the fast-moving fire, taking firefighters at times as far as 200 ft inside the structure with zero visibility. By 7:40 p.m., those nine firefighters had become disoriented and could not find their way out of the building. Running out of breathing air, they would eventually succumb to carbon monoxide poisoning, smoke inhalation, thermal burns or a combination in the untenable environment inside.

TOP PHOTO BY PICTOMETRY INTERNATIONAL; BOTTOM PHOTO BY BRAD NETTLES/*CHARLESTON POST & COURIER*

Photo 1 (top): Aerial view of the building before the fire, facing south. Refuse had accumulated near the loading dock located between the front and rear sections of the building.

Photo 2: Aerial view after the fire. Note the extensive collapse of most of the structure. Roof coatings in the center section of the front showroom contributed to the heavy fire load and were also consumed in the fire.

Frank J. Baker, CSP, CFPS, ALCM, *is manager of risk management for the midwest region of Eastern Alliance Insurance Group. Baker holds a B.S. in Safety from Illinois State University; is certified as a master firefighter by the state of Indiana based on training in fire investigation and fire prevention; and is an NFPA Fire Officer I and Incident Safety Officer. He is a consulting member of the Pike Township Fire Department Safety Committee in Indianapolis, IN. Baker is a professional member of the Central Indiana Chapter and Administrator of the Society's Fire Protection Practice Specialty.*

Abstract: *The fire at the Charleston Sofa Super Store, which caused the deaths of nine firefighters, is one of the most tragic single event outcomes in history for firefighters. The outcome was attributed to actions, inactions and conditions before and during the event itself. This article presents a review of existing investigative reports and highlights those items identified as critical to the overall outcome.*

PHOTO BY DAN FOLK

Photo 3: View of the building from the adjacent property to the west. By this point, the fire had spread from the loading dock area to the main showroom.

The most likely cause of the fire is believed to have been carelessly discarded smoking materials that ignited trash outside the loading dock, which in turn ignited furniture stored inside the loading dock, eventually spreading throughout the building (Photos 1 and 2, p. 35). The fire spread through concealed spaces above the heads of firefighters—meaning the firefighters were unaware of how rapidly the conditions were deteriorating. The fire also communicated unchecked through unprotected doorways and directly penetrated walls that were not constructed of fire-rated materials to reach more fuel (see diagram below). By 7:52 p.m., the roof of the west showroom began to sag due to heat exposure and at 7:56 p.m., the center showroom roof suffered a catastrophic collapse (Routley, Chiaramonte, Crawford, et al., 2008, pp. 53-80).

Several investigations conducted following the incident revealed that many factors contributed to the tragic outcome. The goal of those investigations, and this review, was not to place blame, but to help others learn how similar situations might be avoided.

Investigations Conducted

It has now been more than 2 years since the fire. Because of the high profile nature of an incident where nine firefighters died in the line of duty, the event has been examined by several different agencies to determine what happened and how it or future incidents could be prevented. Investigations by the South Carolina Department of Labor (SC OSHA), Licensing and Regulation/OSHA and the Charleston Post-Incident Assessment and Review Team are complete. NIOSH's Firefighter Fatality and Injury Prevention Program also investigated and released a final report in February 2009.

The SC OSHA investigation results were released on Sept. 20, 2007. Both the store and the city's fire department were cited for both willful and serious violations of occupational safety standards.

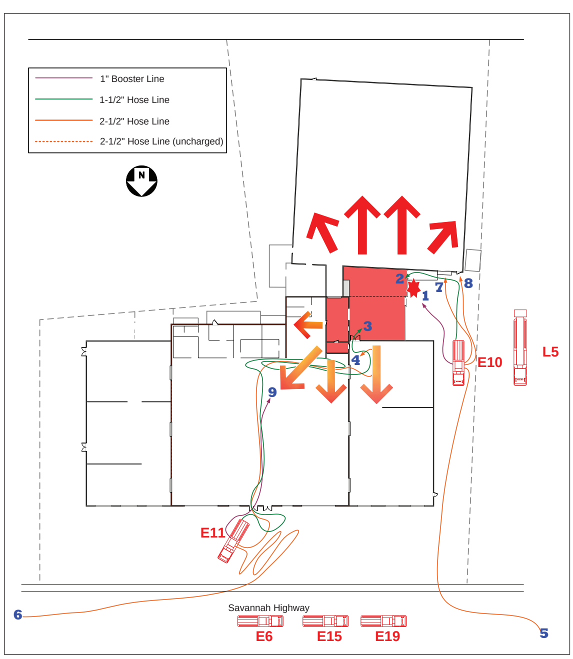


Diagram from the investigation team's Phase 2 report shows the direction of fire travel from the point of origin outside the building.

The Sofa Super Store

•Willful violation. Exit doors locked while the building was occupied [cited under 1910.36(d)(1)]. Initial penalty $49,000, assessed penalty $29,400.

•Serious violation. Failure to properly maintain fire doors [cited under 1910.37(a)(4)]. Initial penalty $7,000, assessed penalty $2,500.

•Serious violation. No emergency action plan for employees [cited under 1910.38(b)]. Initial penalty $7,000, assessed penalty $875.

Charleston Fire Department

•Willful violation. Employer knew or should have known that the command system does not provide for the overall safety of personnel and their activities [cited under the general duty clause]. Initial and assessed penalty $7,000.

•Serious violation. Standard operating procedures were not developed to cover the special hazards associated with fighting and attacking a fire involving a metal truss roof [cited under 1910.156(c)(4)]. Initial penalty $1,000, assessed penalty $900.

•Serious violation. Body protection was not required to be worn by nine firefighters involved in interior structural firefighting [cited under 1910.156(e)(1)(i)]. Initial penalty $1,000, assessed penalty $900.

•Serious violation. Self-contained breathing apparatus (SCBA) not required to be worn by four firefighters while exposed to smoke and toxic substances [cited under 1910.156(f)(1)(ii)]. Initial penalty $1,000, assessed penalty $525.

The state of South Carolina administers its own OSHA enforcement program as do 25 other states and U.S. territories. South Carolina provides for a reduced fine structure for governmental entities as compared to those in the private sector. The Charleston Fire Department eventually reached what many would consider a controversial settlement with the SC OSHA—it agreed to pay only $3,160 of the original $9,325 in fines and had to admit no wrongdoing. The agreement resulted in fines on only two of the violations originally cited (SC OSHA, 2007).

Based on the findings of the Post-Incident Assessment and Review Team and NIOSH, many other potential violations were present during the incident and may not have been individually cited by OSHA. Specific violations of NFPA firefighter safety and health standards (NFPA 1500) included failure to designate one or more incident safety officers on the scene; failure to have the required rapid intervention teams assigned and standing by in the ready capacity; failure to keep crews together when operating inside an immediately dangerous to life or health (IDLH) environment; and failure to have an effective personnel accountability system to track the locations and assignments of firefighters involved in the incident. In the author’s opinion, these individual items, while not separately cited, likely were contemplated in assessing the general duty clause citation noted.

As noted, the NIOSH Firefighter Fatality and Injury Prevention Program issued its final report earlier this year. The findings and recommendations of that report echo the findings of the other investigative bodies. The Charleston Post-Incident Assessment and Review Team performed the most comprehensive work on this incident and to date has released two reports: the Phase 1 Report (38 pp.) on Oct. 16, 2007, and the Phase 2 Report (272 pp.) on May 15, 2008. These reports covered in great detail the time line of events, developing recommendations and lessons learned for others in the fire service. Those recommendations and lessons learned are reviewed later in this article.

Building Construction

The original building was constructed in the 1950s or 1960s of hollow concrete block and a metal deck roof supported by open web steel bar joists as a grocery store. Flanking additions of lightweight metal on preengineered steel beams were added to the original building in 1995 and 1996, bringing the total area to more than 31,000 sq ft. This comprised the showroom area that was separated into three fire areas by hollow concrete block walls with rolling steel fire doors protecting the openings. Because of the installation of the rolling steel fire doors in the openings between these building sections, they were considered separate structures for building code purposes. Treating each section as a separate building kept them under the threshold that would have required automatic sprinklers (Routley, et al., 2008, pp. 26-29).

In 1996, a 15,600 sq ft preengineered warehouse was added to the rear of the structure; it was connected only by an enclosed hall protected with a

Diagram from the Phase 2 report shows those sections built without city approval—highlighted in yellow. These sections enclosed previously required exits and provided pathways for fire to travel around the fire door that was installed to separate the showroom and warehouse sections.

rolling steel fire door to provide the necessary fire separation to classify the structure as two fire divisions. A variance was granted to not require a fire resistance rating on the north warehouse wall that exposed the showroom building by virtue of the physical separation distance and 3-hour protective features on the corridor that attached the two. All of this construction was regulated under the city code enforcement process through proper permitting. As with the first two additions, this was treated as a separate structure and was also under the threshold that would have required it to be protected with automatic sprinklers (Routley, et al., 2008, pp. 26-29, G-2).

After 1996, several small wood frame additions covered with metal siding and roof decking were added to create what are termed *fill-in* additions. These typically take advantage of existing walls of one or more already built structures and effectively fill in the space between them with a floor and roof (see diagram above).

In this case, no building permits were obtained for these additions—nor is it likely they would have been approved. These additions caused two primary problems: 1) they circumvented the fire separation created by the enclosed tunnel with a fire door that was intended to separate the showroom from the warehouse; and 2) they enclosed previously required exits. This created dead-end rooms that would later house high-hazard operations. During the fire, firefighters had to forcibly break through one of the exterior walls to rescue a trapped employee (Routley, et al., 2008, p. 31).

The entire combined structure covered more than 46,000 sq ft not counting the fill-in structures. Because of the unapproved construction, lack of proper fire walls, normally required opening protective devices, and other opening protective devices that did not function properly, all but 7,200 sq ft of the building would be completely destroyed in the fire.

Concealed or void spaces above the showroom ceilings and a roof coating of combustible polyurethane foam caused heat and products of combustion to become trapped and spread laterally through the structure without being easily detected at the floor level where the firefighters were. This void space between the suspended ceiling and the roof created an uninterrupted plenum between 2 and 6 ft high depending on the slope of the roof at that location (Routley, et al., 2008, p. 39). (Investigators concluded that a thermal imaging camera would have readily identified these conditions.) A similar condition began to occur below the ceiling. This was visible to the firefighters, but it was only part of the problem.

The roof also lacked natural vents. These vents typically consist of items such as powered ventilation fans, HVAC units, air handlers, skylights and automatic smoke vents. While not always the best means of vertical ventilation, natural vents can provide some relief inside by releasing products of combustion if assisted by manually opening them up to permit a chimney effect to occur through convection currents that cause heated gases to rise. They also can help incident commanders better gauge what is going on with the fire spread by providing more opportunities to read the smoke conditions (Routley, et al., 2008, p. 43).

Occupancy

Under the NFPA classification system, the occupancy of this building would have been primarily merchantile. The warehouse would have been separately classified since it was being treated as a separate building by city officials, and should have been treated as a storage occupancy due to the high-rack storage containing appreciable amounts of exposed Group A plastics in the form of upholstered furniture containing large amounts of expanded urethane foam (Routley, et al., 2008, p. 36).

The showroom was typical of a furniture sales operation with relatively narrow aisles separating large congested areas of furniture displays. These caused significant difficulty for firefighters attempting to stretch hose lines through the showroom areas as well as for those who became separated from their hose line and were attempting to find their way out (Routley, et al., 2008, p. 36).

The warehouse building was 29 ft from the floor to the roof deck and contained single and double row racks at least four tiers high based on photos in the NIOSH report. The Phase 2 report indicates the storage to have been about 20 ft high. The racks were filled with exposed upholstered foam-filled furniture and bedding. Narrow aisles between these racks created significant radiation feedback and natural flue spaces caused the fire to spread quickly through the building (Routley, et al., 2008, p. 28).

Post-fire investigations also revealed that a significant quantity of flammable and combustible liquids was being stored in the building in 1 gallon cans and aerosols. The occupancy classification did not permit the storage of flammable liquids, hazardous materials or spray finishing operations. At least 28 containers, including some with naphtha and lacquer thinner, were found in the post-fire investigation. This exceeded the amount permitted under the fire code for incidental use (Routley, et al., 2008, pp. 36-37).

Private Protection: Building Owner/Occupant

Private fire protection for this structure consisted only of portable fire extinguishers. Based on an account from an employee who went to the loading

Table 1

Comparison of Protective Schemes

Hazard design	Approved	Additional in-rack sprinklers	Delivery density	Operating area	Total water flow
NFPA 13 Ex Haz. Grp 1	No	Without in-racks	0.3 gpm	2,500 sq ft	750 gpm
NFPA 13 ESFR	No	Without in-racks	1.2 gpm	1,000 sq ft	1,200 gpm
FM Global DS 8-9	Yes	With in-racks at every other level	0.8 gpm	1,500 sq ft	1,200 gpm
FM Global DS 8-9	Yes	With in-racks at every level	0.6 gpm	1,500 sq ft	900 gpm
FM Global DS 8-9	Yes	With in-racks two rows at every level	0.3 gpm	2,000 sq ft	600 gpm

Note. *Adapted from NFPA 13, Standard for Installation of Sprinkler Systems, by NFPA, 2002, and Storage of Class 1, 2, 3, 4 and Plastic Commodities (Loss Prevention Data Sheet 8-9), by FM Global, 2008, p. 41, table 2.3.7.3 (k).*

dock area to attempt to extinguish the fire reported by a passerby, the fire was already too large to control with a single handheld unit. Upon locating and retrieving a second extinguisher from the showroom, the employee could not even enter the loading dock and had to discharge that device through a doorway from the adjacent holding room. He was ultimately unsuccessful in controlling the fire (Routley, et al., 2008, p. 53).

The building also had no automatic heat or smoke detection devices, nor were automatic sprinklers installed in any part of the building. Had building permits been obtained for the fill-in sections constructed, an automatic sprinkler system would have been required to be installed throughout the entire structure at that time since the additions compromised proper fire separations.

South Carolina, which enforces the International Fire Code, now requires merchantile occupancies of more than 12,000 sq ft to be fully protected by automatic sprinklers. With the presence of Group A plastics, a sprinkler system for the showroom and loading dock area would have had to be designed for at least Ordinary Hazard Group 2 (Routley, et al., 2008, p. G-16; International Code Council, IFC 903.2.6). Protecting exposed Group A plastics in high-rack storage to a height of 20 ft in the warehouse would have been a challenge. Rack storage of significant quantities of exposed Group A plastics falls outside the scope of Chapter 12, decision tree 12.3.3.1.1 of NFPA 13.

Therefore, a designer would need to refer to the FM Global (Factory Mutual) data sheets to find a protection scheme capable of controlling this extreme fire load. Schemes for situations similar to this require the use of a combination of overhead and in-rack sprinklers. The overhead component would need to deliver water densities significantly higher than those required by NFPA Extra Hazard Group 1, but not as great as those required with an early suppression fast response (ESFR) overhead system due to the additional protection afforded by various configurations of in-rack sprinklers.

NFPA Extra Hazard Group 1 would typically require a density of about 0.3 gpm over an operating area of 2,500 sq ft capable of flowing about 750 gpm through the system, but would require two rows of in-rack sprinklers at each level to supplement it and meet the FM Global requirements. The ESFR typically delivers 1.21 to 1.25 gpm over a minimum operating area of 960 sq ft capable of flowing about 1,200 gpm through the system and can often be used for Class 1 through 4 commodities, but not Group A plastics in this configuration. The FM Global recommended systems have an overhead delivery density of between 0.3 gpm over a 2,000 sq ft operating area (600 gpm flow) to 0.8 gpm over a 1,500 sq ft operating area (1,200 gpm flow). The number and positioning of the in-rack sprinkler systems determine which overhead system can be employed (NFPA, 2002b; FM Global, 2008, p. 41).

Table 1 presents a comparison of protection schemes, based on protection of storage of 20 ft high

PHOTO COURTESY *CHARLESTON POST & COURIER*

Photo 4: Water supply lines were extended from the nearest fire hydrants and hose lines extended far into the building. The kinked single supply hose in the foreground indicates inadequate incoming water pressure—resulting in inadequate water flow to the pumping engine.

in a building less than 30 ft high containing exposed expanded Group A plastics as are found in uncartoned upholstered furniture and bedding [NFPA, 2002b; FM Global, 2008, p. 41, table 2.3.7.3 (k)].

Although delivering an adequate volume of water is crucial to absorption of the heat being released, how it is delivered is as critical to successful control of such an extreme fire load.

One issue that compounded problems and diverted resources was the lack of an effective emergency action plan that would account for employees as well as patrons (since this was a retail establishment). An employee was trapped in a workshop area that was part of the fill-in construction—it had no exit except through the warehouse or showroom, which were already well involved in fire. He called 9-1-1 on a cell phone to report his situation. Management on site was not aware this worker was in the building until his vehicle was spotted in the parking lot. The worker had to be rescued by forcible entry, through an opening sawed in the exterior wall of the building (Routley, et al., 2008, p. 69).

Buildings frequented by the public often implement a fire warden program in which certain employees are responsible for sweeping designated sections of the building to ensure that everyone has been cleared from the structure. This is done in addition to the manual head count conducted at predetermined muster sites outside to ensure that all are accounted for.

Public Protection: Charleston Fire Department

The last city fire code inspection occurred on March 30, 1998, before the city suspended fire code inspections for merchantile occupancies in 2000. Although preplan visits had been made between 1998 and 2007, they were not complete and did not acknowledge the presence of the high-rack storage in the warehouse or any other unusual hazards (Routley, et al., 2008, p. 37).

Public protection capabilities are graded by the Insurance Services Organization (ISO). This complex

PHOTO COURTESY OF STEWART ENGLISH

Photo 5: Shortly after the front windows of the building were removed in an effort to horizontally ventilate the building, the fire grew rapidly inside. Without adequate water supply for the hose lines inside, there was little hope of controlling the fire.

system is based on many factors. Ten percent of the scoring matrix is based on fire department resources and reliability; 50% is based primarily on availability of engine companies and water demand throughout the community; and the remaining 40% is based on how much of the required fire demand can be supplied over and above the daily community consumption. The resulting score is called the public protection classification (PPC) rating (ISO, 2005).

The system uses a matrix grading system to analyze the capabilities of a department based on equipment, training and response abilities. Ratings range from a PPC-10, which is considered almost nonexistent fire protection, to PPC-1 where the department can provide extremely high-quality fire protection service to the community (ISO, 2005). The city of Charleston was listed as a PPC-1 department. Currently, fewer than 60 departments—or less than 0.2% of all fire departments in the U.S.—have achieved this grading.

This event suggests that some elements of the PPC system may be outdated, such as minimum supply hose diameter and ensuring that departments have adopted use of modern strategies and tactics applicable to today's fire scenarios. Current ISO requirements reflect outdated technology, such as small diameter supply lines and marginal on-board water tanks.

The fire flow (water necessary) for combating today's fires with large quantities of hydrocarbon-based fire loading is higher than ever and continues to grow each year. This has caused movement away from 2.5- and 3-in. diameter supply hose to large 5- and 6-in. diameter hose, and to movement away from ISO minimum 300-gallon water tank capacities toward tanks that hold 1,000 gallons or more.

Although it is not recommended to begin interior firefighting operations until a secondary supply of water has been established, this extra on-board water can make a difference in a quick fire knock down when municipal supplies are marginal. Flow rates through modern 1.5 and 1.75 in. hose lines with adjustable nozzles can be as high as 125 and 175 gpm, respectively. With only 300 gallons of water on board, that equates to less than 2.5 minutes of water flow with only one 1.5 in. diameter hose operating. Even with a 1,000 gallon tank and a single 1.75 in. hose line flowing up to 175 gpm, the water supply would last less than 6 minutes.

The minimum size attack hose lines for many departments fighting commercial building fires is 2.5 in. in diameter because it can flow as much as 275 gpm (Hall & Adams, 1998). Flow rates such as these, even with larger tanks, provide barely enough time to get supply lines connected and water flowing from a hydrant to the apparatus before the on-board water supply is exhausted. As noted, beginning an aggressive offensive fire attack inside a building using only tank water is a dangerous practice (Routley, et al., 2008, p. 126) and should be avoided unless there is a viable life inside the structure that needs to be rescued.

Water supply was a major challenge in this fire (Photo 4, p. 39). There were few hydrants near the building; those that were available and used during the initial phases of the operations were not even on the same side of the four-lane highway as the structure. The nearest hydrant to the building had been removed from service as it was continually being struck by truck traffic in and out of an adjacent property. The next nearest hydrants were more than 500 ft away, requiring relay pumping through a single 2.5-in.-diameter hose lay of 850 ft and a second single hose lay of 1,750 ft of 2.5-in. hose connected to 100 ft of 3-in. hose.

Even with pressure from the city hydrants boosted by placing an engine at the hydrant and pumping toward the engines at the scene, the firefighters could not overcome the friction loss in the hose to deliver the necessary water (Routley, et al., 2008, pp. 124-128).

Friction loss in a hose or pipe is caused by disruption of the laminar flow of water within it due to the interior surface texture. The larger the diameter of hose, the lower the ratio of disrupted flow to laminar flow with the result being more water flowing through the same combined cross sectional area. For example, a single 5-in.-diameter supply line can flow 1,250 gpm through 600 ft of hose using the hydrant pressure of 65 psi and a residual pressure of 10 psi at the discharge end. It takes six 2.5-in.-diameter hoses at the same pressure and distance to flow 1,260 gpm (FEMA, USFA & NFA, 2005, p. SM 5-5).

The total water available from the two initial supply lines was less than 600 gpm even when boosting them to dangerously high pressures in an attempt to overcome the friction loss (Routley, et al., 2008, p. 126-127). As many as nine hose lines had been extended from the two engines pumping at the scene with a calculated demand of nearly 968 gpm. Therefore, none of the hand lines being used during the initial attack were performing at optimal flow. Had proper supply lines been established, hydrants in the area were capable of providing the necessary water flow for the attack lines used during the first 30 minutes of operations.

Later in the operations, master streams would be set up that caused the demand to exceed the water main and hydrant capacity in the area (Routley, et al., 2008, p. 128). Master streams are large flow water application devices for 300 to 2,000 gpm that can either be set up at ground level or from elevated positions such as aerial ladder trucks. They are designed for defensive fireground operations to apply large amounts of water to prevent fire spread from the building of origin by suppressing the fire or to adjacent structures by cooling their exterior surfaces due to radiant heat exposure (Hall & Adams, 1998, p. 596).

Fire flow for purposes of common firefighting is calculated based on the total square footage involved divided by 3 (FEMA, et al., 2005, p. SM 5-4). The showroom being more than 31,000 sq ft and the warehouse being more than 15,000 sq ft would have demands of 10,300 gpm and 5,000 gpm, respectively, if in fact they were separate fire divisions. However, due to lack of proper fire separation, total fire flow in excess of 15,000 gpm could be needed when these areas were fully involved in fire.

Exposures

Exposures on the fire scene can be external areas that must be protected from ignition or radiant heat damage; or can be those areas that create problems with normal fireground operations based on the building's layout or construction.

Some exterior exposures were created by nearby properties—namely some residential properties and a garage building close to the warehouse. Once it was determined that the fire in the warehouse was moving faster than could be overcome, crews on that assignment went to a defensive strategy to protect the adjacent residential exposures (Routley, et al., 2008, p. 93).

In this case, the most critical factor was that the building created its own exposures. This was caused by lack of proper fire separations and opening protection that permitted the fire to extend from its area of origin by communicating through unprotected openings or directly through the metal siding into three adjacent areas (Routley, et al., 2008, p. 85).

Other problems with the building construction that prevented traditional roof ventilation operations were the lack of natural openings in the roof (Photo 5) and the design of the front parapet wall behind the entrance facade. The height of the front parapet wall prevented normal ladder operations from being conducted via the front side of the building where there was space to set up the aerial ladder (Photo 6).

This 23-ft-high parapet was part of the original construction and the two flanking additions to give the appearance of a much larger building above the existing 12- to 14-ft building roof line. It was strictly a cosmetic feature and would prove to be a significant impediment to roof operations (Routley, et al., 2008, p. 41). Effective ladder company operations were also restricted along the sides of the building due to the narrow paved drives on each side that were within the standard collapse zone. Access to the rear of the showroom building was not possible due to trees and insufficient paved space. The rear of the warehouse area was accessible only on the side that abutted the public street as the other sides were unpaved or had adjacent exposures.

The lack of conventional roof operations caused the conditions inside the building to deteriorate much faster than they would had normal vertical ventilation been possible. Without being able to release the superheated products of combustion, they spread laterally at a much faster rate, contributing to the risk of flashover inside (Routley, et al., 2008, pp. 42-43).

Photo 6: The building façade that created a parapet wall at the front of the building that prevented access for normal roof ventilation collapsed along with a major portion of the roof.

Photo 7: Photo shows total collapse of the loading dock area. Fire penetrated through unprotected wall openings and through wall construction materials to spread in three directions.

TOP PHOTO BY TYRONE WALKER/*CHARLESTON POST & COURIER*; BOTTOM PHOTO COURTESY BILL MURTON, CHARLESTON POLICE DEPARTMENT

Fireground Operational Issues: Strategies & Tactics

The fire department is criticized in the investigation reports for errors in how the fire was fought. This is not to say that application of water in an effort to extinguish the fire was wrong, but the reports specifically address how the fireground operations were managed. Problems were deemed to be directly related to the fireground command, the department's culture and equipment issues.

Incident management is the ultimate responsibility of the incident commander (IC) who must conduct a risk assessment, develop an incident action plan


PHOTO BY JOHN PUNDT

As scene conditions change, the incident commander must be able to receive information, process the data, determine whether actions are successful, and change strategies and tactics as necessary.

(IAP), assign resources and monitor the effectiveness of the operations aimed at accomplishing the plan's goal(s). As conditions continually change, the IC must be able to receive information, process the data, determine whether actions are successful, and change strategies and tactics as necessary to continue to have a positive impact on the situation. The IC also must maintain effective communications; establish an accountability system for personnel; and request adequate resources far enough ahead of the current situation to control the fire (NFPA, 2007).

In this case, a single command was not established as evidenced by two separate operational commands attacking the fire with no coordination between them. One group of firefighters was able to escape through a nearby exit, but the other team was too deep inside the building to find its way out before running out of air. At one point, three fire officers were directing independent operations on the same fire scene, which violates the principle of a unified command. The fire chief did not exercise the single point of control over the fireground operations and became personally involved in operations near the loading dock (at the tactical level), making him unable to view or effectively command the overall incident (at the strategic level) (Routley, et al., 2008, p. 97).

Operations that took the firefighters as much as 200 ft into the building were risky because of the intense fire load and lack of readily locatable or even usable exits (Routley, et al., 2008, p. 97). With the noted SCBA air management issues, safe working time inside the building after finally reaching the fire area would have been extremely short and left no margin for safety in case the crew became lost or entrapped. The goal of the air management policy required under NFPA 1404, Chapter 5.1.1, is to ensure that each firefighter is aware of his/her air consumption patterns (NFPA, 2006).

With this in mind, interior firefighting work cycles in an IDLH environment must be kept short enough to ensure that the firefighter can safely exit without the need to encroach on the reserve air supply. This reserve supply is intended to provide the firefighter with a limited margin of safety that is only to be used if s/he needs to be rescued. No rapid intervention team to rescue a firefighter in trouble was assigned even after undertaking the aggressive interior firefighting strategy. Each arriving crew was given the next tactical assignment instead of standing by for rescue operations. This violated OSHA's 2-in/2-out rule found in the Respiratory Protection Standard [29 CFR 1910.134(g)(4)]. Command also did not appoint a functional safety officer(s) as required under NFPA 1500 6.1.4 and NFPA 1521 4.1.4.1 (NFPA, 2007; 2002).

The Charleston Fire Department commonly staffed many of its apparatus with only three personnel; only some were staffed with four. The first apparatus on the scene were only staffed with three firefighters each (Routley, et al., 2008, p. 47). NFPA 1710 states that a minimum staffing of four persons on each fire apparatus is required to ensure the safety of the crew and provide the necessary manpower once on scene (NFPA, 2004). National Fire Academy recommends at least one firefighter for every 25 to 50 gpm of fire flow demand (FEMA, et al., 1991). This incident could have easily used as many as 300 firefighters to provide for the normal search and rescue, suppression, ventilation, rapid intervention crews, back-up crews and support as the incident evolved into a fully involved structure fire.

In addition, many fire service officers would term the initial response light. Originally, two engine companies and one aerial truck company were dispatched along with a battalion chief. When the battalion chief marked "smoke visible" while leaving the station driveway, a third engine company self-dispatched according to established protocol.

An additional six engine companies would be requested—one at a time—in the 20 minutes following the arrival of the first apparatus. In commercial fires, resources are most commonly requested in groups, often referred to as additional alarms or box alarms. The intent of calling multiple pieces of apparatus is to get ahead of where those involved believe the fire will be once those resources arrive. Reflex time required from the request of resources to their arrival on scene becomes greater as the incident grows in size because those resources generally must come from farther away (FEMA, et al., 2004, p. SM 3-4). Combining the lack of manpower and too few apparatuses significantly hindered safe and effective operations.

The Charleston Fire Department was familiar with fighting residential fires, but had little training or experience with large, complex commercial fires. Aggressive offensive interior attacks were common practice in residential fires—something that would be dangerous in response to a commercial fire when the required water supplies to support such activity had not yet been established. Water supplies that were eventually established were far too small to meet the fire flow demand as were the initial attack lines in relation to the fire load. This left the crews inside dangerously exposed.

However, this strategy may have worked had there not been conditions that caused the fire to communicate from the loading dock into other areas of the building and had there been a sufficient water supply. Because the IC had no information that identified the potential problems, the offensive attack continued far longer than it should have. The final change from an aggressive offensive fire attack, withdrawal of the interior crews and the move to a defensive mode came too late. Readily observable conditions existed indicating they could not control the fire (Routley, et al., 2008, pp. 95-99).

No procedures had been developed and communicated to the firefighters to deal with operations involving the recognized safety hazards of metal truss roof structures, as noted in the OSHA citations. Truss roof construction is common to nearly every community, from small neighborhood retail stores to big box stores and commercial warehouses. The major problem is the lack of protection for the structural members from heat, making them highly susceptible to catastrophic collapse. A thermal imaging camera was available on the aerial truck that initially responded, but it was not used to examine the building for fire extension into the ceiling voids (Routley, et al., 2008, p. 86). Use of the camera would have provided early indications that fire was spreading undetected overhead in the concealed space between the ceiling and roof and would have allowed a timely retreat from the building.

The lack of conventional roof venting operations accelerated the fire's lateral spread and would have been an early warning to change strategies. In this case, it is believed that collapse of the structure came after the firefighters had already died of carbon monoxide poisoning, smoke inhalation and/or thermal burns after being lost too deep inside the structure. However, the hazards of truss roof construction are well documented and the outcome is almost always the same—sudden, catastrophic collapse as one or more parts of the system weakens and fails due to heat exposure. Knowing the reasonable limits of safe working time inside once heat levels become critical is essential to preventing loss of life.

This requires an intimate knowledge of building construction and how it is affected by fire. Unprotected structural steel members, as used in this building, will begin to weaken to a point where they will no longer support even their own weight when heated above 1,000 ºF (Hall & Adams, 1998, p. 70). Steel bar joists have been shown to collapse in as little as 9 minutes when directly exposed to fire (FEMA, et al., 2005, p. SM 1-10).

Communication problems were encountered as the entire operation was being conducted on a single radio channel (Routley, et al., 2008, p. 111). This caused many radio transmissions to be broken or unintelligible—and the initial distress calls by lost firefighters went unheard and unanswered from the fireground. The first indication that firefighters were in distress was communicated to the chief by an assistant chief who arrived later at the scene and relayed what he heard on the radio away from the fire scene (Routley, et al., p. 105). Also, without a functional personnel accountability system in place, it was impossible to tell who was doing what and where they were, as crews had become separated and reassigned to other tasks away from their apparatus and normal duties (Routley, et al., p. 122).

Key Factors Affecting the Outcome

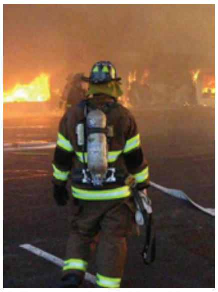
The postincident review team developed a list of key factors that had a direct impact on the outcome of this tragedy and could be used to prevent similar incidents in the future. Following is a summary from the panel opinions with additional commentary by the author.

Building & Property: Owners/Occupants

- It is believed that this fire could have been easily prevented had proper care been taken to prevent employees from smoking near the storage of debris and other combustible materials immediately outside the loading dock.
- An automatic sprinkler system would have easily controlled the fire and prevented it from extending further into the building from the loading dock area—making this a fire of little consequence.
- The building owner would have been required to install a sprinkler system as part of the fill-in construction projects had proper building permits been obtained. This creeping construction compromised the integrity of the fire separation originally provided between the showroom and warehouse.
- The severity of the fire would have been reduced had flammable liquids not been stored improperly in the loading dock area.
- Firefighters might have been able to escape the building before running out of air had proper exits been maintained. Some exits were found to have been padlocked.
- Implementation of an emergency action plan for building occupants would have enabled them to ensure that all employees and patrons were safely out of the building and accounted for. Accountability for occupants reduces the resources that must be directed toward performing search-and-rescue operations by the initial responding fire personnel.
- An effective fire code inspection and engine company preplan program would have discovered the deficiencies in the building, and they would have been addressed through proper administrative procedures (Routley, et al., 2008, p. 133-134).

Fire Department Operations

- Fire suppression activities did not comply with South Carolina safety and health regulations (verbatim of federal OSHA standards) or NFPA consensus standards. These included those items cited in the initial OSHA violations as well as aspects of many NFPA standards such as NFPA 1500, Fire Department Occupational Health and Safety Programs; NFPA 1404, Fire Service Respiratory Protection Training; and NFPA 1981, Open Circuit SCBA for Emergency Services.
- Lack of an effective IC structure complicated a difficult situation. Changes in conditions that should have signaled an immediate change in strategy were not recognized and acted on.
- The Charleston Fire Department was inadequately staffed, trained and equipped to handle a fire of such complexity and magnitude. In an effort to compensate for these problems, personnel engaged in dangerously aggressive tactics, including placing firefighters far too deep inside the structure relative to their available air supplies.
- The department's normal aggressive operational mode of using small hose lines with limited water volume was adequate for most of the fires encountered at the residential level, but was inappropriate for a large commercial occupancy with high fire load. Department personnel were not prepared for a fire where different or changing strategies would need to be employed based on observed conditions (Routley, et al., 2008, pp. 134-135).



Firefighters must be trained in the concepts of crew management so they will be able to recognize situations that affect safety.

Lessons Learned for the Fire Service

The intent of the two-phase investigation report was to provide a learning base so other departments can implement changes to prevent future tragedies. This was one of the most detailed investigations ever conducted in an effort to improve the department involved and allow others to learn as well. As noted in the report, however, many of the recommendations are not new, but reinforce those that already should be known and widely implemented within the fire service.

Incident management must be fully integrated at all levels of the department operations for all incidents, including:

•a single IC;

•establishment of a command post where an overview of the entire incident is possible;

•proper delegation of authority and responsibility for tactical and task level activities;

•use of an appropriate strategy based on size-up of the incident;

•application of risk management principles;

•development of an IAP to organize the strategic- and tactical-level activities;

•effective management of resources;

•situational awareness to be able to respond to changing conditions;

•assignment of safety officer(s) within the command structure;

•control over incident communications so operational and emergency traffic can be heard, understood and responded to;

•implementation of an effective personnel accountability system so the status of crews and individual firefighters can be determined at any time and on a regular basis as the incident progresses;

•standardized procedures for operations involving multijurisdictional responses to maintain a unified command structure (Routley, et al., 2008, pp. 137-138).

Risk management should be integrated into the process of scene size-up to perform a risk/benefit analysis to determine the appropriate course of action for that particular set of circumstances.

Incident strategies should be appropriate for the situation based on the initial size-up of the event. The IC must also consider all factors related to the situation including the resources available and the department capabilities to determine whether an offensive strategy should initially be undertaken. If the resources and capabilities are not in place at the scene to effectively control the situation—such as an established water supply and capabilities for proper ventilation that can be coordinated for maximum effectiveness—the offensive strategy is dangerous and should not be undertaken. Most importantly, if conditions change, being trained to recognize those early warning indicators and changing the incident strategy from offensive to defensive is vital to the safety of the firefighters (Routley, et al., 2008, p. 138).

Firefighter safety issues outlined in OSHA and NFPA standards as well as currently accepted operational procedures that should be implemented by all departments include the following:

•Designate incident safety officer(s) at all working incidents.

•Maintain the integrity of each company or crew so that each company officer has direct supervision of the personnel in his/her charge as all members enter the building together, remain in contact with each other and leave the building together.

•Assign rapid intervention teams (or crews) to provide an immediate response to a firefighter in trouble inside the IDLH environment.

•Implement and use a firefighter personnel accountability system at all incidents to also account for off-duty personnel who may have responded and to help discourage freelancing on the fire scene.

•Train all fire department members in the procedures for maydays, including self-rescue and rapid intervention.

•Train firefighters in the concepts of crew resource management so they will be able to recognize and challenge situations outside the norm that affect safety (Routley, et al., 2008, p. 139).

•As noted, SCBA issues centered around the lack of an air management program as outlined in NFPA 1404. Better ongoing maintenance of equipment, training in its use and accountability for its state of readiness are necessary to ensure the safety of personnel (Routley, et al., 2008, p. 140).

•Radio communications were a challenge—not because the equipment did not function properly, but because communications were not used to properly distribute tactical operations onto separate workgroups that are monitored, making appropriate situational and accountability reports (Routley, et al., 2008, pp. 140-141).

•Training of personnel in both basic skills and command level duties lacked any type of performance evaluation to test the knowledge, skills and abilities of the members and how specifically to apply the principles of operational risk management (Routley, et al., 2008, p. 141).

•Fire department resources should be increased in the areas of on-duty manpower, apparatus staffing and equipment dispatched on incidents. Additional resources should be summoned in a structured manner so adequate manpower and apparatus are available ahead of the actual need, cutting down on reflex time. Truck company operations were lacking within the department as a dedicated function and should be emphasized in standard operations as these are key to successful ventilation, forcible entry and searching for victims (Routley, et al., 2008, p. 141-142).

•Mutual aid agreements should also include standardization of procedures, communication and equipment where possible to reduce the problems associated with interoperability between the departments (Routley, et al., 2008, p. 142).

•Advancing technology should be continually explored and exploited to improve safety, including more use of thermal imaging cameras, improving communication systems, firefighter accountability, prefire planning information management and positive pressure ventilation, etc. (Routley, et al., 2008, p. 142).

•Prefire planning of all business or high-hazard occupancies to identify risks should be expanded as an informational gathering tool to ensure situations are not blindly entered where there is little chance of a successful outcome (Routley, et al., 2008, p. 143).

•Code enforcement and risk mitigation must become part of the normal city activities through systematic inspections followed by corrective action. It must also be performed by qualified members who can communicate code enforcement issues to the appropriate bureau within the city for action. Proactive measures such as stricter requirements for installation of automatic sprinkler systems or other alternative protection systems should be supported at the local, county and state level (Routley, et al., 2008, p. 143).

•Coordination between affected agencies was identified as critical to successful outcomes. These included: the police department for traffic control and scene perimeters, the water department for hydrant placement, maintenance and water main adequacy, EMS and the building inspection division (Routley, et al., 2008, p. 144).

Epilogue

To date, the city of Charleston has set aside or spent more than $7.4 million as result of the Sofa Super Store fire. Most of this money is allocated directly to improvements of the fire department. The money is being drawn from funds budgeted since the fire, emergency reserves and private donation of $228,000 by local businessman Gene Reed to purchase compliant uniforms. It has caused the city's first tax increase since 1999.

J. Gordon Routley, leader of the Charleston Post-Incident Assessment and Review Team, told reporters from *Charleston Post and Courier* that this should send a message to other fire departments and elected leaders who oversee them (Menchaca & Smith, 2008). A Phase 3 report is expected at some future date that will focus on strategic implementation of the recommendations. It is expected that complete implementation may take up to 5 years (Laws, 2008, p. 65).

A detail of the expenditures released under a Freedom of Information Act request showed about $3.6 million is to be spent on staffing, equipment and training for the fire department; about $1.8 million on purchase of the Sofa Super Store property to erect a memorial; $1.2 million to supplement state workers' compensation benefits to the families; and $320,000 for the fees of the panel that investigated the incident. The legal fees and fines to settle the alleged safety violations cited by OSHA totaled about $76,500 not including city legal staff expenses. Posttragedy counseling services for the firefighters and the memorial service conducted came to nearly $270,000 and $62,000, respectively (Menchaca & Smith, 2008).

In addition, nationally noted Fire Chief Thomas Carr of the Montgomery County, MD, Fire and Rescue Services was named by Mayor Joe Riley and confirmed by the Charleston City Council to take over the position as Fire Chief for the City of Charleston. ■

References

Federal Emergency Management Agency (FEMA), U.S. Fire Administration (USFA) & National Fire Academy (NFA). (1991). *Managing company tactical operations: Preparation* (MCTO-P instructor's guide). Emmitsburg, MD: Authors.

FEMA, USFA & NFA. (2004). *Strategy and tactics for initial company operations* (STICO student manual). Emmitsburg, MD: Authors.

FEMA, USFA & NFA. (2005). *Preparation for initial company operations* (PICO student manual). Emmitsburg, MD: Authors.

FM Global. (2008). Storage of Class 1, 2, 3, 4 and plastic commodities (Loss Prevention Data Sheet 8-9). Johnston, RI: Author.

Foley, S.N. (Ed.). (1998). *Fire department occupational health and safety standards handbook* (1st ed.). Quincy, MA: NFPA.

Hall, R. & Adams, B. (Eds.). (1998). *Essentials of firefighting* (4th ed.). Stillwater, OK: Fire Protection Publications.

Insurance Services Organization (ISO). (2005). ISO's public protection classification (PPC) program. Jersey City, NJ: Author. Retrieved from http://www.isomitigation.com/ppc/0000/ppc0001.html.

International Code Council. International fire code. Washington, DC: Author.

Laws, J. (2008, Aug.) The lessons of Charleston. *Occupational Health and Safety, 77*(8).

Menchaca, R. & Smith, G. (2008, May 29). Review, changes costly in Charleston. *The Post & Courier/Firehouse.com*.

NFPA. (2002a). Standard for fire department safety officers (NFPA 1521). Quincy, MA: Author.

NFPA. (2002b). Standard for installation of sprinkler systems (NFPA 13). Quincy, MA: Author.

NFPA. (2004). Standard for the organization and deployment of fire suppression operations, emergency medical operations and special operations to the public by career fire departments (NFPA 1710). Quincy, MA: Author.

NFPA. (2006). Standard for fire service respiratory protection training (NFPA 1404). Quincy, MA: Author.

NFPA. (2007). Standard on fire department occupational health and safety programs (NFPA 1500). Quincy, MA: Author.

NIOSH. (2009, Feb. 11). *Death in the line of duty: Nine career firefighters die in rapid fire progression at commercial furniture showroom: South Carolina* (Investigation Report #F2007-18). Morgantown, WV: Author, Firefighter Fatality Investigation and Prevention Program.

Routley, J.G., Chiaramonte, M., Crawford, B., et al. (2007, Oct. 16). City of Charleston post-incident assessment and review team: Phase 1 report. City of Charleston, SC: Author.

Routley, J.G., Chiaramonte, M., Crawford, B., et al. (2008, May 15). City of Charleston post-incident assessment and review team: Phase 2 report. City of Charleston, SC: Author.

South Carolina Department of Labor, Licensing and Regulation, Office of Occupational Safety & Health (SC OSHA). (2007, Sept. 20). Report of SC OSHA Findings in June 18, 2007, Charleston Sofa Super Store Fire. [Press release]. Columbia, SC: Author.

Memorial Planned

According to a May 27, 2009, story by David Slade in the *Charleston Post & Courier,* a plan submitted to the Charleston City Council calls for the site of the Sofa Super Store to be redeveloped as a memorial, a training and education facility, and a new fire department headquarters. The conceptual plan was the work of a 28-member commission formed by the city. The commission's recommendation calls for a garden-like outdoor memorial with individual markers for each fallen firefighter. The 25,000 to 32,000 sq ft building would include space for firefighter training, public education programs and a new headquarters for the Charleston Fire Department.