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Removing Smoke from Big Box Building Fires

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Abstract

This applied research project addressed a concern that existed in the Richmond Virginia metropolitan fire departments including Chesterfield County Fire and Emergency Medical Services. A metro group created a Standard Operating Guideline describing how to handle commercial "big box" fires. However, the group was unable to determine a safe method to ventilate them. Using the descriptive method, this research investigated what methods are currently used to vent these structures, safety factors that officers consider when sizing up these incidents, and alternative methods to vent them. Recommendations include enhancing the metro pre-plan process, and injecting a specific timed benchmark at these incidents. Also, appropriate use of a crane or excavator to vent a building is detailed in coordination with suppression activities.

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Introduction

In recent years, several firefighters in the United States have died while fighting fires in "Big Box" (large un-compartmented floor area) type structures. The Chesterfield Fire and Emergency Medical Services (CFEMS) Department, in conjunction with other Richmond Metropolitan fire departments, recognized that many such structures exist in the metropolitan area. Therefore the metro departments have created a regional standard operation guideline (SOG) on fighting fires in "big box" structures (Appendix A).

In previous incidents, the inability to safely and timely remove smoke, and superheated unburned fuel gases, from these fire buildings has been identified as one of the contributing factors that led to the deaths of firefighters. The regional big box committee was unable to provide guidance on how to safely ventilate big box buildings with light weight roof construction. To prevent firefighter deaths, guidance needs to be given to fire officers on making effective fire ground ventilation decisions at these fires based on situational realities.

The purpose of this research was to provide appropriate information to fire officers. This information will enable them to manage these incidents utilizing ventilation to their advantage. This research utilized the descriptive research method. The research project included the use of a survey, and interviews with professionals in fire engineering and other disciplines, to address research questions necessary to shed light on the problem.

Several research questions were identified to help identify potential solutions to the research problem. These questions included: (a) what are some of the effective methods being utilized by building owners/occupants and the fire service for removing smoke from big box buildings, with lightweight roof construction? (b) What are the safety factors considered by fire departments in determining whether and how to ventilate a big box building, with light weight roof construction? (c)

What methods from disciplines outside of the fire service would provide the safe removal of smoke and superheated gases from big box structures, during firefighting operations? (d) When faced with a big box structure on fire, what are the key variables that a fire officer needs to analyze to determine the best method of ventilating smoke from the building?

Background and Significance

The loss of 9 career fire fighters in Charleston, South Carolina on June 18, 2007 sparked great concern in the fire service (Slepicka, 2008). Many of these buildings exist in each of the Richmond, Virginia metropolitan jurisdictions. These Richmond area buildings range in age from the 1870's to still under construction. They also have a wide range of construction style and type. One result in the CFEMS Department was the renewed interest in the dangers that big box buildings present to responders during fire fighting operations. Simultaneously, the CFEMS Department began to take stock of the big box structures in Chesterfield County and to begin discussions with the other fire departments in the Richmond metropolitan area. Many of the buildings in the Richmond metro area contain fuel loading similar to the sofa warehouse that burned in Charleston. The Richmond area departments have all experienced similar commercial fires. More often than not, the result of these fires has been the destruction of the building and contents. The area departments anticipate more of these fires in the future. The idea to create one "Big Box Standard Operating Guideline", for the metropolitan fire departments to all use, was born in the metro operations chief's quarterly meetings.

A committee of members from each department was organized, and worked for eight months to devise a common guideline that each department is to follow when dealing with a big box building on fire. During the research for this guideline, the committee found a tremendous number of suggested methods to address fires in these buildings. However, a method to safely and effectively remove smoke and superheated gases from these structures remained a mystery. The guideline shown in Appendix A does not include recommendations on how to ventilate significant smoke and gases from the building. It does recommend that if a significant fire exists in one of these buildings, the officer should evacuate the building and assume a defensive posture. This is due to the dangers that these fires present to fire fighters. The main dangers identified are flashover, backdraft, and building collapse. All of these dangers could be better controlled if the buildings could be effectively ventilated.

The committee consisted of two representatives each from the Richmond, Henrico, Hanover, and Chesterfield fire departments. Each member was able to recount training efforts at large buildings that have not gone well. These training endeavors have included firefighting operations and "firefighter mayday" simulations necessitating firefighter rescue attempts. In Chesterfield one department wide training effort in a warehouse was conducted in the mid 1990's. In that effort, rope tag lines were used to help locate and rescue a down firefighter. The result of that training effort was the virtual loss of many fire fighters in their attempts to save others. Henrico and Richmond conducted wide-area search training, using rope/tag line techniques, for large floor area (big box style buildings) and these resulted in fire fighters being put into virtual jeopardy. In another Chesterfield department wide training endeavor, a big box size store was utilized to conduct firefighting operations with long hose stretches and difficult floor layouts. This also resulted in virtual loss of fire fighters.

Fortunately for Chesterfield, most of the larger commercial buildings have fire protection sprinkler systems. The experience of the CFEMS department is that most of the fires that occur in these buildings are controlled by the system, and the fires are held to be relatively minor. However, these incidents usually involve cold smoke throughout the building. Often very few openings exist to move smoke out of the building. Usually the sprinkler system must be shut down before visibility begins to improve. To safely do this, and ensure the fire does not gain headway, fire fighters must be near the seat of the fire with readied hose lines. Therefore, they must often work their way deep into large buildings with limited or no visibility. At one restaurant fire a CFEMS department truck company lieutenant was injured at such an incident. He led his crew into the second floor of this building without a hose line or tagline. He ran out of air and was lucky enough to happen upon another officer that was able to move him from the building utilizing a buddy breathing technique. This lieutenant suffered smoke inhalation, and was hospitalized, but fully recovered and returned to work.

One ten year study of firefighter deaths indicates that those that die inside burning structures are usually killed by being caught or trapped inside the building. Once detained inside these buildings, they die from exposure to heat or smoke. Of the 173 deaths occurring inside buildings studied, 113 resulted because the firefighter was caught or trapped. To avoid being trapped by fire and superheated gases in smoke, the firefighter must understand how fire and heat spreads. Fire and heat can spread in concealed spaces, in hallways as occupants exit buildings leaving doors open, and generally in any direction that it does not meet a non-combustible surface. Heat and smoke will usually travel vertically through heat pathways and horizontally via conduction. “Venting saves firefighters’ lives and can prevent flash over and backdraft when timed correctly” (Dunn, 1996, p.22). In other research, the National Institute for Occupational Safety and Health studied fifteen fire incidents that occurred in truss construction buildings between 1998 and 2003. Twenty firefighters were killed in these fires. For sixteen of the fatalities, the event leading to the deaths was roof collapse (NIOSH, 2005).

If this research project is successful, it will provide Richmond metropolitan fire officers with guidance of how to safely ventilate big box buildings. A look outside of the normal fire service resources may lead to alternatives not considered in the Richmond area to this point. Once complete, the results of this research can be added to the Big Box Metropolitan SOG, and an appropriate training package can be created and delivered to area fire officers. In the future, the end result will be more positive results in fighting fires in these buildings. The fires will be managed at a moderate size, and the safety of the fire fighters and building occupants will be greatly improved.

This topic relates directly to the content of the National Fire Academy's Executive Fire Officer Program course titled Executive Analysis of Fire Service Operations in Emergency Management. In the Community Risks / Capability section of this course, assessment of risks of both the community and the fire agency is explained. The inability to remove smoke and super-heated fire gases from any of the Richmond metropolitan big box structures can be categorized as a critical risk. Fires in these occupancies are critical risks because they currently tax metro fire agencies beyond their ability to safely extinguish them and protect the public. Another component of the course describes developing resources. This research also targets developing resources, previously not considered for use by the metropolitan fire agencies. In the future, these resources will be ready to assist in smoke removal from big box buildings on fire.

This issue also addresses the United States Fire Administration's (USFA) 2009-2013 Strategic Plan. Two of the goals of this plan are to (1) Improve local planning and preparedness and to (2) Improve the fire and emergency services' capability for response to and recovery from all hazards. (Strategic Plan, 2009). Obviously, if this research leads to the Richmond metro fire service agencies addressing big box fires more safely and effectively, these USFA goals will be assisted.

Literature Review

The primary reason to ventilate a building on fire is to save lives by removing heat and smoke from occupants. Other reasons include to reduce fire growth and spread, and to allow hose crews to safely reach the fire. For interior hose crews to effectively attack a fire, they must gain proximity to the fire within 50 feet. In large buildings, this can be very difficult if smoke conditions are moderate to heavy. To allow safe interior firefighting, ventilation of the roof is desired. With ordinary construction, usually roof crews have time to safely conduct this operation (Dunn V. , Venting Burning Buildings, 1997).

A historical review of fires in large buildings paints a story of fire fighter fatalities decades deep. In 1910, 13 firefighters and a police officer were killed in a leather warehouse fire in Philadelphia. That same year 21 firefighters died in a meat packing plant in Chicago (NFPA, 2009). In 1954, 10 firefighters were killed during a chemical explosion in a warehouse in Philadelphia. Many of the older buildings were made of ordinary or heavy timber construction. Fires in these buildings came with the hazards of heavy fuel loading, chemical storage or hazardous manufacturing processes, occupants/workers to rescue, a building that will contribute to the fuel load and hold heat in, and an intense desire by the fire service to save property (Burns, 1968).

The modern large buildings contain many of the same hazards during fires with some additional realities. These include large floor areas, lightweight truss roof assemblies, high ceilings, and higher fuel loading in the buildings. These conditions result in rapid fire spread with limited ability to achieve timely vertical ventilation. To prevent future fire fatalities, personnel must be familiar with the buildings prior to the fire, and understand hazards associated with each one. This should be accomplished during regular pre-plan visits. A Standard Operating Procedure (SOP) should also be created to help guide decisions at such fires. This SOP should describe the hazards associated with these buildings, appropriate ventilation, use of thermal imaging cameras, and a solid accountability system. Once implemented, all personnel need to be trained on the use of the SOP and how to safely conduct rescue and suppression operations at such incidents. (3D Firefighting Safety Bulletin, 2007)

One study of NIOSH reports where 23 firefighters were killed, inside structural fires, determined the problem of disorientation to be a major contributor to the deaths. Conditions that lead to disorientation include “fire in an enclosed structure, aggressive interior attack or search, prolonged zero visibility, and hand-line separation or tangled lines" (Mora, 2003 p.3). The term enclosed structure is applied to buildings that have very few windows and doors so that prompt ventilation and or emergency evacuation is not feasible (Mora, 2003).

Factories, superstores, and warehouses usually enclose large open areas that often allow rapid horizontal fire spread. These buildings are often windowless with the exception of windows near the front entrance. Quick ventilation directly over the fire will often help to halt the lateral spread of fire in these buildings. However, fire fighters are warned that operating on lightweight truss roofs can be extremely hazardous. Usually truss components of these buildings are not protected from heat, and can warp and fail within minutes of fire ignition (Richman, 2008).

The most effective, and safest, interior firefighting operations occur when a ventilation opening is created directly above the fire, or high on an exterior wall opposite from the suppression forces entry point. This allows the hose stream to be applied onto the fire, and helps to push the combustion bi-products out of the structure. "Ventilation is the planned, systematic removal of smoke, heat and fire gases from a burning building" (Dunn, 1996 p.24). Benefits of ventilation include limiting fire spread, to allow crews to advance hose lines to the fire, and to save lives. Several incidents have shown that "firefighters advancing into a store where neither the roof nor the rear is effectively vented are, in effect entering the barrel of a loaded shotgun – if there is extension, they will receive the full effect of the blast" (Dunn, 1996 p.24).

The Charleston fire of 2007 was one example of many where a lack of ventilation contributed to the deaths of firefighters. However, it also pointed to the fact that ventilation is not a one size fits all concept. If ventilation openings are placed in the wrong place or PPV (positive pressure ventilation) is initiated without coordinating with the fire attack, the situation can be made worse and lives can me put in more jeopardy (NIOSH, 2009).

Many studies point to an understanding that in large span buildings, if interior crews encounter high heat conditions and cannot quickly find and extinguish the fire, they should immediately get out of the building. Allowing crews to continue on with a 15-20 minute search for the fire will end in disaster. If crews can quickly make access to fire over their heads, they should quickly operate large volumes of water into the ceiling area for a full one minute and then shut down the stream. If the fire pushes back at the crews, evacuation of the building needs to occur and a collapse zone should be quickly set up. In essence with modern construction, with modern fuel loading in a large span building, time is not on the fire fighters side. Once on scene of such a building fire, suppression forces must make a quick knockdown, or pull out and conduct a defensive operation (Jaehne, Clark, McCastland, Norman, & Smits, 2007).

Adding to the hazards of these buildings is the inherent danger of opening up the roof of a big box building. In May of 2001, the FDNY made it official policy not to cut metal deck roofs of light weight truss occupancies with an active interior fire. This is due to the hazards that firefighters face when conducting this tasks. Some experts speculate that the decision equates to automatically giving up the building. However, utilizing good size up practices, multiple points of hose stream application, other ventilation tactics and the safe roof ventilation of exposure occupancies, the FDNY maintains success at preventing conflagrations (Dunne, 2006). Along with the hazards of light weight steel failing early under heat conditions is the grave concern of how the metal deck is constructed and tied into the supporting bar joist (photo 1). With the wide supporting spans it is feasible that firefighters can make the first two cuts of a vent hole, and eliminate all support of a section of the roof. In this case, the firefighters can easily fall through the roof into the fire (Norman, 2005).

Truss construction is more vulnerable to loss of strength than heavy timber or ordinary construction. This is due to the lightweight nature of trusses and the large surface area of the truss.

Most steel truss systems have no fire protection. The “non-combustible” construction type incorporates these systems, and is thought by some to be fire safe. In reality, these steel trusses will elongate and twist at 1000 ^{o}F. Tests have shown that if a 100 foot length of steel is heated to 1000 ^{o}F it will expand an average of 9 ½ inches. During past large building fires, this expansion has caused roof failures and pushed out walls. If heated to 1300 ^{o}F steel can totally fail and cause cascading collapse. These temperatures will often be reached with the fuel load that is housed in large buildings, and the high surface-to –mass reality of lightweight steel assemblies leads them to absorb the heat quickly. This situational reality is associated with the thermoplastic properties of steel. With truss construction, the failure of one member of the truss can lead to the collapse of the entire truss. This can occur quickly from a combination of stress on the member, from roof loading, and being weakened by heat. The member can also be cut during ventilation operations of opening up the roof. These facts contribute to the likelihood of collapse under fire conditions. In fact, under fire conditions, the impact of a firefighter jumping from a ladder onto a roof with weakened bar-joist can be enough to cause localized collapse. Heavy steel I-beams can survive an hour of the standard ASTM fire test prior to failure. Light weight steel bar joists however have failed in seven minutes during this same test (Brannigan, 1982).

Buildings of yester-year were built to specific construction criteria. In essence they had good size lumber or steel supports and adequate weight bearing components. These buildings held up for awhile under fire conditions. Also, the average combustibles of yester-year produced 8,500 Btus per pound (Brennan, Fewer fires, but more flashovers, 2001). Today’s buildings are built to minimum performance specifications, and will usually stand up as long as normal conditions exist. Shaping steel gives it greater strength to hold loads under normal conditions. This shaping allows builders to construct lighter-weight buildings. In modern buildings bar joist truss and “C” beams are used where “I” shaped beams were used in the past. The Twin Towers of the World Trade Center utilized mostly shaped steel as the structural support. This support included tubular steel bearing walls, truss floor supports and metal floor systems. Reducing the mass of the steel allows building at less cost (Dunn V. , Steel Bar Joist Trusses and Steel C-Beams, 2008).

However, under fire conditions modern buildings fail quickly. Adding to this complication is the fact that the average pound of combustibles now puts off 17,000 Btus when consumed (Brennan, Fewer fires, but more flashovers, 2001). NIST fire testing demonstrated that plastic bins in a warehouse setting can easily put off over 40 megawatt (1megawatt or MW = 1,000,000 joules of energy per second) of heat (McGrattan, Hamins, & Stroup, 1998). Due to the increased heat production of fires involving modern petroleum based plastics and other building contents, building fires reach the flashover stage quicker than in the past. The result in commercial buildings with little compartmentation is fast vertical and horizontal fire spread. With the modern lightweight structural components, large buildings will experience partial or full collapse quicker than past fires. In these buildings, roofs and walls can collapse without warning. Generally the height of a truss system will equal to 1/8th of its length. As an example, a 100 foot truss span can be expected to be about 12 feet tall. The taller and longer the truss system, the more surface area exists which can lead to superheating. With tall and long truss systems, fire impinging on the system can easily be hidden by smoke conditions or by an inability to see much of the truss space due to building configuration. Often inside crews will report little fire, heat or smoke conditions, while exterior crews report heavy fire in the cockloft area. The incident commander must rely on the worst reports and make decisions accordingly. In the situation where fire is impacting the cockloft area of a large lightweight constructed building, it is not safe for crews to operate on or in the building. Some fire service professionals believe that firefighting crews can open up the roof in an attempt to prevent flashover, and remove smoke if it is positively identified that the fire is small and not impinging on the structure itself. If this is attempted, the crew needs to open the roof quickly and get off of the roof. If at all possible all roof work should be conducted from an aerial platform instead of standing on the roof (Jaehne, Clark, McCastland, Norman, & Smits, 2007). As stated, this conflicts with others that believe all fires in these buildings, which are not being controlled by a sprinkler system, can escalate too quickly so that roof top opening should not be attempted.

Lightweight-steel open web bar-joist roofs can be constructed with joist spacing of 4 to 8 feet apart. This and the failure characteristics of this construction make it extremely dangerous compared to ordinary roof construction. When attempting to cut one of these roofs, the roof deck can suddenly fall or hinge downward, allowing the firefighter to drop into the fire. The metal decking is often laid in three feet wide by twenty foot long panels. These 3 foot sections overlay each other in 6" areas with very few bolt connectors. Due to the wide spans, personnel can fall through the roof just by cutting the metal decking where it is not supported between bar-joist. Under fire conditions, unprotected lightweight steel bar joist roof construction can completely fail within 5 to 10 minutes. Many fire professionals believe that placing crews on the roof to ventilate these buildings should never be attempted (Dunn V. , Collapse of burning buildings, 1988).

The roof supports of a steel bar-joist building are often fewer in number than those of the floor supports. Buildings are engineered to be as light weight as feasible, and roofs are not designed to carry much weight. However, roof loading is often changed over time. During firefighting operations a live load of massive amounts of suppression water is also added to the building (Brannigan, 1982).

A commercial fire on July 15, 2003 claimed the lives of two Tennessee firefighters. Consistent with similar incidents, the NIOSH investigation of that fire described an early collapse of the roof trapping several fire fighters. In this case, a vent crew on the roof narrowly escaped injury when the roof failed (photo 1). The photo published by NIOSH with this investigation shows the surface area exposure to heat and the wide span between bar joist (NIOSH, 2004).

The National Institute of Standards and Technology (NIST) has been conducting the same standard furnace fire tests since 1918. These tests procedures only allow short sections of steel to be tested. While short sections meet standards, longer sections exposed to similar conditions often fail much earlier. The construction of many of the long span truss assemblies calls for protection of the steel from fire and heat. To meet these standards, builders have three common methods of protecting steel. Encasing steel in concrete provides the best method for protecting it from heat. Hanging a protective ceiling membrane below it often fails due to a lack of membrane integrity at the time of the fire, and spray-on fire retarding material has often not been maintained well prior to a fire. This renders it ineffective at protecting the structural components (Dunn V. , Steel Bar Joist Trusses and Steel C-Beams, 2008).

Effective ventilation is the key that allows effective, safe interior fire attack and extinguishment of significant building fires. When sufficient ventilation does not exist, fires will not burn cleanly due to a lack of oxygen. In these incidents, carbon and other more toxic incomplete products of combustion quickly build up inside of buildings. Vertical ventilation directly over the fire is by far the most desirable objective. This method removes the smoke prior to its ignition inside the building, and helps to limit the spread of the fire. However, in modern building fires, it is often not completed in a timely fashion, and often too dangerous to attempt. Many experienced truck company officers and chief officers advocate that it is too dangerous to attempt if the roof is constructed of lightweight steel construction. In some cases, removing skylights or roof scuttles may be safe and provide some ventilation. If necessary, horizontal ventilation can be attempted through windows or loading dock doors. Regardless of the exit holes for the smoke, PPV can assist to remove smoke in these situations. When utilizing PPV in a large un-compartmented area, an increased air volume must be achieved to be effective (Mittendorf, Truck Company Operations, 2006). When horizontal ventilation or PPV is initiated prior to adequate water stream application, the fire can intensify.

When confronted with a large building on fire that contains a sprinkler system the most likely result will be a small fire that is being contained and the necessity to deal with cold smoke. This is a dangerous situation, but is manageable with effective over-site of personnel. However, sprinkler systems are designed to code at the time of building construction to protect a specific occupancy load. When the fire occurs, the system may not be capable of confining a fire with the current fuel load in the building (Brannigan, 1982).

Many big box type buildings have smoke and heat vents installed in the roof. They are usually found in factories (group F) or warehouses (group S), or buildings with hazardous commodities (group H) but are not routinely installed in mercantile buildings. Usually curtain boards are also installed to help limit the spread of heat and smoke and to initiate early activation of these vents. These vents rely on the buoyancy and expansion of a normal burning process to activate early enough to be effective at limiting the spread of fire and smoke. The minimum size of each of these vents is four foot by four foot, and they can be operated by either a gravity-operated drop out mechanism or by manual activation. When mechanical smoke fans are used in these vents, they each have a maximum of 30,000 cubic feet per minute (cfm) capability. When used, in conjunction with a sprinkler system, these exhaust fans are configured to operate once the sprinklers activate. When exhaust fans are functioning at the roof level, make up air needs to be provided at the floor level. A minimum of 50% of the exhaust cfms should be provided for the make up air, and it should be uniformly distributed around the periphery of the fire area (International Code Council, 2002).

A debate among fire engineers and insurance experts has been brewing for decades. Some of these professionals believe that building ventilators in these buildings delay the effective operation of sprinklers while others believe the vent system is more important. They often disagree as to which should activate the fastest during a fire. Some advocate sprinklers working first and fear that smoke ventilators will feed the fire and cause it to grow beyond sprinkler system capabilities. One concern is that the ventilators will activate quickly and prevent a buildup of heat at the sprinkler head level, thereby preventing the quick activation of the heads. Others advocate smoke ventilator quick activation as smoke is the biggest threat to life and sprinklers often quickly spread steam and cold smoke that may inhibit escape of the occupants and ingress of firefighters. To prevent smoke from a continuous-growth fire from banking down into a structure, ventilation openings at the roof level must allow exhaust equal to the mass injection rate of hot gases in the fire plume. To achieve this, vent systems in factory and warehouse roofs are designed to formula based on intended commodity storage and group use (Heskestad, 1997).

One study conducted in Sweden concluded that automatic ventilator and sprinkler operation have no negative effect in warehouses with low to moderate stacks of goods, but that in high stack areas or in industrial settings, only manually operated ventilators with smoke curtain systems should be installed. Other research conducted in the UK and USA concluded that automatic ventilator operation did not significantly delay sprinkler operation, and it did significantly reduce the amount of smoke and heat at lower levels. These tests demonstrated a temperature without ventilation systems of three times that of fires conducted in buildings with such systems. Only those tests conducted without the ventilators resulted in temperatures high enough to distort steel assemblies that can lead to early collapse (Sice, 2004).

Only certain buildings are required by code to have smoke control systems. These generally include buildings with tall atria, covered shopping malls, high rise buildings, some underground buildings, and some stage areas. The most recent versions of the Uniformed Building Code and International Building Code have moved the requirements of these systems to be more performance based and less equipment specified (Muller, 2004). Either the engineered airflow design method or the engineered exhaust method can be fairly effective with maintaining clear exits in these buildings. However, such systems usually require splitting large areas into zones, and are not required in mercantile big box buildings (Evans & Klote, 2005). Smoke removal systems are great when they activate, or when personnel can activate them. However, a building engineer or manager is often needed to provide specifics on utilization of them (Lee, 2008).

Often buildings can be ventilated using built in construction features of the roof to create relatively easy openings in the roof. These include opening vent pipes, skylights, roof hatches, and ventilators. Plastic panels are sometimes used on roofs. These are usually very weak, and will not support much weight, so personnel must stay clear of these panels. They are often easily pried up, for ventilation purposes. Most buildings will have some roof construction features that can be used to initiate quick limited ventilation of areas of the building. Pre-incident planning is necessary to identify these features for use during fire fighting operations. Positive-pressure ventilation (PPV) can also be initiated to push more smoke through these openings. This technique uses a high-volume fan to pressurize the inside of a fire building. With higher pressure inside the building, smoke and fires gases are pushed from the openings that fire fighters create elsewhere in the building. In order to prevent fire spread, this tactic must be well coordinated, with opening up the building and with fire attack (Richman, 2008).

The Fire Department of New York (FDNY) fights many building fires each year. In 2008, that department handled 26,862 structural fires. That department does not cut the roofs of lightweight truss buildings due to the hazards this brings to firefighters. The FDNY does open up skylights and other existing features to quickly vent these buildings as much as feasible. The department has a difficult time knowing that a specific building has a roof system of lightweight construction, and may not find out until attempting to vent the roof. To help with decision making at fires, once a building is identified to have such a roof system, the dispatch center adds an alert to the dispatch screen for that building. This allows the dispatcher to warn personnel of the construction type when they are enroute to alarms at those buildings (Grimwood, 2008). Some localities have adopted legislation that mandates commercial building owners to place a placard on buildings that have truss roofs (figure 1). This information is used by fire officers when making decisions about suppression tactics in those buildings. Again, many experts agree that truss constructed buildings will fail quickly under fire conditions, and advocate that all fires in buildings with truss roofs, with no lives in jeopardy, be attacked defensively (Smith, 2008, p. 85).

However, some fire professionals do believe that roof ventilation can sometimes be accomplished on light weight constructed big box structures. The key to the safe opening up of these roofs is to do so remote from the fire, and to plan and execute the opening with a priority toward safety. The emphasis of this theory is to ensure the crews prepare escape routes, utilize inspection holes to keep track of fire extension, and to quickly open up remotely from the fire area (Mittendorf, Ventilation methods and techniques, 1989).

As opposed to a 20 minute rule utilized by fire officers of yester-year, many authors now advocate that successful fire suppression in modern buildings will only occur if the seat of the fire can be controlled within 10 minutes of arrival on scene. If this 10 minute timeframe is not met, statistics indicate that the building will most likely be lost, and that the safety of fire fighters working in or on that building becomes increasingly dangerous with each passing minute. Due to this reality, many departments have their dispatch center give the incident commander at working fires a time check every 10 minutes. Some departments utilize a 5 minute time check (Coleman, 2005).

While ventilating fire buildings is the safest and most effective method to allow interior firefighting operations, actually achieving effective ventilation can be very difficult in “big box” buildings. Since the mid 1970s most of these buildings are non-combustible type buildings with masonry walls and lightweight truss assembly roof structures. They have very limited openings normally consisting of windows on the front, a few man-way doors on the sides and rear and overhead receiving doors on the rear or side. The limited openings often negate effective horizontal ventilation, and creating large openings in truss roof assemblies is a dangerous tasks. Many fire service leaders now acknowledge that roof operations on these buildings is not feasible (Hines, 2001).

Flashover is considered by many to be the significant point in the lifespan of a structural fire. It is thought to be the point that conditions are untenable for firefighters in the room of origin, and the point that the rest of the structure and any occupants are at increased risk. Ventilation has to be bulky and quick enough to remove heat before a flashover occurs. Heat release rate (HRR) testing in the ISO 9705 test room shows a wide time range from room ignition to flashover of the other materials in the room. The materials range from 8 seconds for rigid polyurethane foam to 225 seconds for plywood walls, gwb ceiling, and mixed furniture to 803 seconds for FR expanded polystyrene foam (80 mm). The mean value for the heat release rate at flashover of the materials tested was 1975 kW (+/- 1060kW) (Babrauskas, Peacock, & Reneke, 2003).

To control fires, many buildings are mandated to have built in smoke management systems. These include all methods that can be used independently or in combination to control smoke movement for the benefit of occupants and fire fighters and for the reduction of property damage. These methods routinely built into buildings are smoke barriers, smoke vents, and smoke shafts (Klote, 1988). Emerging sensor technology, such as micro electro mechanical system (MEMS) and micro-chemical sensor arrays can be utilized in building systems to provide much more building status information and fire behavior information in the future. These systems can also integrate active building ventilation if configured to do so (Jones & Bukowski, 2001).

Many multi-story buildings have built in pressurized stairwells. This is designed to prevent smoke entering the stairwell allowing for occupant egress and firefighter visibility during access (Klote, 1988). Most of the builders of recent big box construction in our country have built type II non-combustible steel and masonry structures (Dunn V. , Strategy for Extinguishing Fire in Noncombustilbe Type II Buildings, 2005). To this point, the egress pathways in these buildings have not utilized such safety systems.

Since the mid 1970's thousands of big box style buildings have been built with no consideration of controlling smoke or heat during a fire. Most recently, designers have begun to place skylights on these buildings to provide lighting into the structures. One example is Wal-Mart Stores placing new skylights, with sun-tracking mirrors that dim lights throughout the store to save energy, on 2000 of their buildings (EERE Network News, 2006). A fortunate side benefit is the ability of fire service to quickly open these skylights during a fire situation.

The fire service routinely removes smoke from all types of burning structures. Conventional 16 inch electric smoke ejectors can move 5,200 cfms with larger fans moving more than 10,000 cfms. In addition, fog patterns from hose streams have been utilized to eject smoke from structures. An 1 ½ inch fog nozzle with an operating pressure of 100 psi has the capacity of moving 10,000 cfm of air, and a 2 ½ inch fog nozzle with the same pressure has the capacity of moving 30,000 cfms (Clark, 1991). This is more air than that of conventional electric fans. Portable master streams can flow three times the volume of water as that of a 2 ½ inch line (up to 1000 gpms), and therefore should be able to move more air than the handheld hoses can.

Fire experiments were conducted in an old high school by the National Institute of Standards and Technology (NIST) during the fall of 2008. The test was designed to study the effects of PPV on structural fires. However, six tests were conducted inside of a 340,080 cubic foot high school gymnasium. Although the roof structure included concrete, the size of the gymnasium correlates well to big box structures. During these experiments, a fuel package of pallets, excelsior and mats were ignited in the middle of the gymnasium floor and allowed to burn for 9 to 14 minutes prior to opening up two exterior man-doors or one door size opening in the roof (each door opening was 21 sq. ft.). With each experiment, as the exit door(s) were opened, PPV fans were started in the front of the gymnasium. During these experiments, the heat release ranged from 2.5 MW to 56 MW (NIST, 2008).

The results of these tests showed that, with a ventilation opening, PPV assisted with reducing the temperature inside the gymnasium, and kept the spread of fire and smoke out of the rest of the structure. It also showed that the larger truck mounted fans did a much better job than the portable ones did at confining the fire and smoke. When only the roof vent was opened, the value of using the truck mounted fan was not realized. It was judged that the roof opening would have to be four times larger or 84 sq. ft. in area to take advantage of the effectiveness of the truck mounted fan. One interesting finding was an unexpected flashover that occurred in the gymnasium (even with the limited fuel being burned). This occurred when both PPV and vertical ventilation was occurring (Kerber, 2008).

Procedures

Fire officers faced with a big box building containing a significant fire have limited options. Beyond the literature review, original research was conducted with fire based agencies and other disciplines. This research was conducted in an attempt to give fire officers more information on which to base tactical decisions.

A survey was sent to fire service personnel in an effort to identify how fire service professionals will handle this issue in their area (Appendix B). This survey was designed to capture a snapshot of the fire service understanding of the hazards of big box building fires and of the management of these incidents. It was designed to gain some insight into three of the four project research questions. In essence the survey asked questions to identify how professionals in the fire service currently view the dangers of big box buildings with light weight truss roof construction, and methods they currently would use to vent them during a fire. Questions were also designed to elicit information of what professionals consider to be key factors in the decision making process while managing a big box fire.

The survey was field pre-tested prior to distribution. The survey was taken by several Richmond metro personnel to validate understanding and retrieval of substantive content. After receiving feedback on the survey format, and viewing initial responses, three of the five survey questions were altered to ensure feedback of appropriate concepts. During the rewrite, open ended questions were added to elicit new concepts from respondents. The survey was taken by a few more metro personnel with better results.

The final survey was posted on SurveyMonkey.com from December 20, 2008 through February 20, 2009. On December 20, 2008 a link to the survey was placed on the website of the National Society of Executive Fire Officers, and a request went out to the members to link to the survey on SurveyMonkey.com. Also, a request went out to the members of the NFAED2004 yahoo group to link to the SurveyMonkey.com site. At the time of the request, the yahoo group had 230 members. At the completion of the survey 178 fire professionals had provided a response. These responses were all viewed for frequency information. A few of the questions were cross filtered looking for any correlation of thought or unanticipated results. A few of the respondents also provided additional documents from other fire departments. These were also studied looking for new information.

As discussed, an assumption made in this research is that big box buildings cannot be quickly and safely opened up, using standard fire service operations. This was reinforced by the literature review. An interview was conducted with a fire protection engineer with NIST to address how much smoke needs to be removed from such a structure (D. Madrzykowski, personal communication, March 23, 2009).

In an attempt to help identify the current methods being utilized by building owners/occupants and the fire service for removing smoke from big box buildings a certified fire protection specialist was interviewed. This interview focused on smoke removal systems in big box buildings, what specific codes require, and how sprinkler systems and smoke vents operate during a fire (F.J. Kinnier, personal communication, March 13, 2009).

Alternative methods to ventilate these structures were searched out in industries outside of the fire service. This was an attempt to identify what methods from disciplines outside of the fire service would provide for the safe removal of smoke and superheated gases from big box structures, during firefighting operations. Experienced professionals in the demolition industry and the military were interviewed about the possibility. An interview was conducted with the safety manager of a large crane company to determine the possibility of utilizing a crane for safe ventilation. This interview also led to an interview with an excavation company owner in the Richmond area. Finally, a military asset was considered as an alternative. Unfortunately, early research determined that the closest full time military assets for this type of work are located in Norfolk, Virginia. These assets are too far from the Richmond metro area to be of practical use for such an incident.

Results

To prepare for a fire in one of these structures, this research attempted to determine how much heat and smoke will be generated. This was thought to correlate with how much will need to be removed per minute. During discussions with the Fire Protection Engineer from NIST it was determined that studies so far have shown that the amount of heat and smoke being generated is an aggregate of several variables. This is determined by the type of fuel(s) burning, the amount of fuel(s) on fire and the surface area exposed for the burning process, the percentage of consumption (availability of oxygen and burn rate), and if a sprinkler system is cooling some or all of the burning materials. While NIST experiments have provided data on heat release rates on natural gas and some other specific commodities, it is unlikely one of these will be the only fuel burning at a big box building fire (NIST, 2008). Due to the many factors that affect the amount of heat and smoke generated in a commercial fire, a specific amount cannot currently be assured.

The objective of building ventilation is the prevention of heat build up that will cause the failure of the truss components or a flashover. Specifically, effective ventilation will halt the growth rate of the heat and smoke in the enclosed fire area in order to prevent either of these occurrences (F.J. Kinnier, personal communications, March 13, 2009). Tests, with controlled fuel loads, have shown that fires in these buildings generate 50+ megawatts (MW) of energy. In comparison, an average 20 square foot ventilation hole, utilizing natural ventilation, will only exhaust about 10 MW (D. Madrzykowski, personal communicaitons, March 23, 2009). With mechanical ventilation at the ventilation hole or PPV at ground level a much greater amount will be exhausted.

Understanding the status of a building's sprinkler system is a major determining factor to help make good ventilation decisions. Most warehouse or mercantile buildings with 12,000 or more square feet of non-fire separated space, constructed since the 1972 BOCA Building code, usually have a sprinkler system. Therefore, almost all of these buildings in Chesterfield, Va. have such systems, and the rest of the Richmond metro area has a mix of old and new construction.

When addressing one of these buildings on fire, the sprinkler system will usually be controlling the fire. However, depending on the type of sprinkler system, and the fuel load at the time of the fire, it may not extinguish it. If the occupancy type has changed hands since the building construction, a sprinkler system that was designed for light hazard occupancy may be attempting to extinguish a fire in ordinary or extra hazard occupancy. Even if the occupancy hazard is accurate, storage areas of specific commodities or manufacturing processes often change. In these situations, systems can be incapable of controlling a fire (F.J. Kinnier, personal communications, March 13,2009). Therefore, the fire fighting forces will be faced with cold smoke often filling the structure and obscuring the fire conditions inside the building.

The survey of fire service professionals resulted in 178 respondents (Appendix C). One question asked about departments having a safety concern with roof operations, on a big box building fire with a light weight truss roof. Of the 176 responses to that question, 154 respondents (or 86.2%) answered yes. Of the respondents that elaborated on this concern, 50 specifically used terms of early failure of the roof system or collapse. Obviously, many departments are extremely concerned. However, only 8 of the respondents reporting that their department does not perform roof operations on any building on fire with light weight truss roofs. A few others indicated that they will perform such work as long as the truss space is not involved in fire. Also, only 10 of the 178 responses indicated that their department had written guidelines on ventilating large buildings.

Of 176 respondents only 22 reported that they capture how to ventilate a building during their pre-planning efforts at large buildings. However, most of the respondents agreed that along with fire and smoke conditions, construction type was the most important critical factor to analyze when deciding on smoke removal methods.

When asked how they would remove smoke from a big box building on fire, 156 responded they would use PPV, also 141 advised they would activate existing exhaust fans. Although 86.2% have concerns about roof operations, over 62% (111 out of 177) said they would cut holes in the roof of these structures. In the comments section of the survey, many elaborated that they would seek to use natural openings on the roof (skylights, vent pipes, scuttle openings, etc) to provide quick vent openings.

Several explained they would use either large truck mounted fans, or airboats on trailers to provide powerful PPV. Several also stated they would seek out overhead doors to exhaust smoke through.

Working on the assumption that standard fire service ventilation practices may be too dangerous to conduct at a big box fire, alternative methods were explored in this research. Professionals in the construction and demolition industries were interviewed to gain insight to this possibility. The questions utilized for these interviews are included as appendix D.

The W.O. Grubb Crane Company has offices and equipment yards in Richmond Va., Fredericksburg Va., Portsmouth Va., and Baltimore Md. Mr. Charles Cooke is the company safety manager. During an interview with Mr. Cooke it was determined that the best piece of crane equipment for this use is an 80 ton crane. This crane is large enough to provide the needed service, and just small enough as to not need counter-weights that have to be carried to the site in a separate tractor-trailer. This crane has a 128' boom, with a cable that can reach the ground from any position. It was decided that for speed of use and for simplicity, the crane should be used without a lattice extension.

Several methods of how to use the crane was discussed. Use of a wrecking ball or other heavy device to break a hole in the roof or wall was discounted as too dangerous. It was decided that such gross impact to the structure could easily cause the structure to become unstable and lead to early collapse of the roof or wall assemblies. This would be counter-productive to the intent of making the structure safe for interior firefighting operations. Instead, it was decided that the best use of the crane would be to place a man-basket in service hovering just inches above the roof. The 4' by 4' man-basket would carry two firefighters equipped with ventilation equipment to the roof and provide them a stable platform, which is totally independent from the structure, to operate from. A safety analysis of this procedure with a 5:1 safety factor of basket weight leads to an assumed 3000 lb. work load. Given this load, with the 80 ton crane, no restrictions would exist on the crane's working height or angle when using the man-basket. Therefore, if the crane is set up at 35’ from the building, the ventilation crew in the man-basket could operate up to 55’ from the side of the building on the roof (90’ from the crane). This is shown on the “working range” chart assuming the boom operates at 40 degrees to clear the side of the building (drawing 2).

One concern with any method of firefighting ventilation is time. With the crane method, in a best case scenario, during a work day with an available operator at the equipment yard, W.O. Grubb can usually have an 80 ton crane on the road in 15 minutes from request of an emergent response. On nights, holidays and weekends it will take 1 ½ to 2 hours for the crane to leave the yard. The yard is located in Chesterfield County, and while the crane is slow, it can arrive at most areas in the county within 30 minutes. Some other areas in the metro area will involve a longer drive time. Once on site, it will take approximately 15 to 30 minutes for set up, paperwork, and communications review between the crane operator and the ventilation crew. Therefore, in a best case scenario, a ventilation crew can be hovering just over a roof an hour from request. Obviously, this response time can vary greatly. The time it takes for the ventilation crew to cut the hole would need to be added to the travel and set up time to arrive at a total time of actually completing the vent hole. Assuming an efficient crew with a fast opening up time of 15 minutes, the total time from request to completed ventilation could be 1 hour and 15 minutes to 3 hours.

Cost is also always a concern. The basic cost of an 80 ton crane is $500 for a delivery fee, plus roughly $265 an hour for working time including the crane operator and assistant. On nights and Saturdays the cost per hour can be multiplied by one and a half and on Sundays and holidays, they can be multiplied by two (C. D. Cooke, personal communicaions, March 13, 2008).

Part of the interview with Mr. Cooke centered on the best piece of heavy equipment available to help ventilate big box type buildings. This discussion led to consideration of excavators used by demolition companies. The Dwight Sneed Company was chosen as a contact for this research as it has a contract with the city of Richmond to perform demolition in the city.

Mr. Dwight Sneed Jr. of the Dwight Sneed Construction Company provided information on how an excavator can be utilized during a big box building fire. Mr. Sneed advised that for the purposes of ventilating a big box building on fire, a hydraulic excavator with a thumb in the 55,000 lb. to 65,000 lb. range would be the best choice. He advised against using this machine to ventilate a roof, as the operator would be working without seeing the surface, and damage to the structural integrity of the building would be likely. The most effective use of this machine would be for the operator to pull out pieces of the wall near the roof line. An experienced operator can perform this with precision, and can create a large hole within a few minutes of set up. If the construction of the building includes tilt-slab masonry walls, the operator will not be able to pull out specific holes in the wall. Instead, the operator will use the thumb to crumble the top of the wall and work down the wall from the top. This will not be as exact, and may cause instability of the roof section near the wall.

Most of the excavators operate on sites, with a few usually parked at the Ashland Va. company yard. Mr. Sneed advised that if an emergent request such as a big box fire is received, they will normally find the closest excavator to the incident, and pull it off of a job to respond to the fire. If a crew is working a site, the excavator will need to be taken down, and secured onto the low-boy transport vehicle to be ready to move. This will usually take about 30 minutes. Drive time will obviously be dependent on proximity to the fire incident. Once on site the excavator can usually be removed from the low-boy transport and begin work within 15 minutes. A demolition plan will need to be created and agreed upon prior to the beginning of picking apart portions of the wall. This plan will be predicated on the construction of the building, and fire location and conditions. In a best case scenario, a company foreman would arrive quickly, and ensure the creation of the demolition plan. On nights and weekends, one and one-half hours of response time can be added to this scenario. So, during normal work hours, an excavator may be on-location and working within an hour and 15 minutes, and at other times it can be expected to be functional in two and one-half hours or more.

The mobilization charge for the excavator is approximately $400. The per hour rate for excavator operations, including personnel, is approximately $140 and hour, and the company mandates a four hour minimum fee. Therefore, any such response should be expected to bring a bill of at least $1,000 (D.H. Sneed, personal communcations, March 16, 2009).

Finally, the survey of fire professionals shows the variables used by officers to determine the best method of ventilating smoke. Many professionals espoused the need to ensure a good size-up was completed in order to identify the true magnitude of the incident. Most agreed that the fire conditions and type of construction are critical factors in decision making. Many also agreed that life hazards and status of the suppression system and its effectiveness would be critical (Appendix C.)

Discussion

Over the years, fires in true non-combustible warehouse buildings built decades ago have led to the death of many firefighters. In these incidents, literally hours of firefighting and attempting to ventilate one foot thick concrete roofs eventually led to smoke inhalation deaths and often late collapse of the warehouse. While recent fires in large buildings have resulted in the similar tragedies, the deaths and injuries now happen within minutes of arrival on scene (Burns, 1968).

Prior to the 1970’s most construction of commercial properties was of ordinary type. Since then, most firefighter training references and training programs through the 1990’s advocated tactics to ventilate that type of construction. However, with the new construction, has come a new reality. The fire service leaders of today received their initial ventilation training years ago, and some are still not up to speed on the safety concerns that newer construction brings. This is one more reason that new department wide training initiatives along with a regional SOG be established for the Richmond region.

Although several tests have been conducted with both sprinklers and smoke vents in these buildings, some experts still differ over the advantages of having vents in place in the roofs of sprinklered buildings. Most now agree that sprinkler systems are needed, and they will be found in buildings constructed since the mid 1970s. The controversy is exactly how the sprinkler systems should operate with smoke removal systems. The challenge for the fire service responders is to have pre-identified all of the systems of a building, and to be ready to utilize them to their fullest advantage.

The U.S. fire service has a tradition of aggressive interior fire attack. During the Charleston Sofa Warehouse fire, interior crews noticed that the overhead trusses were red hot and were not able to apply water onto the trusses. Quick ventilation was also not possible in the enclosed building. In the future, these circumstances should be communicated to command quickly and evacuation take place immediately (NIOSH, 2009).

A recent NIST study corroborated NIOSH reports depicting flashover occurrence in big box buildings on fire. This study reinforces the understanding that attempted ventilation will often not prevent a flashover from occurring if a significant free burning fire exists in one of these buildings. It is also obvious that these conditions can occur within a few minutes of fire service arrival at such a fire. With the potential for a large volume of unburned fuel as part of the smoke inside one of these buildings, known fire physics and conventional tactics of venting high on a structure will be necessary to prevent flashover.

One concern is the concept held by some in the fire service that it is safe to perform roof operations on these buildings as long as the truss space is not involved in fire. Due to the smoke conditions (hot or cold smoke) it will often be impossible to be sure if the truss space is involved in fire. Therefore, alternative methods to ventilate these buildings need to be developed.

Information gathered about the use of a crane or excavator to vent these buildings is not conclusive. Use of either is not going to be a quick response initiative, and either will necessitate special considerations of set up on the fire ground. Of further concern, is the fact that most fire personnel are not familiar with the operation of these machines, and related safety concepts.

Some attention has recently been given to alternatives of opening up big box buildings. This includes the practice of having an elevated platform company practice and plan to open up these buildings high on exterior walls. This practice will allow for ventilation and for heavy fire flow into the cockloft of these structures. This also is not a quick job, and at this point, most fire crews are not practiced at it.

The results of this study did not reveal a specific rate of air removal necessary to allow safe interior firefighting to occur inside a big box on fire. Nor did the research determine a good formula to estimate this number. Some understanding of the desired quantity can be estimated using the understanding that each mechanical smoke roof vent may exhaust a maximum of 30,000 cfm. This would be the expected amount of air movement necessary to control a fire over a single area of high piled storage in a factory or warehouse.

The challenge of removing smoke from a big box on fire will vary at each building. However, two basic situations need to be considered. Buildings with working sprinkler systems, that can effectively control a fire, create a different set of circumstances from those without such systems. The Richmond area has a multitude of both of these types of buildings.

The buildings without effective suppression systems are often viewed as the most hazardous. The shear size of the buildings will often prevent easy access to fires allowing the fire to grow and involve the truss space. This can quickly lead to flashover and early collapse of the roof structure. Those buildings with systems will often create cold smoke throughout the structure. These systems may or may not totally control the fire. Therefore, personnel will often be required to enter these buildings in an attempt to reach the seat of the fire and assess the conditions. Either scenario can easily lead to an entry of several hundred feet. This attempt obviously, brings a danger of running out of breathing air, or getting lost or both in the building. To prevent firefighter injury or death during either of these situations, firefighting strategy and tactics should be developed, communicated and implemented in a very controlled manner.

Overall, a complication of conditions makes it much more difficult and much more unsafe to fight fires in big box buildings than in most other structures. Also, some of the techniques that firefighters have been successful with in the past or in other types of structures are unsafe acts in these buildings. Now crews are often reaching the buildings just prior to flashover conditions occurring or the roof beginning to fail (Brennan, Fewer fires, but more flashovers, 2001).

Much has been documented about light weight construction and big box buildings on fire. Upon study of past incidents, it is evident that several known hazards converge in these incidents making fires in these buildings extremely hazardous to both occupants and firefighters. Due to the hazards and the inability to quickly ventilate these buildings, when an active fire in one of these buildings cannot be quickly extinguished, the only safe alternative is to conduct a defensive attack (Norman, 2005).

Recommendations

More experiments with various methods of ventilating commercial structures should take place. These should be designed to demonstrate the impact of vertical ventilation vs. horizontal ventilation. These experiments need to also include various types of PPV or hose stream hydraulic ventilation. From these experiments and the close study of how ventilation occurs in large building fires, a more specific set of tactics can be determined. This set of tactics should then be incorporated into future fire service instructor's manuals concerning general fire fighting principles and ventilation.

Recognizing the varied hazards that these buildings present marks the beginning of enhancing the safety of firefighters. Once the hazards are understood, incident commanders must be ready and willing to alter strategies and tactics of firefighting forces in order to safely approach these incidents. Behaviors that need to be employed include: Early declaration of a fire inside an "enclosed structure", a thorough size-up including an immediate thorough view of all sides of the building and the roof (utilizing thermal imaging technology), a determination and incident wide declaration of the type of roof construction, attacking fires utilizing the shortest possible path not necessarily from the unburned side, establishing a strong RIC capability before any entry, taking a strong safety posture including limiting on-air time of crews and bringing them out of the building well before they run out of air, finally coordinating the ventilation of smoke and superheated gases from these structures with all other incident activities.

In Survey Question 3 responses many professionals reported that roof operations may be initiated as long as the truss space is not involved in fire. How an incident commander is to know this fact is not well understood, as no questions addressed the size-up factors of the interior of the building. In future study, how to effectively size-up the incident should be explored further. As this type of construction is now prevalent, this body of knowledge needs to be expanded upon.

While it is not exactly clear yet of the best method or timing of PPV use it is clear that when used appropriately the more air introduced into the building the better. Therefore, the Richmond area should explore the purchase of either an air boat or large trailer mounted fan. This equipment could be used for numerous fires, and a boat could be used by any of the metro water rescue teams.

The research design chosen was not flawless. Some changes should be considered prior to future studies on this topic. During the literature review, it was obvious that many light weight commercial buildings that do not meet the definition of “big box” present most of the hazards that big box buildings do. Therefore, the focus of future research should be on all commercial buildings with light weight truss construction, not just big box buildings. Also, when constructing the next survey, using ambiguous terms like big box should be avoided as they lead to various interpretations.

Several of the recommendations listed in the Charleston NIOSH report are proactive. These include requiring sprinkler systems in all commercial buildings, requiring the use of automatic ventilation systems in large commercial buildings, and improving the communications systems utilized by fire service personnel (NIOSH, 2009). As soon as feasible, each locality should adopt these recommendations.

To date many experiments have been conducted attempting to identify the best use of sprinkler systems and ventilators. This is still not clear and more research needs to be conducted to verify which of the studies is most accurate. It is possible for this future research to provide fire officers with the best practice to protect people and large buildings (Sice, 2004).

Specific to Richmond metro fire departments, the pre-plan process should be altered to capture the type of roof construction of the buildings. This information needs to be captured in the computer aided dispatch system of each jurisdiction and it needs to be announced by the dispatcher while resources are enroute to alarms at the buildings. As well, the pre-plan process should include a description of ventilation methods to be employed with each building along with a picture of the roof.

As discussed, it is not safe for crews to open up metal roofs above a fire in a big box building. In order to achieve this in the future, aerial platform companies need to be practiced and ready to open up the walls near the roof of each building in their district. A commitment will need to be made by each department to train personnel on this skill. This needs to be considered during each pre-plan visit, and added to the pre-plan process.

Much more is understood about these situations and the dangers of fires in these buildings today than just a few years ago. This is somewhat due to the work being done at NIST in the new Large Fire Research facility, and through the study of actual fires that have occurred in such buildings. However, the totality of the convergence of hazardous factors does not appear to be well understood by many in the fire service. To ensure the reality is well understood, a comprehensive training package should be created and delivered to all fire departments in the country. This could be delivered by the USFA working with each state's office of fire programs. This package should include all of the hazardous factors associated with a building fire of this type, and a complete set of appropriate strategy and tactics. This training initiative will need to address both sprinklered and non-sprinklered buildings. To be most effective, the program should address fires in all commercial buildings with light weight construction.

Due to the dangers of firefighters working on the lightweight truss roofs of most of these buildings, use of alternative heavy equipment, such as a crane or excavator, should now be one more tool in the incident commander's toolbox. Each situation will include a myriad of items to be considered, leading to decisions on strategy and tactics to be deployed. Keeping the costs and lead time to performance in mind, the incident commander at a big box may wish to have an assistant check on the availability of one or both of these resources. The timely availability of this option will vary by the time of day and location of the incident. These resources will normally take well over an hour to be placed into service, but may be the safest option in some situations.

Recent fires and experiments point to the likelihood that extreme smoke and unburned fuel will be generated within the first hour on scene. As many of these buildings contain large fuel loads, the potential for flashover to occur in the building, as long as enough oxygen exist to sustain free burning, is great. In all of the fires reviewed, for this research, neither flashover nor backdraft occurred until the buildings were opened up at ground level. Several fire investigations detailed that the fire at roof level violently increased only after ceiling was pulled and oxygen was introduced into the upper regions of the building. One tactic at a significant commercial fire, unexplored to this point, is to close the building up tight until vertical ventilation can be accomplished. During the time it takes to safely ventilate the building, suppression forces can be readied to perform either an offensive or defensive attack according to conditions once effective ventilation is completed. Experiments should be conducted using this tactic, with various types of PPV being included in the trials. Depending on the results of such experiments, the use of cranes or excavators may become more desirable.

From the results of the research it is apparent that the Richmond Metro Big Box SOG should be amended. The SOG should include a mandated decision point if an offensive attack is initiated. This decision point can naturally be inserted into the SOG when the first interior crew is called out of the building at 12 minutes. At that point, the incident commander must determine if ALL size up indicators agree that the fire is under control? If there is any indicator that the fire is getting larger, or involves the truss area at all – All personnel should be removed from inside of or on top of the structure. A defensive operation should then be set up with collapse zones.

More specific research should be conducted in the future. Research should be focused toward the use of current technology including detection devices and video imagery to provide future fire officers with an improved size-up capability. Other research should dwell further into the use of sprinkler systems with ventilation systems, and put the controversy to rest. This will help lead to better codes and safety buildings in the future.

One day suppression systems may put out every fire and size-up technology will give incident commanders a very clear picture of all conditions. Until then the commanders of big box fires will need to err on the side of safety. For the safety of all involved, fires in these buildings need to be ventilated in coordination with fire attack and rescue efforts. A firefighter dying in one of these buildings, while trying to save property is no longer acceptable.

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Photo 1: This shows the light weight steel roof construction type of the commercial warehouse building that claimed the lives of two Tennessee fire fighters on July 15, 2003. (NIOSH Reference TN-12993)

Figure 1: Truss Placard

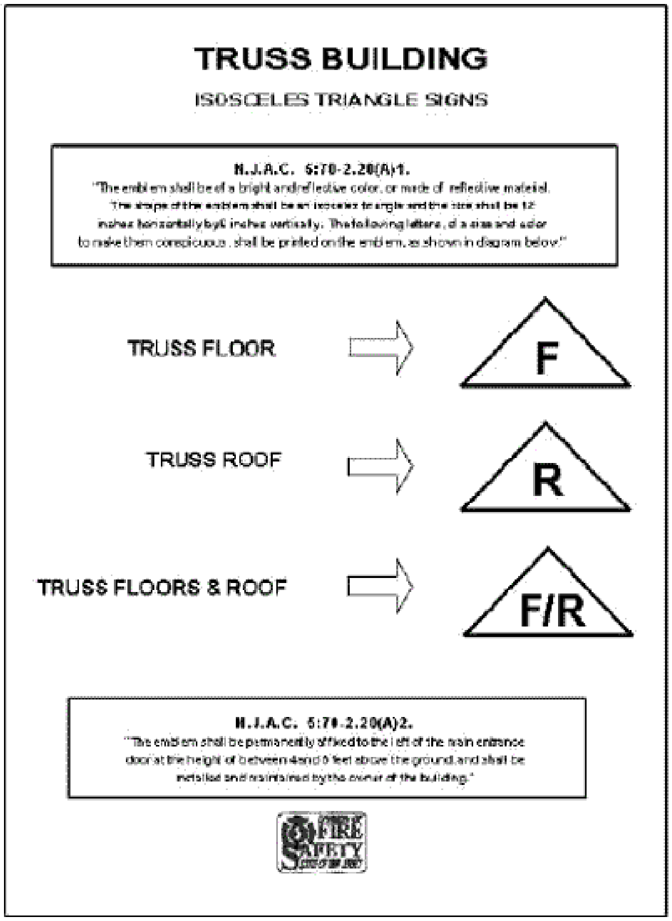

Figure 2: 80 ton Crane Working Range Chart