BRFRS Fire Fighting Strategies and Tactics:

Are They Safe?

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CERTIFICATION STATEMENT

I hereby certify that this paper constitutes my own product, that where the language of others is set forth, quotation marks so indicate, and that appropriate credit is given where I have used the language, ideas, expressions, or writings of another.

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Abstract

Despite the fact that the modern fireground had evolved due to changes in product materials, building construction and resulting fire behavior, the firefighting strategies and tactics implemented by Boca Raton Fire Rescue Services (BRFRS) personnel had, for the most part, remained the same. The problem was, the Department had not evaluated the safety of the strategies and tactics implemented by its first arriving Company Officers at structure fires. The purpose of this research was to determine the strategies and tactics these officers would employ during initial operations at structure fires, assess the frequency with which both safe and unsafe strategies and tactics were implemented, and identify safety related areas of improvement. Using Descriptive research, this project attempted to determine the strategies and tactics first arriving Company Officers would employ at structure fires, the frequency with which both safe and unsafe strategies and tactics were employed and any areas of potential safety improvement. A literature review was conducted to identify and gather information on trends in safety issues related to firefighting strategy and tactics and the impact that modern product materials, building construction and fire behavior had on strategic and tactical safety. An on-line survey was used to determine the strategies and tactics Company Officers would employ, given various structure fire scenarios. Results showed that while in some cases those strategies and tactics were safe, there was room for improvement. As a result of these findings, it was recommended that the Department (a) provide specific training on topics that impact strategic, tactical and general fireground safety and (b) review and revise Department policy and procedural guidelines as necessary to support safe and effective fireground operations.

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The dynamics of the modern day fireground, like many other facets of life, have changed dramatically over time. These changes include the increased use of plastics and other synthetic materials in the manufacturing of home contents and finishes as well as an increased reliance on lightweight, engineered components in home construction and renovation (Peterson, 2009). As a result, today's structure fires burn hotter and faster and today's structures are prone to earlier collapse (Kerber, 2012).

Life safety, including that of the firefighter, is the number one priority in incident management (U.S. Department of Homeland Security [USDHS], 2010). In order to adhere to this doctrine while conducting fireground operations, it is essential that fire service strategies and tactics are adjusted in response to the changes in product materials, building construction and resulting fire behavior (Kerber, 2012; Peterson, 2009). The problem is, the Boca Raton Fire Rescue Services (BRFRS) department has not evaluated the safety of the strategies and tactics implemented by its first arriving Company Officers at structure fires. The purpose of this research is to determine which strategies and tactics first arriving BRFRS Company Officers employ during initial operations at structure fires, assess the frequency with which both safe and unsafe strategies and tactics are implemented and identify safety related areas of improvement. Through the use of Descriptive research, the questions to be answered are (a) given scenario based structure fire information, what strategies would first arriving BRFRS Company Officers employ? (b) given scenario based structure fire information, what tactics would first arriving

BRFRS Company Officers employ? (c) Based on current product material, building construction and fire behavior data, what is the frequency in which both safe and unsafe strategies and tactics are employed by first arriving BRFRS Company Officers? and (d) What changes can be made to improve safety?

Background and Significance

BRFRS is an emergency response organization that provides Fire Suppression, Emergency Medical, Fire Prevention and Education and Special Operations (Hazardous Materials, Confined Space / High Angle Rescue, Marine related emergencies) services in the city of Boca Raton. The city is located on the South East coast of Florida, covering 29.6 square miles, with an approximate population of 84,000 full time residents. This number intermittently increases due to business community members commuting to the city for work and the fact that the city is a year round tourist travel destination. The city is also home to Florida Atlantic University (FAU), one of the largest universities in the state of Florida.

Transportation infrastructure running through the city includes Interstate 95 (Miami to Maine), the Florida East Coast (FEC) and CSX Railroads, transporting both passengers and freight, and the Intracoastal Waterway, an inland marine commuting option for vessels seeking protection from the sometimes extreme elements of the ocean. Air travel options are also available as the city contains one executive airport.

The Boca Raton Fire Department began in 1925 with a combination of volunteer and paid on call members operating out of the then City Hall facility. Financial compensation, for those who qualified, was 4 dollars per fire and 2 dollars per training drill. As the once quiet city and its demands for emergency services grew, so too did the Fire department.

Today, BRFRS is comprised of an approximate 200-member force, including Operations personnel, Chief Officers and Administrative staff. Eight fire stations strategically located throughout the city are staffed with 45 – 49 operational personnel working 24 hour shifts. Combined, the stations house 10 Fire Suppression apparatus and 12 Medic Units. The number of in service (staffed) Suppression and Medic units fluctuates with the demands for service at any given time. One station houses a Special Operations truck, two stations house Brush Trucks with wildland and aircraft fire suppression capabilities. A 28' boat with fire suppression and EMS capabilities is also manned as necessary.

The ability of BRFRS to safely and effectively respond to fire related emergencies is influenced by many factors. Internal factors include firefighters' training, experience and familiarization with the structures they respond to. External factors include changes in product materials, building construction and resulting fire behavior.

Entry-level firefighters hired by BRFRS possess a variety of levels of training and experience, ranging from no prior fire fighting experience to having worked many years with other busy Fire Rescue departments. However, at a minimum, candidates must possess state of Florida Fire Fighter II and Paramedic certifications in order to apply for employment with the Department.

Training and safety go hand in hand (Dodson, 2007). Once hired, recruits spend approximately two months in basic refresher training covering fire fighting, EMS, vehicle extrication and other skills. At the end of the two-month refresher training, they are assigned to shift work and actively participate in all fireground operations.

Non-probationary firefighters also possess a variety of levels of training and experience, ranging from one year to over 30 years on the job. Regardless of time on, all non-probationary personnel receive the same training provided by the Department's Training and Safety division. As in the case of recruit training, due to competing interests, training time must be divided between many disciplines, including fire fighting, EMS, vehicle extrication, hazardous materials and many more.

Fire related training involving fire behavior and tactics such as attack, ventilation and search and rescue are provided approximately every two years. This training is conducted using a mobile trailer unit consisting of propane-fed props inside a steel trailer. These props are controlled by instructors and simulate a stove-top fire, mattress fire and rollover effects. Live fire training using real structures is not provided by the Department. Attendance of this type of training outside of the scope of employment with BRFRS is, for the most part, at the discretion of the individual employee.

BRFRS responds to approximately 16,000 calls for service annually (City of Boca Raton, 2013). Approximately 70% of these calls are medical in nature. In 2012, of the balance of approximately 5,000 calls, 31, or less than 1%, were coded as building fires by personnel reporting to the National Fire Incident Reporting System (NFIRS). This is consistent with the average of 33 building fires per year that occurred during the ten-year period from 2003 to 2012. These range from room and content fires to major conflagrations involving both residential and commercial structures.

The fire service needs to have building knowledge prior to the event of an emergency (DeCrane & Murphy, 2012). However, other than a select few target hazard properties, firefighter familiarization with buildings in the city of Boca Raton prior to a fire event is, for the most part, limited to the exposure they get when responding to calls for service or conducting other routine duties. Pre-plan and building inspections are not required for single-family residential properties. Due to budget, staffing, training and other related matters, the Department's formal building survey program, which previously required firefighters to familiarize themselves with commercial properties through site visits, is not currently active. Inspections of commercial properties are completed by Fire and Life Safety division personnel. Any pertinent training and safety matters related to their findings are passed on to Operations division firefighters via verbal or written communication. At the discretion of Chief Officers, significant issues can be addressed by requiring those firefighters to visit the site in question for familiarization.

While firefighter familiarization with the buildings they respond to has decreased, the changes in product materials and building construction components and techniques has increased. Product materials found in home furnishings and other contents in the 1920s and 1930s were generally composed of wood, cotton, leather and wool. These materials have now, for the most part, been replaced by plastic, synthetic fiber, foam and other engineered products, resulting in fires that burn twice as hot as those involving the older, legacy era products (Angle, Gala, Harlow, Lombardo & Maciuba, 2008). Large dimension lumber has been replaced by lightweight structural components such as roof and floor trusses in the construction of new homes and renovation of existing structures, resulting in earlier structural collapse during fire events (Peterson, 2009).

Despite the limitations on BRFRS firefighters' training, experience and building familiarization, most members, from upper-level administration to recruit firefighter, would consider the Department to be an aggressive, interior attack fire department. In the past, BRFRS Company Officers have implemented strategies and tactics that require firefighters to engage in aggressive interior operations while working on the fireground. These actions are consistent with current department SOPs and training. However, this culture and resulting behavior, combined with the fact that modern-day fire behavior and the fireground in general have become more volatile, suggests that an increase in future fireground injuries and deaths is possible.

The National Fire Academy's (NFA) Executive Analysis of Fire Service Operations in Emergency Management course curriculum is designed to "prepare senior fire officers in the administrative functions necessary to manage the operational component of a fire department effectively" (USDHS, 2005). The operational problem identified above can have a significant impact on the life safety of BRFRS firefighters and the organization as a whole. These facts are the motivation for conducting this Applied Research Project (ARP) to evaluate the safety of strategies and tactics implemented by first arriving BRFRS Company Officers at structure fires and identify any potential areas of safety-related improvement. The results of this effort will serve to support United States Fire Administration (USFA) operational objectives by improving the Department's professional status and ability to safely and effectively respond to fire related emergencies.

Literature Review

The literature review for this project focused on the safety of fire fighting strategy and tactics and the impact current product materials and building construction have on firefighter life safety when working at structure fires. An initial review of firefighter line of duty death investigation reports determined the operational nature and circumstances, including strategies and tactics implemented, in incidents involving firefighter deaths on the fireground. The trends revealed from this study were the basis for further examination of the strategies, tactics and general safety elements found to be common factors in those incidents. Finally, a review of modern product materials and building construction provided information on the role those elements play as contributing factors in fire behavior and structural integrity during a structure fire event.

Incident Report Review

The National Institute for Occupational Safety and Health (NIOSH) is a division of the Department of Health and Human Services (DHHS) responsible for matters pertaining to safety and health in the American workplace (Department of Health and Human Services [DHHS], 2013). As part of its responsibilities, NIOSH conducts investigations of all firefighter line of duty deaths. Once these investigations are complete, a report is published summarizing the details of the incident including the nature of the scene, actions taken by on-scene personnel, factors that contributed to the firefighter(s) deaths and recommendations on how to prevent future similar occurrences.

For the purposes of this ARP, reports for the ten-year period from 2002 to 2011 were reviewed (DHHS, 2013) to identify trends in firefighter deaths that were related to firefighting strategies and tactics. This review revealed a total of 71 incidents that occurred in which 109 firefighters were killed while operating at structure fires. In 90% of these incidents, firefighters were conducting offensive interior operations including search, rescue, locating fire and advancing hose lines for fire attack. The remaining 10% of these incidents occurred during defensive operations.

In 82% of these incidents, there were no civilian victims present in the involved structures. Civilian victims were reported to be or known to be in the involved structure in the remaining 18% of these incidents. In all, 2 civilians located and removed by firefighters conducting interior search, rescue and fire fighting operations, survived these incidents.

Factors that contributed to 108 of these firefighter deaths included rapid fire progress and structural collapse. Rapid fire progress, including flashover (38%), flashover as a result of ventilation (22%) and wind related flashovers (4%), was a contributing factor in 64% of these incidents. Structural collapse, including failure of roof and floor truss assemblies, walls and other components attached to the structure such as awnings or other decorative elements, was a contributing factor in 36% of these incidents. Hazardous energy claimed the life of 1 firefighter when he walked into a downed power line while walking around the exterior of an involved structure.

The firegrounds where these deaths occurred involved various types of occupancies and structures. Single-family residential homes accounted for 58% of these incidents while multi-family residential occupancies, including high-rise buildings, accounted for 10%. Commercial occupancies were involved in 32% of these incidents. These incidents also included structures found to be vacant (8%) and/or undergoing renovations (7%).

Strategic Considerations

One of the first priorities at all structure fires is the completion of a scene size-up (USDHS, 2010) . According to the International Association of Fire Chiefs (IAFC), a size-up, including an assessment of occupant survivability, must be conducted prior to formulating a safe incident action plan (International Association of Fire Chiefs [IAFC], 2013) . NIOSH concurs in its position that a size-up must be completed prior to beginning any firefighting efforts and continue throughout the incident (DHHS, 2009) .

In most cases, initial size-up is the responsibility of the first arriving Company Officer and should include a 360-degree visual assessment of all four sides (A, B, C, D) of the structure and hazards present. This includes an analysis of building construction and occupancy, life hazards, fire location, intensity and potential for growth and other tactical information. To be both accurate and comprehensive, the use of a Thermal Imaging Camera (TIC) is recommended for evaluating fire and heat conditions (Peterson, 2009) and the overall assessment should include an evaluation of both the area above and below the fire (Marsar, 2010). The information provided by this size-up is used by the Incident Commander in choosing to implement an offensive, defensive or combination strategy.

Ninety percent of the incidents studied occurred while firefighters were engaged in offensive operations. The offensive attack is the most commonly implemented strategy on today's firegrounds (Avillo, 2008). This strategy involves aggressive interior operations including search, rescue, fire attack, forcible entry, ventilation and other tactics occurring simultaneously in coordination with one another. This strategy is deployed when the number of on scene personnel is sufficient and fire conditions are such that an aggressive attack will result in rapid hazard mitigation and overall control of the incident.

The Incident Commander (IC) is responsible for overall incident safety, including firefighter life safety, on the fireground (USDHS, 2010). In the event that the implementation of an offensive strategy is not succeeding, the IC must demonstrate operational flexibility by being willing to switch from an offensive to a defensive strategy (Kline, 2012). Signs that a switch may be in order include delays in forcible entry, ventilation and/or fire location, smoke getting darker, more voluminous and pressurized despite water application, any indication of possible flashover or structural compromise and any problems establishing a continuous water supply (Avillo, 2008).

Ten percent of the incidents studied occurred during defensive operations. The implementation of defensive attack strategies upon arrival of fire companies is only indicated in approximately 1% of all fires (Avillo, 2008). This strategy involves application of water from exterior positions using large master fire streams in an effort to protect exposures (surrounding buildings) and extinguish the fire. This mode of operation is usually deployed when deep-seated or extensive fire involvement, inadequate number of personnel and/or insufficient water supply prohibit a safe offensive attack.

Between these two extremes, ICs have the ability to use a combination of strategies including offensive-defensive and defensive-offensive strategies (Avillo, 2008). An offensive-defensive attack strategy is used when both fire attack and exposure protection are required simultaneously. Defensive-offensive attack strategies are deployed when first arriving fire companies encounter heavy fire conditions that prohibit immediate entry of the structure or require additional personnel to safely combat. An example of this is the "transitional attack" used by the Colorado Springs Fire Department in which firefighters begin initial fire suppression from the exterior of the structure to reduce further fire progress (Schwarz & Wheeler, 2009). Once fire conditions and/or the number of on-scene personnel allow, firefighters move in to offensive positions to completely extinguish any remaining fire. In extreme cases, due to the extent of fire and/or volatility of materials burning, the IC may choose not to attack at all, allowing the fire to consume the hazardous materials and burn until there is no more fuel to feed the fire (International Fire Service Training Association [IFSTA], 2008).

Tactical Considerations

In the fatality reports reviewed, the most common tactics implemented when firefighters were killed on the fireground include search, rescue, locating fire and advancing hose lines for fire attack. In each of these cases, firefighters encountered deteriorating conditions due to rapid fire progress and/or structural collapse that lead to them becoming caught, trapped lost or disoriented. According to a National Fire Protection Association (NFPA) study, while the overall reduction in number of annual firefighter deaths parallels the reduction in number of structure fires, the rate of firefighter deaths, has increased (Fahy, 2010). Since the mid 2000s, the average number of annual firefighter deaths, due to becoming caught or trapped by rapid fire progress or structural collapse, has increased while the average number of structure fires per year has remained relatively constant.

Consistent with the fact that life safety is the number one incident priority at structure fires, if the Incident Commander's size-up determines that there are potential, savable civilian victims in the structure, search and rescue operations for location and removal of these victims is one of the first tactical objectives to be considered at these incidents (USDHS, 2010). However, life safety considerations pertain not only to civilians, but also to firefighters. In order to enhance the safety of search and rescue operations, it is imperative that other tactics are implemented in support, and just ahead, of these efforts (USDHS, 2005). These support efforts include placement of charged hose lines between the fire and search group personnel, ventilation and creation of secondary means of egress.

Advancement of charged hose lines to the seat of the fire protects both the search group personnel and potential civilian victims they are trying to locate by reducing the advancement of fire. They also serve as a guide for firefighter escape if necessary. The tactical choices made in placement of initial charged hose lines have a major impact on both civilian and firefighter life safety. While some contend that initial lines should be placed between the fire and potential victims (USDHS, 2005), other factors must also be taken into consideration. Wind speeds as low as 10 mph can have a significant impact on fire behavior (Kerber & Madrzykowski, 2009). Hence, wind conditions, including speed and direction, should be considered part of the initial scene size-up and included in determining initial line placement (Barowy & Madrzykowski, 2012). When interior operations are required to locate and attack the fire and wind conditions are such that they will have an impact on fire behavior, initial suppression efforts should be anchored on the windward (upwind) side of the structure (Garcia, 2011).

Conducting interior operations to locate and attack the seat of a fire can be one of the most dangerous actions taken at a structure fire (Dunn, 2012). Hidden fire can pose a severe hazard to firefighters searching for its location (Brannigan, 2008). These actions often require firefighters to advance deep into a structure while navigating through high heat and heavy smoke conditions. Advancements in modern personal protective ensembles (PPE) and self-contained breathing apparatus (SCBA) allow firefighters to progress farther and faster through these hazardous environments (Dunn, 2008). However, this equipment does have limitations. Hence, one additional factor to consider in initial line placement, especially in larger commercial structures, is the distance from the firefighter entry point to the seat of the fire. Advancing initial attack lines from an entry point nearest the seat of the fire minimizes the distance firefighters must navigate in hazardous conditions, facilitates rapid retreat to safe zones and decreases the chance of firefighters becoming disoriented, lost or trapped by rapid fire progress (Parker, 2010).

When scene size-up reveals fire visible from the exterior of a structure, multiple attack options exist. Some maintain that even if fire is visible from the rear of the structure, the initial attack lines must be laid into the structure through the front door to protect interior stairs, corridors and other primary means of occupant egress (McCormack, 2006). Others contend that initial cooling and extinguishing efforts can be accomplished from the exterior of the building on the fire side (Nash, 2009). Tests conducted by Underwriters Laboratories (UL) on heat and fire behavior in both legacy and modern era residential homes revealed that when straight fire streams were applied to the fire room from the exterior, fire progress was reduced with no temperature increases recorded in other rooms of the structure (Kerber, 2010). Further, no fire was “pushed” through the structure and there were no negative impacts to occupant survivability.

Although attacking the fire from the fire side may require stretching initial attack lines to locations other than the Side A front door, these actions allow rapid knock down of the initial body of fire by reducing the need for firefighters to navigate through high heat, limited visibility interior conditions in order to locate the seat of the fire prior to extinguishment. This results in improved interior conditions for both potential civilian occupants as well as firefighters that need to enter the structure for additional operations (Schwarz & Wheeler, 2009).

Ventilation is another support function that must be considered prior to firefighters entering a structure for interior operations including search and rescue, fire location and fire attack (USDHS, 2005). As ventilation can have both positive and negative impacts on interior heat, smoke and fire conditions, multiple factors must be weighed in determining when, where and how to ventilate.

Positive ventilation impacts include the benefits to potential civilian occupants as well as firefighters operating in the structure through removal of heat and smoke from the atmosphere (Garcia, Kauffmann & Schelble, 2006). For civilians, the removal of products of combustion means an increased chance of survival. For firefighters, ventilation enhances the safety and efficiency of interior operations by reducing heat and improving visibility.

Although ventilation improves interior conditions, it can also have a negative impact on fire behavior. By allowing fresh air to replace the heat and smoke, ventilation of a structure can also serve to provide a ventilation-limited fire the air it needs to resume burning or burn more intensely (Kerber, 2012). This results in an increase in Heat Release Rate (HRR) and potential for rapid fire progress, such as flashover, to occur.

In addition to impacting fire intensity, ventilation can also influence the direction of heat, smoke and fire spread (Kerber & Madrzykowski, 2009). Openings made in a structure, including that of doors or windows during forcible entry, create flow paths through which heat, smoke and flames can spread. Hence, ventilation efforts should be timed and reversible whenever possible (Klaene & Sanders, 2008). They should also take into consideration the location of potential civilian victims as well as firefighters operating inside the structure. Finally, ventilation must be coordinated with the placement of charged hose lines to minimize fire growth and spread once the openings are made (USDHS, 2005).

The removal of heat and smoke can be accomplished by creating openings that allow these products of combustion to flow horizontally, vertically or in a combination of both directions (IFSTA, 2008) . Horizontal ventilation is accomplished by opening existing doors, windows or a combination of both. Decisions on where to create openings should take into consideration wind speed, direction and the flow paths that will result within the structure. Based on these factors, initial openings should be made from the exterior, at air exit points, allowing the release of heat and smoke from spaces impacted by fire. This should occur prior to the introduction of fresh air at an air entry point (Parker, 2010). When vertical ventilation is necessary, openings in the roof will be required. While this can be an effective means of releasing large amounts of heat and smoke, it is also time consuming, labor intensive and requires firefighters to work above the fire. Given the increased quantities of heat and smoke produced by today's fires, traditional-sized ventilation cuts may not be sufficient to achieve the desired effect (Garcia et al., 2006). Depending on the structure, fire progress and available personnel, creating roof openings large enough to release these products of combustion may be an unrealistic endeavor.

Removal of heat and smoke can be enhanced by using mechanical devices such as positive pressure ventilation (PPV) fans (IFSTA, 2008). However, while use of these devices expedites the removal of harmful products of combustion, it can also accelerate the burning process by increasing the volume and velocity of air being introduced to the fire (Smith, 2002). Therefore, the status of potential civilian victims, fire location and progress in fire control must be considered prior to implementation of these ventilation tools.

Creating a secondary means of egress by means of forcible entry or ladder placement provides firefighters with escape options in the event their primary means of egress is no longer available due to fire progress, structural collapse or other hazards. At ground level, this can be accomplished by opening doors or windows at strategic locations around the structure. On upper floors, alternative means of egress can be created with the raising of ground and/or aerial ladders (USDHS, 2005).

Once these tactical support considerations are addressed, firefighters assigned to Search Group are expected to begin a primary search in the area of the fire and work their way back to their point of entry, looking, listening and feeling for any signs of civilian life (Angle et al., 2008). This search should begin on the fire floor, followed by the floor above, the top floor and all other floors in the case of multiple story structures. The use of a Thermal Imaging Camera (TIC) assists in locating civilian victims and maintaining an awareness of the location of other crew members while searching. The use of a search line or charged hose line while conducting the search enhances the safety of this operation, though it is not always practical, given time, personnel and search pattern constraints (Smith, 2002). Search crews depending on protection from other charged hose lines must communicate that to personnel manning those lines prior to entering the structure. The practice of conducting search operations on the floor above the fire without a charged hose line can lead to firefighters becoming caught and trapped by fire progress and should be avoided (Dunn, 2008). In the case of occupied buildings, firefighters are expected to extend a high level of risk in their search for victims. However, minimal risks should be taken in the case of unoccupied buildings and no risk should be taken to search structures known to be abandoned or vacant (Angle et al., 2008).

General Safety Elements

Whether conducting search and rescue, searching for or attacking the seat of the fire or engaging in any other interior operations during a structure fire, firefighters must maintain a keen awareness of heat, smoke and fire conditions and the impact they can have on the environment and structure they are working in (IFSTA, 2008). Burning combustibles produce heat that is absorbed by the contents of the structure. When these contents can no longer absorb any more heat, they begin to off-gas products such as carbon monoxide (CO), without flaming. At this point, the smoke they are producing is flammable (Dodson, 2007). As the burning process continues, the temperature within the structure can rise to the ignition point of CO, resulting in an explosive ignition of these superheated gases (Avillo, 2008). Indicators that this phenomenon, known as flashover, is about to occur include the buildup of heat inside a smoke-filled room and intermittent fire mixed with smoke overhead or emanating from doors or windows (Dunn, 2001). When flashover does occur, it creates conditions that are most often fatal to civilian occupants in the area. Despite the protection that modern personal protective ensembles

(PPE) provide, when firefighters become caught, trapped or lost in these hostile fire events, they too have a low chance of surviving the untenable conditions that result.

Untenable conditions can also occur in the absence of active flaming (Dodson, 2007). The presence of dark black, dense, pressurized smoke is an indicator of impending flashover. This type of smoke, sometimes referred to as black fire, is capable of damaging and destroying contents by charring them, weakening steel elements by heating them and killing civilian occupants by burning and asphyxiating them. While some contend that it is acceptable for firefighters to enter areas of extreme heat when there is a potential for saving lives (Klaene & Sanders, 2008), others recommended that they refrain from operating in these areas until efforts have been made to ventilate and cool the environment (Dodson, 2007). By reducing heat and improving visibility, these efforts serve to increase the chances of civilian survival, minimize the chances of firefighters becoming lost or disoriented and improve the efficiency and safety of interior operations.

Whether you have high heat, heavy smoke, flames or all of the above, becoming disoriented, lost or trapped by hostile fire conditions is not the only safety concern for firefighters operating in and around a burning structure. According to some fire service and building construction experts, the building itself is the enemy when it comes to the safety of firefighters operating at structure fires (Brannigan, 2008). Structural elements such as roof and floor trusses and other building components are quickly weakened and subject to collapse when exposed to high heat and flames. The presence of prolonged high heat, heavy fire or heavy smoke conditions without adequate ventilation are all indicators that structural collapse may be eminent (Smith, 2002).

In the presence of heavy fire conditions, it is safe to assume that structural components of the building may be weakened. However, exterior conditions alone may not accurately indicate the extent of fire and damage occurring within a structure (Klaene & Sanders, 2008). Even in the absence of visible flames, voids and other hidden spaces allow accumulation of explosive CO gas and provide a path for rapid fire spread, increasing the potential for hostile fire events and structural collapse (Brannigan, 2008). Therefore, firefighters must always maintain a keen awareness of the conditions they are working in. Any indication that these events are eminent should prompt firefighters to evacuate the building (Terpak & Viscuso, 2012).

In an effort to prepare for the possibility that interior firefighters may become lost, trapped or otherwise need assistance while conducting interior operations, the Incident Commander should have a designated group of personnel standing by on the exterior, prepared to provide assistance (USDHS, 2010). Rapid intervention teams (RIT) or rapid intervention crews (RIC), are to familiarize themselves with the structure, including construction, means of egress and other pertinent features or hazards. These personnel are then staged in a strategic location with a full complement of rescue tools and equipment, including forcible entry tools, search ropes, lighting and SCBAs. In the event that interior firefighters need assistance, RIT personnel are activated by the Incident Commander and responsible for locating, supporting and removing the firefighters requesting help. Although these actions provide some hope for firefighters in need of assistance, these types of operations often require a considerable amount of time and personnel to locate and remove downed firefighters (Klaene & Sanders, 2008).

Product Materials

In the 1920’s and 1930’s, home finishes and furnishings were generally composed of natural materials including wood, leather, cotton and wool (Angle et al., 2008). Due in large part to economic and environmental concerns, these materials have been replaced by plastics, foams and other synthetics in products found in modern homes. As a result, today’s fires burn hotter and faster than ever before (Kline, 2012). While burning of natural materials commonly produces 7,000 – 8,000 british thermal units (BTUs) of heat per pound, burning of plastics and other synthetics can yield 12,000 – 18,000 BTUs of heat per pound (Dunn, 2007). Others estimate the amount of heat produced as a result of the combustion of these synthetics to be closer to 20,000 – 24,000 BTUs of heat per pound (Peterson, 2009).

In addition to an increase in heat production, these modern product materials are also responsible for an increase in the quantity and toxicity of smoke produced during the burning process (Peterson, 2009). When common household items such as televisions, computers, carpeting, mattresses, furniture, insulation and other materials burn, they produce large volumes of dense, black smoke containing toxic elements including CO and hydrogen cyanide (HCN). Even in incipient stage fires, the heat and smoke produced by the burning of these materials can be immediately fatal to unprotected civilian occupants (Sendelbach, 2011).

The increase in heat and smoke production each contribute to an increase in the overall hazardous conditions at today’s structure fires. However, the combination of these elements has a synergistic effect. In testing conducted by Underwriters

Laboratories (UL), two identical structures were outfitted with ordinary household contents and furnishings (Kerber, 2012). These included items such as televisions, chairs, couches, end tables, lamps, etc. Though the inventories in both rooms were the same, the actual products used were from two different eras. One room included items made from natural ingredients such as wood, cotton and wool commonly used during the earlier period referred to as the legacy era. The other room was outfitted with items fabricated from modern-era materials including plastics and other synthetics. When fires were started in both rooms in similar locations, the results displayed dramatic differences in fire behavior. The fire in the legacy-era room took approximately 29 – 30 minutes to reach flashover while the modern-era room was engulfed in flames in just over 3 ½ minutes.

Building Construction

The increased levels of heat production and volatility of fire behavior not only pose a threat to civilian occupants and firefighters inside a burning structure, but also have a major impact on the structural integrity of the components used in the building's construction (Klaene & Sanders, 2008). Similar to the case of modern product materials, economic and environmental concerns have had a significant impact on modern building construction elements and techniques (Hull & Stec, 2011). Due to shortages in supply and increased costs of obtaining large dimension lumber, the construction industry has shifted toward using engineered, lightweight wood components in the construction of new structures and renovation of older ones. Computerization of this industry has made the production of components that are both strong and lightweight possible (Parker, 2010). Examples of these types of components include the use of lightweight wood roof and floor truss assemblies and I-beams.

In the case of the roof and floor trusses, long nails have been replaced by gusset plates as a means of connection in their assembly. Gusset plates are typically stamped on to areas where different pieces of small dimension lumber come together, relying on their multiple protruding teeth to bind the pieces together. However, in most cases, these teeth only protrude a fraction of an inch (Klaene & Sanders, 2008). These components have a high surface to mass ratio and accumulate heat under fire conditions. This can lead to deformity of the metal and weakening or failure of the connection, resulting in potential collapse of the roof or floor truss assembly.

Wooden I-beams are constructed by joining top and bottom chords made up of 2" X 4" boards with plywood sheeting. However, engineered wood and composites such as laminated veneer lumber (LVL) and oriented strand board (OSB) are also used in their construction (Dodson, 2007). LVL, sheet veneers of wood glued and pressed together to form a piece of lumber, is used for the top and bottom chords. These chords are joined together using OSB, a type of sheeting comprised of wood chips and emulsified glue. Ambient heat alone can cause failure of both the binding glue within these materials as well as the glue used to assemble the components, without fire contact.

The use of engineered, lightweight wood assemblies has allowed modern structures to be built stronger, while also reducing construction time and costs (Kerber, 2012). Under normal conditions, these assemblies are structurally strong. However, as described above, when exposed to heat and fire conditions, they are prone to early failure and collapse (Smith, 2002). Tests conducted by Underwriters Laboratory exposed two unprotected floor systems to the heat of fire to test strength and endurance under heat and fire conditions. Similar to product materials testing, one system was considered legacy-era and was supported by 2” X 10” solid dimensional lumber. The other system was considered modern-era and was supported by .3m deep engineered wood I-joists. The floor systems were identically loaded with furniture and two mannequins, simulating firefighters. When subjected to heating, the legacy-era system supported its load for approximately 18 ½ minutes prior to collapsing. The modern-era system lasted 6 minutes prior to collapse.

The combination of changes in modern product materials, building construction elements and techniques have resulted in the potential for earlier flashover and structural collapse to occur during structure fires (Kerber, 2012). This reduction in time for safe interior operations at structure fires is a factor that must be considered by all firefighters, beginning with initial scene size-up and continuing for the duration of fireground operations.

Procedures

To conduct this Applied Research Project, a variety of procedures were implemented. These included a literature review on the safety of firefighting strategy and tactics and an on-line survey (see Appendix) of BRFRS Company Officers responsible for implementing these strategies and tactics at structure fires.

Literature Review

Between December 2012 and January 2013, NIOSH line of duty death investigation reports were reviewed in an effort to identify which strategies, tactics and other safety-related elements were common factors in firefighter fatalities on the fireground. Reports from the ten-year period 2002 – 2011 were examined (DHHS, 2013). Between January and March 2013, the information provided by these reports lead to further review of those strategies and tactics found to be common factors. Review of strategic considerations focused on scene size-up and initial attack strategies. Review of tactical considerations focused on search and rescue, fire suppression and ventilation. The balance of the review focused on smoke and fire behavior, modern product materials and building construction. This included a review of related books, trade journals and other published articles.

Survey

Based on information obtained from the literature review, in March 2013, an on-line survey was created consisting of multiple choice, structure fire scenario based questions. Question content was based on actual circumstances and factors found, through the review of NIOSH reports, to be common in firefighter line-of-duty deaths. The questions sought to determine the strategies and tactics that first arriving BRFRS Company Officers would employ at structure fires, the frequency in which both safe and unsafe strategies and tactics were deployed and any areas of safety related improvement. Strategy related questions addressed scene size-up and initial line placement. Tactic related questions addressed search and rescue, fire suppression and ventilation. Additional questions addressed general tactical safety issues including working above fire, the use of charged hose lines during interior operations and recognition and response to deteriorating conditions.

The target audience for this survey included all BRFRS Company Officers, working on fire apparatus in the rank of Fire Captain. In addition to 32 Fire Captains assigned to shift work in a firehouse, 2 40-hour Fire Captains and 7 firefighters qualified to act in the capacity of Fire Captain on fire apparatus were included in this pool. In March 2013, an email with a link to the survey was sent to a total of 41 personnel. The email provided information on the research being conducted and requested participants to contribute to the process by completing the anonymous on-line survey. Of the 41 recipients of this request, 39 completed the survey.

Limitations

The feedback provided by this survey includes that of personnel who are not full time Fire Captains. However, their participation was requested as they do periodically act in the capacity of Fire Captain and hence, are responsible for implementing strategies and tactics as first arriving Company Officers at structure fires.

Results

Questions from this survey were based on information provided in multiple structure fire scenarios. In an effort to maintain continuity of subject matter, the results are provided categorically by topic, rather than in numerical order.

Strategy

Three separate scenarios required first arriving Company Officers to choose between establishing command and conducting a 360-degree size-up or engaging in tactical operations without conducting a complete size-up as an initial action upon arrival at a structure fire (questions 1, 5, 14). In these three scenarios, an average of 88% of the officers chose to establish command and conduct a 360-degree size-up. Of the remaining 12%, 7% chose to conduct a quick attack while 5% chose search and rescue as their initial action taken.

The same scenarios then required the officers to choose a location for initial hose line placement. The information provided in these three scenarios indicated that the fire or other hazardous conditions were on Side C or otherwise toward the rear of the structure. Choices for initial hose line placement included the side A front door, the fire side or a flank attack. In the three scenarios (questions 4, 8, 17), an average of 58% of the officers chose to lay the initial hose lines to the side A front door. Of the remaining 42%, 38.5% laid their initial lines to a fire-side door or window, while 3.5% of the officers chose a flank attack.

In one of the three scenarios above, information provided in the question (number 8) pertaining to initial hose line placement described heavy smoke showing on side A of a two story residential townhouse with flames showing on the ground floor, Side C, winds of 10 – 15 mph coming from the Side C direction and time of day, 2100 hrs. The presence of civilian occupants was unknown. Given these conditions, 66 % of the responding officers chose to lay the initial hose line to the side A front door, while 34% chose to attack from the upwind side, C.

A fourth scenario indicated that a 360-degree size up had been completed, revealing a single-family residential home with heavy, black, pressurized smoke showing down to ground level throughout the home at 0530 hrs. Question 19 required officers to assess the probability of civilian victim survival in the structure, ranging from very high to very low. Of the officers responding, 78.9% indicated these conditions would result in a “very low” chance of survival and 21.1% indicated the chances were “low.” No officers selected the “moderate,” “high” or “very high” options.

Tactics

Four survey questions (number 2, 6, 15, 20) required officers to choose an initial action following the completion of a 360-degree survey of the scene. The action choices included search and rescue, fire suppression and ventilation. Ventilation was the initial action taken by an average of 55% of responding officers. Of the remaining 45%, 32% chose suppression and 13% chose search and rescue as the first action to take following size-up.

The percentages above represent an average result, given four different scenarios. Two of those scenarios provided information indicating the structures were unoccupied. One scenario described a structure with heavy black smoke showing throughout the home and did not indicate whether there were civilian occupants in the structure. When analyzing the results of the two story residential townhouse (conditions included heavy smoke showing on side A, flames showing on the ground floor, Side C, winds of 10 – 15 mph coming from the Side C direction, unknown if occupied, time of day, 2100 hrs.) in question 6 individually, the results revealed 18% of responding officers indicated the first action they would take following size-up would be ventilation while 40% chose suppression and 42% chose search and rescue.

Three survey questions (numbers 3, 7, 16) required officers to choose an initial method of ventilating the structure. Horizontal (natural) ventilation was the first choice of an average of 54% of responding officers. An average of 7% of officers chose vertical ventilation, while the remaining 39% chose a combination of horizontal and vertical, with or without positive pressure ventilation (PPV). Information provided in two out of three of the scenarios indicated that the location of the fire was not known. A separate analysis of the results of those two scenarios (questions 3, 16) revealed that an average of 26% of officers opted to use some form of PPV during initial ventilation efforts in those scenarios.

Questions 9 – 12 were also based on the two-story residential townhouse scenario (conditions included heavy smoke showing on side A, flames showing on the ground floor, Side C, winds of 10 – 15 mph coming from the Side C direction, unknown if occupied, time of day, 2100 hrs.).

Questions 9 and 10 explored the topic of working above fire while considering both safety and speed. Question 9 sought to determine the conditions under which officers would commit to working on the floor above the fire floor while conducting a primary search. Given the conditions described, 50% of responding officers indicated they would search the second floor prior to fire suppression and ventilation in an effort to expedite locating any potential civilian victims. Of the remaining officers, 21.1% chose to search after fire suppression had begun, prior to ventilation and 18.4% chose to wait until both fire suppression and ventilation efforts had begun. The option to not only wait for fire suppression and ventilation to begin, but to wait an additional 1 – 2 minutes after ventilation had been initiated was selected by 10.5% of the officers.

Question 10 sought to determine what tools and equipment, if any, officers would use while conducting the primary search on the floor above the fire floor. In an effort to expedite location of any potential civilian victims, 15.8% indicated they would conduct the search without using a rope/bag or charged hose line. Of those that did choose to use tools or equipment while searching, 39.5% opted to use a rope/bag to maintain a path of egress while 47.44% preferred using a charged hose line.

Questions 11 and 12 sought to explore the topic of recognition and response to deteriorating conditions. Question 11 indicated that fire suppression and ventilation had begun when the search team, operating on the floor above the fire in moderate-high heat, limited visibility conditions, reached the entrance door to a bedroom above the fire area and noted that the floor was increasingly spongy. Given these conditions, conducting a full search of the bedroom and the rest of the second floor was considered the best course of action to take by 2.6% of the responding officers. Conducting a limited search of the bedroom, without entering the room, by using a tool to sweep inside the doorway followed by a complete search of the second floor was considered the best course of action by 36.8%. The same limited search of the bedroom, followed by an immediate exit from the second floor was the choice of 26.3% while 34.2% chose to cease search efforts, exit the second floor and notify Command.

Question 12 also indicated that, following fire suppression and ventilation, a primary search was being conducted on the floor above the fire in moderate-high heat, limited visibility conditions. The information described an initial improvement in heat and visibility followed by the presence of dark black smoke banking down and a dramatic increase in heat as ventilation efforts continued. Given these conditions, conducting a limited search of the second floor prior to exiting the structure was selected as the best course of action to take by 7.9% of the responding officers while 94.7% opted to exit the structure and notify Command. None of the responding officers chose to conduct a full search of the second floor prior to exiting the structure.

Question 18 also focused on recognition and response to deteriorating conditions. The information provided indicated that initial attack efforts had succeeded in knocking down a fire inside an auto parts store, ventilation had begun and interior heat and smoke conditions were improving. However, as drop-ceiling tiles were pulled while checking for extension, dark black smoke began to bank down and heat levels increased dramatically. Given these conditions, 7.9% of responding officers chose to continue overhaul efforts and request a back-up line while 94.7% opted to exit the structure and notify Command. The option to continue overhaul efforts without taking additional actions was not selected by any of the responding officers.

Finally, question 13 explored the topic of conducting interior search operations while considering both safety and speed. The scenario information provided indicated the main body of a living room fire had been knocked down by first arriving suppression unit personnel. The question sought to determine the actions these personnel would then take with regards to conducting a primary search and ventilating the structure. In an effort to expedite location of any potential civilian victims, 13.2% of the responding officers indicated they would commence search efforts without the charged hose line. An additional 13.2% indicated they would search without the charged hose line and ventilate as they proceeded through the structure. The option to use a charged hose line while conducting the search was selected by 21.1% of the officers while 52.6% indicated they would search with a charged hose line and ventilate as they proceeded through the structure.

Discussion

The research conducted for this applied research project provided information on both firefighting strategic and tactical safety as well as the behaviors BRFRS may expect from its Company Officers in their implementation of strategies and tactics upon arrival at structure fires. As was learned, many variables have a direct impact on both fire behavior and structural integrity. The ability of the Company Officer to not only understand each individual variable but also comprehend the interrelation between variables when combined is critical to the life safety of all firefighters working on the fireground. The following discussion will examine the strategies and tactics BRFRS Company Officers chose to implement in an effort to assess the level of safety that may result from these choices.

In order to gain the most information possible in an effort to formulate a safe incident action plan at a structure fire, a 360-degree size-up should be conducted upon arrival, prior to engaging in firefighting operations (IAFC, 2013). This information assists in conducting an accurate risk benefit analysis of the emergency scene and helps determine the appropriate strategies and tactics based on the situation and available personnel. According to the on-line survey results, an average of 88% of the first responding Company Officers chose establishing command and conducting a 360-degree size-up as the first action they would take upon arrival at a structure fire. Of the remaining 12%, 7% chose to conduct a quick attack while 5% chose to begin search and rescue efforts prior to conducting a 360-degree size up of the structure.

Based on these results, the majority of the officers are proceeding in a safe manner. Their decision to gather critical scene-related information prior to engaging in operations will provide support for the choices they make in implementation of strategies and tactics on the fireground. The balance of officers who chose to engage in offensive operations without first gaining a more complete understanding of the hazards present put themselves and all firefighters on the scene at increased risk. In the event that these officers and their crews required assistance, other personnel would be called upon to help. This not only extends the risk, but also reduces the number of personnel available for other fireground operations, including providing assistance to potential civilian victims.

The placement of the initial hose line at a structure fire is influenced by multiple factors. Some contend the initial line should be laid into the side A front door to protect the primary means of occupant egress and stairs, if any (McCormack, 2006). Others argue that additional factors such as wind speed and direction (Barowy & Madrzykowski, 2012) as well as distance from the point of entry to the seat of the fire (Parker, 2010) should also be considered in the decision on placement of initial hose lines. In some cases, an initial exterior attack from the fire side may be the safest and most efficient option (Schwarz & Wheeler, 2009). The results of the on-line survey revealed that an average of 58% of the responding officers chose to lay the initial hose lines to the side A front door. Of the remaining 42%, 38.5% laid their initial lines to a fire side door or window, while 3.5% of the officers chose a flank attack. In a separate analysis of the results of the two-story townhouse scenario that indicated fire showing on the side C ground floor with winds of 10 – 15 mph coming from the side C direction, 66% of responding officers chose to lay their initial hose line to the side A front door while 34% preferred to initiate an attack on the upwind, fire side.

Despite the fact that all three scenarios pertaining to initial line placement indicated the fire and other hazards to be on side C, or otherwise toward the rear of the structure, a majority of responding officers chose to lay initial hose lines to the side A front door of the structure, even when wind was a key factor. These decisions would require personnel to navigate through potential limited to zero visibility conditions in an attempt to locate the seat of the fire, increasing the time to extinguishment. Fire intensification and spread during this period could cause an overall deterioration in conditions, posing an increased hazard to firefighters while also reducing the potential for civilian occupant survival.

In addition to visibility issues, the firefighters entry through the front door would require them to operate in the flow path of super-heated smoke moving from the fire location to their point of entry. According to testing conducted by NIST, even in the absence of wind, the increased velocities and temperatures in these flow paths can result in untenable conditions for civilian occupants and create hazardous conditions for firefighters on the fire floor (Kerber & Madrzykowski, 2009). With winds of 20 – 25 mph imposed, temperatures in the flow path exceeded 750 degrees Fahrenheit, a level not consistent with firefighter survivability.

Given these facts, there is room for safety-related improvements in deciding where to place initial attack lines. The Company Officer’s consideration of all pertinent size-up variables and available attack options will enhance the safety and efficiency of fireground operations. This will result not only in an increase in firefighter life safety but also an increase in potential civilian victim survivability.

Assessing the potential for survivability of potential civilian victims must be completed during the initial size-up (IAFC, 2013). Incident Commanders need to give ample consideration to the stage of fire progression, volume of smoke production and number of on-scene personnel prior to engaging in simultaneous aggressive interior operations such as search and rescue and fire attack (Marsar, 2010). Smoke from today's fires is capable of doing damage equivalent to that normally associated with direct flame contact (Dodson, 2007). Low visibility, high heat smoke conditions that progress to flashover can result in rapid temperature increases that far exceed the upper limits of human temperature tenability (Marsar, 2010). Given these conditions in the on-line survey, 78.9% of responding officers indicated that the probability of civilian survival would be "very low" while the remaining 21.1% described the probability as no greater than "low."

In this case, the majority of the responding officers' perceptions of civilian victim survivability were consistent with the literature on this topic. Although the automatic assumption, based on time and occupancy, that there are potential civilian victims in a structure has lead to many rescues, it has also lead to many firefighter deaths in structures where no civilians were ever found (Marsar, 2010). The ability of BRFRS Company Officers to accurately assess the potential for civilian survival in a structure fire will contribute to sound decisions based on risk benefit principles in the implementation of fireground strategies and tactics. This will enhance firefighter life safety by reducing the frequency with which unnecessary risks are taken in conducting search and rescue operations. By not using resources for unnecessary tasks, it will increase not only the number of personnel available to perform other mission-critical tasks but also the overall efficiency of fireground operations.

Although search and rescue efforts are a high priority at structure fires where there is a potential for civilian victims to be trapped, in situations involving advance stages of fire with high heat and heavy smoke conditions, tactics including fire suppression and ventilation should precede these efforts (USDHS, 2005). Execution of these tactics enhance the safety, efficiency and effectiveness of search and rescue operations. In the on-line survey questions in which Company Officers, given four different structure fire scenarios, had to choose an initial action following completion of size-up, ventilation was the initial action taken by an average of 55% of responding officers. Of the remaining 45%, 32% chose suppression and 13% chose search and rescue as the first action to take following size-up. Two of those scenarios indicated there were no civilian occupants in the structures. In a separate analysis of the two-story residential townhouse scenario (conditions included heavy smoke showing on side A, flames showing on the ground floor, Side C, winds of 10 – 15 mph coming from the Side C direction, unknown if occupied, time of day, 2100 hrs.), the results revealed 18% of responding officers indicated the first action they would take following size-up would be ventilation while 40% chose suppression and 42% chose search and rescue.

Based on these results, the majority of officers recognize the importance of ventilation and suppression at structure fires. However, despite the fact that these efforts can improve interior conditions for both civilians and firefighters, the officers are willing to engage in search and rescue efforts prior to implementation of these measures when size-up indicates there is a potential for civilian occupants to be present in a structure.

The choice to allow the fire to intensify and spread will lead to increased heat and smoke production and reduced visibility inside the structure. These conditions can increase the time required to locate civilian victims and hence, reduce the probability of their survival. For firefighters inside the structure, the increased probability of becoming caught or trapped by rapid fire behavior or structural collapse poses a threat to their life safety as well.

In addition to recognizing the importance of ventilation, Company Officers must have a thorough knowledge of ventilation methods and ramifications (IFSTA, 2008). Options for removing heat and smoke from the interior of a structure include natural horizontal and/or vertical ventilation. At times, the use of positive pressure ventilation (PPV) can be effective to supplement these efforts. However, as the introduction of air can contribute to fire intensification, location of the fire and any potential building occupants should be known prior to implementation of this method (Smith, 2002). Of the Company Officers responding to the survey questions that required officers to choose an initial method of ventilating the structure, horizontal (natural) ventilation was the first choice of an average of 54% of officers. An average of 7% of officers chose vertical ventilation, while the remaining 39% chose a combination of horizontal and vertical, with or without positive pressure ventilation (PPV). Information provided in two out of three of the scenarios indicated that the location of the fire was not known. A separate analysis of the results of those two scenarios revealed that an average of 26% of officers opted to use some form of PPV during initial ventilation efforts in those scenarios.

The majority of officers chose a ventilation method that would, in most cases, be both safe, effective and non labor intensive. In these cases, the officers would be able to meet their objective with the personnel available on scene while minimizing the risk to personnel conducting these operations. Although vertical ventilation is, in some cases, the most effective means of ventilating a structure, it is also time consuming, labor intensive and requires personnel to work on roofs that may be structurally damaged. The increased number of personnel required to accomplish this task reduces the number of personnel available to meet other fireground objectives. Further, the fact that firefighters are working above the fire level on a platform with unknown structural integrity increases the risk to firefighter life safety. As the use of PPV to supplement natural ventilation efforts can lead intensification and spread of a fire that has not been located, it too can pose an increased threat to the life safety of civilians as well as that of firefighters.

Under most conditions, the products of combustion will travel vertically until they reach a barrier and then spread laterally (IFSTA, 2008). When high heat and low visibility conditions exist, support efforts such as fire suppression and ventilation should precede search and rescue efforts (USDHS, 2005). When working on the fire floor or floor above the fire, the use of a charged hose line is recommended (Smith, 2002). In response to the on-line survey questions that explored the topic of working above fire while considering both safety and speed, 50% of responding officers indicated they would search the floor above the fire prior to fire suppression and ventilation in an effort to expedite locating any potential civilian victims. Of the remaining officers, 21.1% chose to search after fire suppression had begun, prior to ventilation and 18.4% chose to wait until both fire suppression and ventilation efforts had begun. The option to not only wait for fire suppression and ventilation to begin, but to wait an additional 1 – 2 minutes after ventilation had been initiated was selected by 10.5% of the officers. Of all responding officers, 15.8% indicated they would conduct the search without using a rope/bag or charged hose line. Of those that did choose to use tools or equipment while searching, 39.5% opted to use a rope/bag to maintain a path of egress while 47.44% preferred using a charged hose line.

In a separate on-line survey question, 13.2% of the responding officers indicated they would commence search efforts on the fire floor without a charged hose line, after knocking down the main body of fire, in an effort to expedite location of any potential civilian victims. An additional 13.2% indicated they would search without the charged hose line and ventilate as they proceeded through the structure. The option to use a charged hose line while conducting the search was selected by 21.1% of the officers while 52.6% indicated they would search with a charged hose line and ventilate as they proceeded through the structure.

In the structure fire scenarios where there was a possibility of civilian occupancy, the majority of Company Officers put a high priority on initiating search and rescue efforts. In their quest to save lives by searching the floor above the fire, half indicated they would do so prior to fire suppression and ventilation. Only 10.5% indicated they would not only wait until suppression and ventilation had begun, but also wait 1 – 2 minutes to see the impact ventilation would have on fire behavior prior to initiating interior search efforts. However, when operating on the fire floor, just over half of the officers indicated they would not abandon their charged hose line after knocking down the main body of fire in an effort to expedite search efforts. These officers also preferred to ventilate as they proceeded through the structure. These results suggest that although these officers are willing to extend greater risks where there is a potential civilian life hazard, they are less inclined to extend these risks on the fire floor than on the floor above the fire.

Although in some cases the officers do put a priority on reducing hazards prior to conducting interior search operations, there is room for improvement in recognizing the impact that rapid fire progress can have on civilian and firefighter life safety. Failure to minimize this impact by prioritizing initial suppression and ventilation efforts will reduce the potential for civilian survivability and increase the potential for firefighter fatalities as a result of deteriorating conditions caused by rapid fire progress and structural collapse.

When conducting interior operations at a structure fire, firefighters must maintain a keen awareness of heat, smoke and fire conditions and the impact they can have on the environment and structure they are working in (IFSTA, 2008). The potential for structural collapse is another variable firefighters must be aware of as both can lead to firefighters becoming disoriented, lost or trapped (Brannigan, 2008). Any indication that these events are eminent should prompt firefighters to evacuate the building (Terpak & Viscuso, 2012). The results of the on-line survey provided insight on both the Company Officer's recognition of and response to deteriorating conditions while operating inside a burning structure. In both the residential and commercial structure fire scenarios, 94.7% of responding officers indicated they would immediately exit the structure in the presence of rapid heat buildup and smoke banking down to the floor. In the residential scenario, the remaining 7.9% engaged in search and rescue opted to conduct a limited search and exit the structure while 7.9% of responding officers conducting overhaul in the commercial scenario chose to continue and call for a back-up line when these conditions occurred.

The on-line survey questions that indicated there was a potential for structural collapse produced similar results. When the floor became increasingly spongy during search and rescue, 60.5% of the responding officers progressed no further and immediately exited the structure while the remaining 39.5% finished some form of search on the second floor prior to exiting.

The fact that deteriorating conditions were recognized by a majority of Company Officers demonstrates an awareness and concern for these conditions and the impact they can have on interior conditions. However, while deteriorating conditions were recognized in all scenarios, the results indicate that the potential for rapid fire progress was a more powerful motivating factor than that of structural collapse in persuading BRFRS Company Officers to cease operations and exit the structure. As no two fires are exactly alike, unless all signs of significant deterioration in conditions are treated with equal merit, BRFRS Company Officers will expose themselves and the personnel they supervise to unnecessary risk. In addition, firefighters who would respond to their call for assistance in the event they become caught, trapped or lost will also be subjected to unnecessary risk.

The original motivation for this applied research project was the fact that, despite changes in product materials, building construction and resulting fire behavior, the strategies and tactics implemented by first arriving BRFRS Company Officers at structure fires have, for the most part, remained the same. As the review of NIOSH reports confirmed, in many cases, firefighter line of duty deaths are the result of implementation of traditional strategies and tactics on modern firegrounds (DHHS, 2013). Similar to firefighters across America, BRFRS Company Officers are willing to put themselves at great risk when the potential to save civilian lives exists. However, while saving lives is a commendable pursuit, the reports also revealed that in many cases, civilians thought to be trapped in a structure fire were not in the building at all. Further, in only18% of the incidents involving firefighter deaths were civilian victims thought or known to be in the structure and in only 3% of the incidents did the civilians rescued survive.

As the literature suggests, Company Officers must take the time to conduct thorough size-ups upon arrival at structure fires, prior to engaging in other fireground operations. These size-ups should include an assessment of occupant survivability based on conditions. As is the case across America, BRFRS Company Officers should risk a lot to save known, savable lives. However, in the absence of good information that civilian occupants are present or in the case of conditions not being conducive to occupant survival, these officers must exercise sound judgement in managing the risk to themselves, as well as to other firefighters who are impacted by their decisions, on the fireground. The strategies and tactics they choose to implement must reflect not only the life safety of the civilians they wish to rescue from peril, but also that of the firefighters which they command in their quest to accomplish their mission.

If civilian lives are to be saved and the unnecessary loss of firefighter lives are to be prevented, the strategies and tactics implemented by BRFRS Company Officers must reflect a thorough knowledge of and respect for fire and smoke behavior and the impact each can have on structural integrity. Further, they must also take into consideration the full impact that modern product materials and building construction have on the speed with which fire intensifies and structures succumb to collapse. Despite the fact that the average annual number of structure fires has declined, failure to recognize and consider these critical changes in the modern fireground while continuing to implement traditional strategies and tactics will allow the current trend reflecting an increase in the rate of firefighter deaths to continue.

Scientific research conducted by industry experts such as Underwriters Laboratories (UL) and the National Institute of Standards and Technology (NIST) on product materials, building construction and fire behavior has motivated other professional agencies to take a proactive stance on firefighter life safety. The International Association of Fire Chiefs' (IAFC) Rules of Engagement for Structural Fire Fighting stresses that all actions taken on the fireground, both by Incident Commanders as well as firefighters, should be based on sound risk management principles (IAFC, 2013). The National Institute for Occupational Safety and Health (NIOSH) has suggested that firefighters refrain from conducting offensive interior attacks on unoccupied or unsafe structures, whether currently in use or vacant (DHHS, 2009). By providing training on topics such as current fire and smoke behavior, building construction and ventilation, the BRFRS department will also be proactive in providing its Company Officers and firefighters the information they need to recognize and respond to the hazards of the modern day fireground. Further, by ensuring all current policies and procedural guidelines reflect the current literature on safe fireground operations, the Department will provided its Company Officers and firefighters the support on which to base their decisions when implementing safe strategies an tactics.

On September 11, 2001, many agencies had information regarding potential terrorist attacks. On that date, failure of the individual pieces of information to come together resulted in tragedy. Similarly, many agencies and organizations currently have critical information regarding firefighter safety. Like a puzzle waiting to be assembled, all the pieces are sitting on the table. Putting these pieces together will allow professional firefighters across America to see the big picture of firefighter safety on the modern fireground. As in the rest of the United States, where the rate of firefighter deaths has increased despite a decline in the number structure fires, failure to put these pieces together and act on the information will result in an increased probability of firefighter deaths and injuries in the City of Boca Raton.

Recommendations

It is recommended that Boca Raton Fire Rescue Services complete the following tasks:

- Conduct training on current product materials and building construction with an emphasis on the impact they have on fire behavior and structural integrity. This training will provide the information required for all BRFRS firefighters to implement safe strategies and tactics on the fireground.
- Conduct training on risk management principles, including risk benefit analysis. This training will provide the information required for all BRFRS firefighters to make fireground decisions based on sound risk management principles.
- Conduct training on Survivability Profiling. This training will provide the information required for all BRFRS firefighters to accurately assess the potential of civilian occupant survival based on conditions inside a burning structure and take appropriate action.

- Conduct training on ventilation, including methods, principles and the impact this action has on fire and smoke behavior. This training will provide the information required for all BRFRS firefighters to implement this tactic in a safe and effective manner on the fireground.
- Conduct training on the Incident Command System, including principles and practices. This training will supplement the basic National Incident Management System (NIMS) ICS training and ensure all BRFRS firefighters have a full understanding of this system as it relates to safe fireground operations.
- Conduct a review of all policies and procedural guidelines pertaining to fireground operations and ensure all reflect current literature on this subject. This will provide the guidance and support for all Company Officers and firefighters to implement safe strategies and tactics on the fireground.
- Reinstitute the Department's Building Survey program. This action will allow all BRFRS firefighters to become familiar with the structures they may respond to, prior to fire and other emergencies.

It is recommended that others wishing to conduct similar research on safety of firefighting strategies and tactics include survey questions on product materials, building construction and the impact they have on fire behavior, as viewed by the respondents. The inclusion of questions on these specific topics, in addition to those that require a choice of specific strategies or tactics, will provide insight into the thought process used by Company Officers and firefighters when choosing these strategies and tactics.

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Appendix

Survey

Firefighting Strategy and Tactics

1. Units are dispatched to a single family residential structure fire. Upon arrival, first due Engine/Ladder finds a 1500-2000 sq. ft., single story CBS structure with light-moderate gray smoke emanating from the open front door. The homeowner advises she was watching TV when she smelled smoke and evacuated the premises, no other occupants are home. Weather is not a factor. A Medic unit is one minute out and 2nd due Engine/Ladder is laying a supply line. Based on these conditions, the first action the first arriving Company Officer should take is

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	Response Percent	Response Count
Search and Rescue	0.0%	0
Fire Suppression (Quick Attack), passing Command	10.3%	4
Ventilation	0.0%	0
Establish Command, conduct 360 Size Up	89.7%	35
	answered question	39
	skipped question	0

2. Given the same scenario conditions, assume first due Company Officer establishes Command. A 360 size up is completed, revealing no visible fire. However, windows on Side C, near the C/D corner, appear to be black and show high heat upon observation with a Thermal Imaging Camera. Black smoke is pushing out from the eaves at the C/D corner. The next priority that needs to be addressed is

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	Response Percent	Response Count
Search and Rescue	2.6%	1
Fire Suppression	20.5%	8
Ventilation	76.9%	30
	answered question	39
	skipped question	0

3. Initial ventilation efforts for this fire should include Create Chart Download

	Response Percent	Response Count
Horizontal and Vertical ventilation with PPV fan	7.7%	3
Vertical ventilation with PPV fan	2.6%	1
Horizontal ventilation with PPV fan	12.8%	5
Horizontal (Natural) and Vertical ventilation	15.4%	6
Vertical ventilation	12.8%	5
Horizontal (Natural) ventilation	**51.3%**	**20**
	answered question	**39**
	skipped question	**0**

4. A rear window on Side C (at C/D corner) that was originally showing high heat has broken. Flames are exiting and impinging on the eaves. Smoke exiting the front door is now getting more dense, pressurized and darker. The initial 360 Size Up revealed a set of French doors that opened onto a rear patio on Side C (center) and a single door opening on Side D. Placement of the initial attack line should be to the Create Chart Download

	Response Percent	Response Count
Side A front door	**35.9%**	**14**
Side C french door	33.3%	13
Side D side door	10.3%	4
Side C window showing flames	20.5%	8
	answered question	**39**
	skipped question	**0**

5. Units are dispatched to a single family residential structure fire. Upon arrival, first due Engine/Ladder finds a newly developed 3000 sq. ft., 2 story townhouse with heavy black smoke showing from Side A. Winds are 10-15 mph from the Side C direction. A Medic unit is one minute out and 2nd due Engine/Ladder is laying a supply line. It is 2100 hrs. Based on these conditions, the first action the first arriving Company Officer should take is Create Chart Download

	Response Percent	Response Count
Search and Rescue	15.4%	6
Fire Suppression (Quick Attack), passing Command	5.1%	2
Ventilation	0.0%	0
	79.5%	**31**
	answered question	**39**
	skipped question	**0**

5. Units are dispatched to a single family residential structure fire. Upon arrival, first due Engine/Ladder finds a newly developed 3000 sq. ft., 2 story townhouse with heavy black smoke showing from Side A. Winds are 10-15 mph from the Side C direction. A Medic unit is one minute out and 2nd due Engine/Ladder is laying a supply line. It is 2100 hrs. Based on these conditions, the first action the first arriving Company Officer should take is — Create Chart — Download

Establish Command, conduct 360 Size Up		
	answered question	39
	skipped question	0

6. Given the same scenario conditions, assume first due Company Officer establishes Command. A 360 size up is completed, revealing smoke and flames exiting the ground floor sliding glass doors on Side C. The next priority that needs to be addressed is — Create Chart — Download

	Response Percent	Response Count
Search and Rescue	43.6%	17
Ventilation	17.9%	7
Fire Suppression	38.5%	15
	answered question	39
	skipped question	0

7. Initial ventilation efforts for this fire should include — Create Chart — Download

	Response Percent	Response Count
Horizontal and Vertical ventilation with PPV fan	2.6%	1
Vertical ventilation with PPV fan	2.6%	1
Horizontal ventilation with PPV fan	28.2%	11
Horizontal (Natural) and Vertical ventilation	20.5%	8
Vertical ventilation	2.6%	1
Horizontal (Natural) ventilation	51.3%	20
	answered question	39
	skipped question	0

8. Placement of the initial attack line should be to the — Create Chart — Download

	Response Percent	Response Count
	answered question	39
	skipped question	0

8. Placement of the initial attack line should be to the	Create Chart	Download
Side A front door	**66.7%**	**26**
Side C sliding glass door	33.3%	13
	answered question	39
	skipped question	0

9. All first alarm units are arrival. A Primary Search of the second floor should be conducted or assigned	Create Chart	Download
	Response Percent	Response Count
prior to Fire Suppression and Ventilation, to expedite location of any possible victims	**51.3%**	**20**
after Fire Suppression has begun and prior to Ventilation	20.5%	8
after Fire Suppression and Ventilation have begun	17.9%	7
after Fire Suppression has begun and approximately 1-2 minutes after Ventilation has begun	10.3%	4
	answered question	39
	skipped question	0

10. A Primary Search of the second floor would best be accomplished	Create Chart	Download
	Response Percent	Response Count
without using a rope/bag or charged hose line, to expedite location of possible victims	15.4%	6
using a rope/bag to maintain a path of egress	41.0%	16
using a charged hose line	**46.2%**	**18**
	answered question	39
	skipped question	0

11. Fire Suppression and Ventilation have begun. The Primary Search Group is operating on the second floor in moderate-high heat, limited visibility conditions. As they reach the open door to a Side C bedroom, they notice the floor is increasingly spongy. Their best course of action would be to conduct	Create Chart	Download
	Response Percent	Response Count
	answered question	39
	skipped question	0

11. Fire Suppression and Ventilation have begun. The Primary Search Group is operating on the second floor in moderate-high heat, limited visibility conditions. As they reach the open door to a Side C bedroom, they notice the floor is increasingly spongy. Their best course of action would be to conduct

Create Chart Download

a quick full search of the bedroom and the rest of the second floor	2.6%	1
a limited search of the bedroom without entering the room, sweeping inside the doorway with a tool, then search the remainder of second floor	38.5%	15
a limited search of the bedroom without entering the room, sweeping inside the doorway with a tool, then exit the second floor	25.6%	10
no further search, exit the second floor and notify Command of conditions found	33.3%	13
	answered question	39
	skipped question	0

12. Fire Suppression and Ventilation have begun. The Primary Search Group is operating on the second floor in moderate-high heat, limited visibility conditions. Initially, conditions improve and the smoke begins to lift, allowing visibility 3-5 feet above the floor. However, as Ventilation continues, dark black smoke begins to bank down toward the floor and heat levels increase dramatically. The best course of action for the Search Group would be to

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	Response Percent	Response Count
quickly conduct a full search of the second floor and exit the structure	0.0%	0
conduct a limited search of the second floor and exit the structure	7.7%	3
notify Command of change in conditions and exit the structure	94.9%	37
	answered question	39
	skipped question	0

13. Units are dispatched to a multi-family residential structure fire. Upon arrival, first due Engine/Ladder finds a single story, 3000 sq. ft., 2 unit duplex with heavy black smoke and flames exiting the Side A living room window of one unit. Winds are 10-15 mph from the Side A direction. A Medic unit is one minute out and 2nd due Engine/Ladder is laying a supply line. The first arriving Company Officer opts to pass Command and conduct a Quick Attack, entering through the front door and knocking down the main body of fire in the living room. At this point, heavy smoke is still present but beginning to lift. In order to conduct a Primary Search, this crew should

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	Response Percent	Response Count
commence Search efforts without the charged line (to expedite locating possible victims)	12.8%	5
commence Search efforts with the charged line	20.5%	8
	answered question	39
	skipped question	0

13. Units are dispatched to a multi-family residential structure fire. Upon arrival, first due Engine/Ladder finds a single story, 3000 sq. ft., 2 unit duplex with heavy black smoke and flames exiting the Side A living room window of one unit. Winds are 10-15 mph from the Side A direction. A Medic unit is one minute out and 2nd due Engine/Ladder is laying a supply line. The first arriving Company Officer opts to pass Command and conduct a Quick Attack, entering through the front door and knocking down the main body of fire in the living room. At this point, heavy smoke is still present but beginning to lift. In order to conduct a Primary Search, this crew should

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commence Search efforts without the charged line and ventilate as they go	12.8%	5
commence Search efforts with the charged line and ventilate as they go	53.8%	21
	answered question	39
	skipped question	0

14. Units are dispatched to a structure fire at an auto parts store at 0815 hrs. Upon arrival, first due Engine/Ladder finds a 2500-3000 sq. ft. single story structure with light-moderate black smoke showing from Side A. The store manager advises he arrived to open up this morning and found light smoke in the retail area. He proceeded to the office/storage area in the rear of the store to investigate. Upon opening the door to the office, he encountered heavy smoke and flames. He was unable to close the door and he exited the structure. No other occupants are present. Weather is not a factor. A Medic unit is one minute out and 2nd due Engine/Ladder is laying a supply line. Based on these conditions, the first action the first arriving Company Officer should take is

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	Response Percent	Response Count
Search and Rescue	0.0%	0
Ventilation	0.0%	0
Fire Suppression	5.3%	2
Establish Command, conduct 360 Size Up	94.7%	36
	answered question	38
	skipped question	1

15. Given the same scenario conditions, assume first due Company Officer establishes Command. A 360 size up is completed, revealing black smoke pushing out from closed single and roll-up doors on Side C. The next priority that needs to be addressed is

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	Response Percent	Response Count
Search and Rescue	2.6%	1
Fire Suppression	51.3%	20
Ventilation	46.2%	18
	answered question	39
	skipped question	0

16. Initial ventilation efforts for this fire should include — Create Chart — Download

	Response Percent	Response Count
Horizontal and Vertical ventilation with PPV fan	5.1%	2
Vertical ventilation with PPV fan	0.0%	0
Horizontal ventilation with PPV fan	23.1%	9
Horizontal (Natural) and Vertical ventilation	10.3%	4
Vertical ventilation	5.1%	2
Horizontal (Natural) ventilation	**59.0%**	**23**
	answered question	39
	skipped question	0

17. Placement of the initial attack line should be to the — Create Chart — Download

	Response Percent	Response Count
Side A front door	**71.8%**	**28**
Side C rear doors	28.2%	11
	answered question	39
	skipped question	0

18. Fire Suppression and Ventilation have begun. The fire in the office had spread into the storage room and drop ceiling area. The fire has been knocked down. The Attack Group is pulling drop ceiling tiles to check for extension and the Thermal Imaging Camera shows high heat above the ceiling tiles. Initially, conditions improve and the smoke begins to lift. However,as Ventilation continues and a PPV fan is put into service, dark black smoke begins to bank down toward the floor and heat levels increase dramatically. After approximately one minute, visibility is zero and high heat levels persist.The best course of action for interior crews would be to — Create Chart — Download

	Response Percent	Response Count
continue to check for extension and hit hot spots	0.0%	0
continue to check for extension, hit hot spots and request a back-up line	7.7%	3
notify Command of change in conditions and exit the structure	**94.9%**	**37**
	answered question	39
	skipped question	0

19. Units are dispatched to a single family residential structure fire. Upon arrival, first due Engine/Ladder finds a 3000-4000 sq. ft., single story CBS structure with heavy black smoke pushing out from the eaves. It is 0530 hours and a heavy rain storm with lightning moved through the area approximately 30 minutes ago. A 360 size up reveals that the entire home is full of smoke with no visibility through the windows. Upon opening the front door with Forcible Entry, black pressurized smoke pushes out at ground level. Based on these findings, the probability of civilian victim survival in this structure is

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	Response Percent	Response Count
very high	0.0%	0
high	0.0%	0
moderate	0.0%	0
low	20.5%	8
very low	**79.5%**	**31**
	answered question	**39**
	skipped question	**0**

20. Given the same scenario conditions, the next priority that needs to be addressed is

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	Response Percent	Response Count
Search and Rescue	5.1%	2
Fire Suppression	15.4%	6
Ventilation	**79.5%**	**31**
	answered question	**39**
	skipped question	**0**