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Structure Fire Training Conducted In Wind Driven Conditions

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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.

Signed:_____

Abstract

Firefighters at Boynton Beach Fire Rescue (BBFR) have been training to respond to wind driven fire (WDF) in a structural setting. The problem is the training program for control of WDF utilized by BBFR may be exposing firefighters to unnecessary risk, without providing any measurable benefit to the firefighter. The purpose of this research was to assess the WDF training program for safety and value as a training tool. Descriptive research was used to perform this study. The research answered the questions: How great a threat, if any, is the occurrence of a WDF event to firefighters in Boynton Beach? What strategies and tactics exist that address the control of WDF in a structure? What, if any, methods of training are being conducted that specifically address firefighting strategies and tactics for a WDF event? What, if any, evidence is available to suggest that methods being utilized to train firefighters at BBFR are safe and may improve a firefighter's likelihood of success during an emergency operation? Personal interviews, literature and departmental records reviews, National Fire Protection Agency (NFPA) standards, industry reports, a survey and test showed training methods used by BBFR were essentially sound but that some modification of current practices would be beneficial. Research revealed that weather conditions support the potential for WDF to occur at a structure fire in Boynton Beach, Florida. Strategies for the control of WDF exist and are currently in use by the firefighting personnel. A study by National Institute of Standards and Technology validated tactics to carry out these strategies. Research indicated that methods being utilized to train firefighters at BBFR to control a WDF are safe and have potential to improve their likelihood of success. Recommendations include increasing hands-on practice, use of tools, and reassessment of the program.

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STRUCTURE FIRE TRAINING IN WIND DRIVEN CONDITIONS

Introduction

Firefighters are expected to safely and effectively mitigate fires regardless of wind conditions that may affect the intensity of the fire. In response to this, firefighters at Boynton Beach Fire Rescue (BBFR) are participating in training for the control of wind driven fire (WDF) within a structure. This training includes an exercise in which the firefighters observe a WDF under live fire conditions. The WDF training program is new and has not been examined to determine its effect on firefighters. Without validation, it cannot be assumed that the training program adequately prepares firefighters to operate safely and effectively during emergency operations. The problem is that the training program for the control of WDF in a structure that is used by BBFR may be exposing firefighters to unnecessary risk for loss of life and health, without providing any measurable benefit to the firefighter.

The purpose of this research is to assess the WDF training program for safety and value as a training tool. Descriptive research will be used to perform this study. Source information will include articles, books, professional journals, National Fire Protection Agency (NFPA) standards, published studies, and personal interviews. A survey tool will be utilized to obtain information about the instruction of firefighters outside the City of Boynton Beach. An examination will also be employed to assess the level of retention by firefighters who participated in the WDF training program at BBFR.

Questions that will be addressed in this applied research project are: How great a threat, if any, is the occurrence of a WDF event to firefighters in Boynton Beach? What strategies exist that specifically address the control of WDF in a structure? What tactics exist that specifically address the control of WDF in a structure? What, if any, methods of training are being

conducted that specifically address firefighting strategies and tactics for WDF? What, if any, evidence is available to suggest that the methods being utilized to train firefighters at BBFR to control a WDF are safe for use in training firefighters? What, if any, evidence is available to suggest that the methods being utilized to train firefighters at BBFR to control a WDF will improve their likelihood of success during an emergency operation?

Background and Significance

The citizens of Boynton Beach enjoy the protection of a paid, professional fire rescue service. Firefighters at BBFR serve the needs of over 66,000 citizens by providing fire protection and emergency medical assistance to an area of just over 15 square miles (IDcide, 2009). The City of Boynton Beach is located on Florida's east coast and is approximately 75 miles north of Miami. The climate could be categorized as sub tropical. A steady ocean breeze is present on a typical day. However, the area is also subject to seasonal threat from hurricane winds. The city's landscape consists of residential housing, light industrial parks, and isolated areas of wildland urban interface. A variety of occupancy types can be found in the city, including single-and multi-family residential, commercial, and mixed-use high rise structures. Fire rescue personnel respond to just over 11,000 emergency responses annually (Boynton Beach Fire Rescue, annual report, 2008, p. 1). A record number of these emergency responses were recorded during October, 2004. It was during this time that Hurricanes Frances and Jeanne made landfall near Boynton Beach. Fire crews responded to emergency calls in wind conditions in excess of 30 mph (Boynton Beach Fire Rescue, 2004 response records).

Fortunately, the City of Boynton Beach is adequately prepared to handle emergency situations, including most hurricane conditions. Its resources include five fire stations, one of which houses the emergency operations center for the city. A minimum staffing level includes a

complement of 31 firefighters daily. These firefighters provide around the clock fire protection and emergency medical services to the community. Response personnel receive direction in the form of written protocols and policies and procedures, as well as verbal orders from supervisory personnel. Standard Operating Guidelines (SOGs) are used to lead the actions of emergency response personnel. A decidedly proactive approach to fire protection is represented by BBFR's Fire and Life Safety (F&LS) Division. The division consists of one plans reviewer, one administrative assistant, one fire inspector, four assistant fire marshals, and one fire marshal (BBFR website, 2009). The F&LS Division protects life and property through the enforcement of fire codes. The progressive and comprehensive nature of these codes may be the reason the city has had less than 205 structure fires in the past four years (BBFR, Annual Report, 2008 pg. 5). Not only has enforcement of fire codes been successful in controlling the number of building fires, but it has also been responsible for the reduction of hazardous conditions allowed to exist within the community. Fire codes alone, however, can not eliminate all hazardous conditions that firefighters must face. Dangerous wind conditions are an example of a hazard that building and fire codes cannot control. Firefighters are expected to respond to and extinguish fires during conditions which are often difficult to anticipate. Although no information was available for Boynton Beach, wind conditions in the neighboring city of West Palm Beach have been documented for over 60 years. In West Palm Beach, a mean wind speed of 10 mph, with gusts between 32 and 53 mph in the area (National Oceanic and Atmospheric Administration, 2009). Due to the number and severity of hurricane events, it is possible that firefighters will be called upon to respond to a structure fire during high wind conditions. The wind can be challenging in a single story structure but the difficulties can multiply exponentially in a high rise structure. In the fire service, line of duty deaths (LODDs) have been documented that have been due in part to

the challenges presented by WDF (National Institute for Occupational Safety and Health [NIOSH] F2005-03, F2007-12,).

Responsibility for instruction of firefighters and company officers is shared by the battalion chiefs and the fire department captains. The division chief of training and safety has the overall responsibility of managing the education and training of all general staff positions. This responsibility includes educating operations personnel in objectives, strategies, and tactics used to control WDF. Education also includes disseminating knowledge contained in fire department SOGs and pre-incident plans. An SOG that specifically addresses the issue of WDF does not exist at BBFR. In past years training officers appear to have no clear direction to follow in the development and delivery of training specific to the control of WDF.

At BBFR, hands-on training is preferred by most firefighters and is often requested by personnel through feedback received from annual performance evaluations. Hands-on training programs for the control of WDF are not readily available in the area serviced by BBFR, and it would not be practical for 122 firefighters to travel to an outside class or seminar should one become available. As a result, an in-house program that addresses the subject was developed for use as a training tool.

The WDF training program at BBFR consists of a lecture portion (Appendix A), which covers strategies such as wind control and exterior water application, tactics such as the use of a wind control device (WCD), positive pressure attack (PPA), or positive pressure attack (PPV) fan, and safety measures such as the utilization if a safe space. New and experimental equipment such as the HRN and wind curtain are presented in a video-based presentation. Door control measures are discussed. Recognition and avoidance of a potential emergency are discussed and reinforced through live-fire training (LFT) in a WDF training prop (Appendix B). The WDF

prop was designed and built by members of BBFR under the direction of the training division. The prop was designed for use with class-A combustibles and contains a fire set consisting of three industrial wood pallets stacked to form a tee pee, and approximately two square feet of hay. The prop consists of an engineered fire containment box that is open on the leeward side and has an induction opening that is square. The opening, which is approximately 14 inches high by 14 inches wide, introduces air with velocities recorded between 5-10 mph. The air movement was measured at approximately six feet from the source and is just past the fire set. The box is constructed of a standard frame made from 2x4 pine boards is lined with a layer of ¼ inch plywood. The plywood is lined with a 5/8 inch drywall fire stop, and finished with an inner layer of ¾ inch plywood which serves as a sacrificial liner. The engineered firebox, that has been dubbed "Pandora's Box" by BBFR firefighters, is designed to burn inside while limiting direct flame contact to the surrounding structure. Inside the chamber, hot gases build up and rollover occurs within approximately 1½ minutes. The fire and hot gases follow an engineered hallway built to specifications similar to the engineered fire containment box. Once the fire and hot gases reach a critical point where they multiply with the introduction of a 5 to 10 mph wind, air is introduced via a PPV fan. The resulting effect is that forced convection currents create a vortex of fire, which simulates natural WDF. Fire in the prop is controlled by direct extinguishment and through the use of a remotely operated deluge sprinkler system. Although the replication of WDF in a training prop is an impressive accomplishment, the WDF program at BBFR has not been examined for its safety or its predicted effect on the actions of firefighter operating at a WDF emergency. Due to the nature of LFT, the current program may pose an unnecessary threat to the wellbeing of firefighters. By conducting training exercises under the current program, instructors may be risking the safety of their students by exposing them to an atmosphere that is

immediately dangerous to life and health. They are put in this situation without evidence to suggest that the training program increases the firefighters' chances of a safe and successful performance during an emergency operation. Additionally, the program may be endangering firefighters by offering strategies and tactics that may not prove effective against a WDF.

Through information provided in this research, BBFR should gain valuable insight into the effectiveness of the current WDF training program. Personnel will appreciate an accurate assessment of the threat that WDF poses to firefighters at BBFR. The study is expected to reveal new strategies and tactics that may be incorporated into future training exercises at BBFR. Results of a survey process will allow the Training Division at BBFR to examine training methods used in other fire departments and use this data to increase the safety and effectiveness of its current program. Through this research, rescuers will understand to reduce the risk to the citizens of Boynton Beach by revising and utilizing the fire department's WDF training program. An awareness of current processes and practices will be helpful in the management of changes to the program. The knowledge gained from this study will be used to provide the department with recommendations for the continuation, termination, or revision of the current WDF training program. Examination of the training program will have a positive impact on safety. It will meet the fire department's organizational mission, which reads, "To provide the highest level of emergency response and community services, through fiscally responsible leadership, in order to meet the needs of both the customers we serve and the members of the Boynton Beach Fire Rescue Team" (Bingham, 2008).

Firefighters are an essential part of the National Response Framework. Among the many positions they are called upon to fill, it is their role as a fire suppression resource that frequently positions them in harm's way. The executive fire officer plays a role in the preparation and

training of this vital resource. It is the training officer that provides the firefighter with the training and education needed to perform emergency management functions. This research project applies concepts discussed in the Executive Analysis of Fire Service Operations in Emergency Management (EAFSOM) course as described in unit two, "Incident Command System," of the EAFSOM student manual. Common responsibilities for the Incident Commander (IC) are clearly delineated in the text. Among these responsibilities are: to ensure the safety of all personnel, determine incident objectives and strategies, determine resource needs, and to order and deploy resources. Firefighters are a single resource that functions as part of a team. They are assigned by the IC or his/her designee to perform emergency functions. As part of the overall strategy, it is imperative that each resource performs its function within the emergency management plan. For this to occur, all firefighters must be trained to function in the role they are assigned (National Fire Academy [NFA], 2009, p. 2-3). The research also applies concepts discussed in unit four, "Community Risk and Capability Assessment," of the EAFSOM-Student Manual. The potential for a WDF event in Boynton Beach to escalate from a routine fire response to an event that is well beyond the capabilities of first-in units should be examined through research. Assessment tools from unit four, such as a hazard identification matrix, a vulnerability assessment, and risk rating can be applied to determine a community risk assessment for WDF in Boynton Beach (NFA, 2009 Sec. 4, p. 9-54).

The United States Fire Administration (USFA) has five operational objectives. This research meets the USFA operational objectives, "to reduce mortality from fire by 15%, to develop a comprehensive multi-hazard risk reduction plan for 2,500 communities, led by or including the local fire service, and to reduce line of duty deaths among firefighters by 25%" (United States Fire Administration, 2002).

Literature Review

Forced Convection Currents

Contrary to normal fire growth and behavior, WDF causes a change in the forced convection currents of hot gasses that normally stratify in a fire situation. Heat, which normally rises, is evenly dispersed from ceiling to floor as a result of the churning effect of WDF in a structure (Ceriello, 2009). This thermal upset can be lethal to firefighters, whose personal protective equipment is not designed to withstand exposure to temperatures above 260 degrees Celsius for more than five minutes (Kerber & Madrzykowski, 2009 p. 335). As a result, normal firefighting strategies and tactics cannot be relied on to safely mitigate WDF in a structural setting.

The Governors Island Study

A landmark WDF study was conducted on Governors Island, New York, the results of which were published in 2009 by the Fire Protection Research Foundation. The final report, entitled "Firefighting Tactics Under Wind Driven Conditions," was prepared by the National Institute of Standards and Technology (NIST). This widely publicized study has generated a great deal of interest in the topic of the control WDF. Key points of interest examined in the study were tactics that had been used to combat WDF by fire departments in the past, but had not been studied in detail. Also examined were tools that could be used to effectively facilitate these tactics (Kerber & Madrzykowski, 2009 p. 4). The study followed scientific method and had an extensive roster of technical experts to achieve its objectives. Conducted during the research were a number of activities, which included measurements of heat release, wind speed, and gas concentration. Firefighting tools and tactics were subjected to the scientific process. These

included the use of wind control devices and external water application. As a result of this study, a number of firefighting tactics were validated for use in the control of WDF in the structural setting. These included the use of Wind Control Devices (WCDs) and external water application devices. The study generated recommendations for future research which included the training aspect of controlling WDF using the tactics and tools validated by the research (Kerber & Madrzykowski, 2009 p. 353).

The Evolution of WDF Strategies and Tactics

The topic of strategies and tactics for controlling WDF has emerged as an issue of great interest to the fire service. Along with the recent study published by the Fire Protection Research Foundation, which contained the final report by NIST, two additional studies, one in Toledo, and one in Chicago, have evolved into a comprehensive tool box for ICs to use in the event that they are confronted with a WDF. Each of the studies was conducted by and in cooperation with expert authorities in the fields of firefighting or research such as NIST, New York's Polytechnic Institute (PI), the Toledo Fire Department (TFD), the New York City Fire Department (FDNY), the Chicago Fire Department (CFD), and the Ottawa Fire Services of Canada (Ceriello, Healy & Tracy, 2007). A summary of 565 fires was included as an appendix in the final report on WDFs conducted on Governors Island. The fires were being reviewed to discover if wind may have been a factor in the total amount of damage to property. They were also being reviewed to see if wind was a factor in the loss of life to civilians or to firefighters. It was confirmed by NIST that wind was a factor that altered firefighting tactics in nearly 30 fires since 1945. Many of the fires examined resulted in civilian or firefighter fatalities (Kerber & Madrzykowski, 2009 Appendix A3-A30). The State of Florida was listed 17 times in the data for historical summary of fires that may have been impacted by wind. Whereas 7 of the listings were

classified as “possible but unlikely; further documentation not available or confirmed but not relevant,” the other 10 were listed as “under consideration; still needs to be pursued” (Kerber & Madrzykowski, 2009 Appendix A3 - A30). Loss of civilian life for the state during these fires totaled 39, whereas no firefighters were killed in the state.

Although the study conducted on Governors Island was the most comprehensive of the three, none of these studies can be credited as the genesis of WDF research and recognition. In fact, reference to the impact of WDF can be established as far back as 1871. Wind, for example, was cited as a factor at the Great Chicago Fire that burned 2,000 acres. It was also cited as a factor in the Great Peshtigo Fire that took the lives of 1,152 people (Kerber & Madrzykowski, 2009 p. 2). Strategies and tactics for the control of WDF have been under development over a period of time and include references to building pressurization, wind control, indirect fire attack, and the utilization of shelters.

The first modern-day study which recognized the hazardous conditions of a WDF for structural firefighting was performed by Chief John T. O’Hagan, and Battalion Chief Joseph W. Rooney of FDNY, and with support of PI. The New York City Mayor's Advisory Committee ordered the test in 1972. The study was conducted to examine stairwell pressurization as a means of reducing smoke and toxic fumes from stairwells. Rooney described that external winds are a cause of pressure differences that contribute to smoke and toxic conditions in a high-rise building (Rooney, 1972 p. 4-7). The study employed the use of a fan that can produce 40,000 cubic feet per minute of air movement to pressurize the stairwell. Live-fire conditions were created for the test. Results of the study confirmed that stairwell pressurization could be achieved, which was sufficient to clear smoke from the stairwell.

Joseph Callan, who was Chief of Training for FDNY in 1999, conducted research on the control of WDF using a fire-resistant window blanket. The research was prompted by the deaths of Lieutenant Joseph Cavalieri, Battalion 39, and Firefighters Christopher M. Bopp and James F. Bohan. The researchers utilized a fire blanket to control the flow of wind entering the windward side of the fire room. This was accomplished by covering the window with the blanket during live-fire conditions. Battalion Chief John Norman of FDNY described the success of the fire blanket in an article printed in With New York Fire (WYNF) 2nd Ed., 2002. Norman also reported that the blanket's effectiveness had not yet been tested in an actual WDF. Norman advised that the blanket should be used if a fire exists in a high-rise building and the door has been left in the opened position. It should also be utilized when a WDF is so intense that hand-line crews are unable to advance to the apartment (Norman, 2002 p. 17, 18).

Wall breaching, as a method to access the seat of a WDF, was utilized as a result of a failed attempt at a traditional direct attack using a 2½-in hose line. In September of 2004, FDNY firefighters battled a high-rise fire that began as a routine fire until a door was opened that allowed a WDF to engulf the firefighters. Entry was made into an adjacent apartment and a sheetrock wall was breached. This difficult fire was not considered to be under control until more than two hours after the initial call was received. Deputy Chief Robert Carroll and Assistant Chief Patrick McNally relayed the following recommendation in a post event article. In the event of WDF, firefighters should consider the use of a fire blanket to stop the flow of air back into the fire company. Additionally, Chief Carroll pointed out that firefighters may have difficulty advancing two lines through the hallway (Carroll, McNally, 2005 p. 1-4). By recognizing the difficulty advancing hose lines in a direct attack, along with the successful

mitigation of WDF fire using the indirect tactic of wall breaching, FDNY firefighters may have hastened acceptance of exterior attack for WDF control.

Deputy Chief Mark Cuccurullo and Battalion Chief Vincent Mavaro of FDNY wrote an article for WYNF about the use of an exterior attack to knock down a WDF that injured an interior attack team. The incident occurred on November 28, 2005 and involved a WDF making rapid progress though a cockloft of an apartment building. During the incident, a team of firefighters received burn injuries secondary to a forced entry attempt made on the fire-involved apartment. The attempt was abandoned after multiple firefighters received burn injuries. The door was closed by the team and command ordered an exterior attack. Exterior master streams were used to reduce the size and intensity of the fire. After the exterior attack was discontinued, firefighters were able to complete the extinguishment from their interior positions. This documents the strategic use of an exterior attack from the burned side. Use of this strategy created tenable conditions inside the fire-involved apartment and made an interior extinguishment possible (Cuccurullo, Mavaro, 2006 p. 6, 7).

The strategy of sheltering a person in place within an area of safe refuge has been a subject of intense interest since the events of September 11, 2001. It has been successfully utilized as a strategy to protect firefighters. It was part of the overall strategy used in a WDF in Queens, NY at which there were several firefighters in peril (Daly Jr., Healy, 2006). Even though it is a widely accepted tool in the strategic planning of WDF fire emergencies in the wildland setting, the act of sheltering a person in place can present a challenge when the strategy is applied to the structural realm. An interview was conducted with Lt. John Ceriello of FDNY. Ceriello was a participant in the WDF studies at Governors Island and has co-authored numerous articles on the subject. According to Ceriello, the apartment that is on fire may be located at the

end of a hallway and may not have an adjacent unit. In this case, finding an area of safe refuge may not be an option. Ceriello also commented on the tools and appliances that were tested during the study. He felt there were definite advantages to using the high rise nozzle (HRN) and the wind control blanket or the smaller version that sells under the brand name K.O. Curtain. As a result of the study, FDNY added additional HRNs for indirect attack on the fire, bringing their total number up to 17. Additionally, K.O. Curtains and wind control blankets were added, bringing their numbers up to 22 and 33 respectively. According to Ceriello, training for these new tools of the trade was conducted in part by mobile training teams using a combination of lecture format and hands-on training. Ceriello was asked to view a video representation of a WDF training event that was conducted by BBFR. He was then asked to comment on LFT as a delivery method for the strategies used, and the tactics validated by NIST. Ceriello said, "I certainly recommend it." (LFT for WDF) "The thing is, when you try to describe the intense heat of WDF to most firefighters, they don't get it." Ceriello went on to comment that he felt a video representation of the WDF training conducted in Boynton Beach could not show heat and fire at the floor level and that this may cause a false sense of security (personal communication with John Ceriello, June 2009).

Dr. Shane LO Siu-hang, Deputy Chief Fire Officer of the Hong Kong Fire Services Department was an observer at the Governors Island Study. He was chosen for interview as a result of his unique circumstance. Deputy Chief LO reported that he has over 25,000 high rise buildings in his jurisdiction, and he is well versed in the dangers of WDF. In a personal communication with Deputy Chief LO, he affirmed that the Hong Kong Fire Department was interested in the concept of stairwell pressurization using PPV, but not in some of the other tactics, such as use of the a wind control blanket and the HRN. Deputy Chief LO declared that

these tools might not be suitable for use in Hong Kong. Deputy Chief LO commented that the HRN is too heavy for sustained use. He further stated that the blanket device requires firefighters to place themselves above the fire, a practice that he could not support. He stated that it would be impossible to assure the safety of firefighters who were operating above a fire. According to Deputy Chief LO, if a fire is too dangerous to fight from the same floor, conditions above such a fire would pose an extreme risk to firefighters. Conversely, if the fire can be controlled from above, the firefighters should be able to control and manage the fire while operating on the same floor as the fire. When asked if hands-on LFT is used for delivery of WDF strategies and tactics, Deputy Chief LO reported that, although he felt it would be the best method, the financial cost of LFT makes this practice prohibitive (personal communication with LO, S.H., June 19, 2009).

Fire Service Training Methods

General educational principles apply to all training that occurs in the fire service. Fire service instructors are trained to create objectives and to follow lesson plans. Fire instructors are usually well versed in courses such as Instructional Methodology. A learning model referred to by fire service instructors for over 15 states about learning: "We remember 10% of what we read, 20% of what we hear, 30% of what we see, 50% of what we see and hear, 70% of what we say, and 90% of what we say and do" (Duffy, 1991 p. 43). A similar learning model was referenced by Mel Silberman, author of Active Training. In his book, Silberman quoted Confucius as stating, "What I hear, I forget. What I see, I remember. What I do, I understand" (Silberman, 1998 p. 2). Silberman goes on to explain why the lecture format is not an effective means of conveying information. He reports that a lecturer speaks at a rate of 100 to 200 words per minute (wpm), whereas a participant tends to listen at a rate of approximately 50 to 100 wpm

(Silberman, 1998 pg. 3). Additionally, it was discovered in a 1984 study that college lecture format participants are inattentive 40 % of the time (Pollio, 1984). Moreover, in a 1988 study of knowledge retention secondary to a lecture based delivery, it was revealed that participants who were present for the lecture knew only 8 percent more than control subjects who were not (Rickard, Rodgers, Ellis, and Beidleman, 1988 p. 3)

Standards of WDF Training

In a USFA special report, Starbaugh and William explain, that with the declining number of structure fires, active firefighters do not have the experience of past generations (Starbaugh & William, 2003).

The guideline NFPA 1410 serves as the industry standard for training engine companies for their initial actions on a fire scene. At the present time, however, there are no existing NFPA standards for WDF training for the structural setting. A compilation of best practices and scientific research from the disciplines of wildland firefighting and structural firefighting make up the subject matter of the existing data base for WDF training. Wildland firefighters are taught to read fire conditions, while taking into account the direction the wind is pushing the head of a fire. They are taught that a direct attack of a fire at the head is a dangerous practice and it should be avoided. Students are required to study the dangers created when wind impacts a fire. They learn that, although wind is difficult to predict, it is the most critical weather element affecting wildland fire behavior (National Wildfire Coordinating Group, 2006 p. 2C.15). Wildland firefighters receive training via lecture and by participating in hands-on training during a field day class. Like their wildland counterparts, structural firefighters may encounter conditions of WDF. It is accepted practice that structural firefighters follow the standards of the NFPA when

performing monthly training. Although firefighters may be required to respond to a WDF event, no standardized NFPA approved drill was discovered that specifically addressed the topic (NFPA, 2005).

Recommendations for training of firefighters in live-fire conditions are delineated in the NFPA 1403 Standard. This standard has been a statutory requirement in the state of Florida since January, 2006 (Florida State Statutes, 2006). Training documentation is available through BBFR's training division to support adherence to the standard (BBFR, 2008, 2009). A second document, NFPA 1402, is the guiding document that includes general and safety considerations for exterior props that are used in LFT. The standard does not address the general or safety considerations for a prop built for use inside a live fire training structure. The use of the prop used for the WDF training was examined to see if its use would conflict with any NFPA guidelines covering traditional use of the live fire training center. No conflict was found (NFPA 1402, 2002). The prop utilized in the WDF training program at BBFR was designed for use with a sprinkler system that allows for remote extinguishment of the fire. This method of extinguishment was used for all WDF training events conducted by BBFR and was said to be very safe and effective (personal conversation with Captain Ed Herrmann of BBFR, December 5, 2009). Captain Herrmann was in charge of construction for the WDF prop and was also in charge of instructor training for the WDF exercises.

Recent research conducted by NIST validated tactics which were considered to be best practices. FDNY has begun a pilot program to begin organized instruction based on these validated tactics. A DVD was placed into circulation in 2009, through the Department of Homeland Security, that contains the final version of the study that was conducted by NIST.

Literature Review Summary

The purpose of this research is to assess the WDF training program for safety and value as a training tool. The literature review was instrumental in establishing the basis for which to formulate a study that will definitively answer the research questions. The literature review was essential in revealing that WDF can threaten the health and safety of firefighters who are operating in single occupancy buildings, as well as those who are working in high-rise multi-use structures. Sources examined revealed a series of studies, each appearing to build on concepts introduced in the previous study. It was discovered that many strategies and tactics currently in use by firefighters against WDF have been validated through the analysis of empirical data which was collected at Governors Island and published by the Fire Protection Research Foundation. The literature review revealed that there is little published information available that specifically references the training of firefighters to safely and predictably respond to WDF emergencies. Literature was examined which delineated hands-on training as superior to other forms of training for knowledge retention and performance expectations. This review confirmed that the NFPA has standards for LFT and the design and use of props when training firefighters in a live-fire environment. Information discovered in the existing knowledge base will assist in the formation of recommendations for future revisions of the WDF training program at BBFR.

Procedures

Literature Research Methodology

Research was initiated in June 2009. A computer search was conducted at the Learning Research Center located at the National Emergency Training Center in Emmitsburg, Maryland. The database was examined to reveal the existence of research papers that related to the topic of WDF training. The search was expanded to include information related to the topics of WDF strategies and tactics, education and training methodology, and line of duty injuries and deaths

related to WDF. Additional searches were performed over the next four months to check for new information that might not have been available through earlier searches. Information was examined in books, professional journals, and other publications. The data search, which began in the LRC, was completed in Boynton Beach, FL by November 23, 2009. The literature review was conducted to assist in answering the following questions. How great a threat, if any, is the occurrence of a WDF event to firefighters in Boynton Beach? What strategies exist that specifically address the control of WDF in a structure? What tactics exist that specifically address the control of WDF in a structure? What, if any, evidence is available to suggest that the methods being utilized to train firefighters at BBFR to control a WDF are safe for use in training firefighters? What, if any, evidence is available to suggest that the methods being utilized to train firefighters at BBFR to control a WDF will increase their likelihood of a success during an emergency operation?

Records Review Methodology

Emergency response records were reviewed for evidence of a WDF event in Boynton Beach, Florida. The records were further reviewed for evidence that wind was cited as a contributing factor at a fire event. Structure fire reports that occurred within a four year period were included. The period of time selected was between January 1, 2005 and December 31, 2008 and was chosen based on the initiation date of the computer reporting system at BBFR. The records review was conducted in the training offices of BBFR and was limited to records stored and retrieved via a computer-based records system called FireHouse Reporting. Information from this review was used to discover evidence of past threats from WDF towards firefighters at BBFR.

Training records were also reviewed for this study. A seven-year period beginning March 1, 2002 and ending February 28, 2009 was examined. This period was chosen because it included all available company training records and ends with the WDF training events that influenced the current research. The training records were examined for any evidence that firefighters had received instruction in strategies and tactics related to WDF emergencies. The records were also reviewed for any evidence of injury reported by a firefighter as a result of LFT.

A meteorological record review was conducted via the National Climate Data Center. This review was conducted to determine the average wind and wind gust norms for the City of Boynton Beach and to compare these figures to those of Chicago and New York. This information was used to identify how great a threat, if any, is the occurrence of a WDF event to firefighters in Boynton Beach.

Interview Methodology

Personal interviews were conducted to identify any information that might help to evaluate the effectiveness of the current WDF training program. A successful interview would yield subjective information, opinion, and cultural information, which would be helpful in gauging the fire department's readiness to accept strategies and tactics used to control WDF. Information obtained from the interview process could also be used to assess the fire department's acceptance of potential recommendations that may result from this study. The interview might also offer insight into the acceptance of the tactics validated through the study conducted on Governors Island by FDNY and the HKFD. The interview would also assist in determining what, if any, methods of training are being conducted that specifically address firefighting strategies and tactics for a WDF event at fire departments other than BBFR. Lt. John Ceriello was one of the principal participants in the study conducted on Governors Island. Lt.

Ceriello of FDNY was interviewed about the Governors Island Study and its effect on current training and operations at FDNY. Also interviewed was Dr. Shane LO Siu-hang, Deputy Chief Fire Officer of the Hong Kong Fire Services Department. Dr. LO was present as an observer at the Governors Island Study. Dr. LO was questioned about his experience and perception of risk from WDF in Hong Kong. The Hong Kong Fire Department (HKFD) protects an area with over 25,000 high rise structures within its jurisdiction.

Survey Methodology

Survey questionnaires were sent via email to fire departments across the US. Of the estimated 30,185 fire departments in the US, 156 responses were collected. The response represents only .005% of the estimated total population of US fire departments based on available figures (United States Fire Administration [USFA], 2007). The mailing lists were generated from the National Society of Executive Fire Officers, the Fire Training Officers of the Palm Beaches, and the Florida Fire Chiefs Association membership listings. Two international responses were obtained through personal contact with the respondents. Data from these were utilized as background information but were not included in the statistical data.

The survey (Appendix C) was for the purpose of identifying what, if any, further strategies exist that specifically address the control of WDF in a structure in addition to those discovered in the literature review. Additionally, the survey was utilized to discover what, if any, further tactics exist that specifically address the control of WDF in a structure in addition to those discovered in the literature review? The survey also would assist in determining what, if any, methods of training are being conducted that specifically address firefighting strategies and tactics for a WDF event at fire departments other than BBFR.

Testing Methodology

An examination (Appendix B) was administered to a sample group of firefighters at BBFR. All tests were administered under conditions of anonymity. The randomly selected group consisted of 62 of the 122 firefighters employed by the city. The examination was reviewed for its agreement with strategies used, and tactics validated by NIST as well as the description of a hallway involved in a WDF by John Ceriello of FDNY. The questions were separated into two categories. The first category contained strategic and tactical information that was covered in lecture format during a WDF training event. The second category included questions about safety, the recognition of the potential for a WDF, and the conditions a firefighter might experience during a WDF. The information covered in the second category was initially presented in lecture format, and then reinforced with LFT. The training was completed four months prior to the initiation of this research. The instructors and participants had no knowledge of this research at the time of the initial training. Subjects of the examination process included 33 firefighters who had participated in WDF training at BBFR within the past year and 26 subjects that denied having participated in any WDF training. The group consisted of a random sample of the total group and represented approximately 50% of the total group. It was assumed that this number provided an accurate assessment of the total group. Three subjects were excluded from the process as they had received WDF training other than at BBFR. The results of this test were used to assist in the discovery of evidence that may suggest that methods being utilized to train firefighters at BBFR to control a WDF may or may not increase their likelihood of a success during an emergency operation. An informal post-test discussion spontaneously began after the tests were collected. Feedback related to the examination was obtained and some criticism of the test was received and can be referenced in the discussion section of this research.

Risk Identification and Assessment Methodology

A hazard identification matrix and a vulnerability assessment were completed to assist in determining how great a threat WDF is to firefighters at BBFR. Additionally, risk rating was conducted for the same reason. A hazard-identification was performed to assess the areas of risk and the number of firefighters that could be impacted by WDF in Boynton Beach (Appendix C). Hazards were quantified by assuming a total loss of firefighters in companies that would normally respond to a fire emergency in each hazard class. The response numbers were extracted from SOG O-1 of Boynton Beach's standard operating guidelines (Carter, 2009). In addition, the numbers of at-risk personal generally agree with the response assignments in the Countywide High Rise SOG (Fire Training Officers of the Palm Beaches, 2008). Vulnerability to the firefighter was assessed through a vulnerability matrix (Appendix D). The presumed ease of egress from different building types was used as a measurement of the relative danger to firefighters from the hazards of WDF if present in a particular structure. Other factors such as the economic, environmental, and social impact that would result from the loss of a firefighter, as well as the effect a LODD could have on political planning, were considered. No effort was made to validate this assumed effect. A total risk rating was established by considering the probability of occurrence and the vulnerability of firefighters to WDF in a structure (Appendix E).

Assumptions and Limitations

Emergency run report narratives were basic and a description of weather conditions was not discovered for any fire that occurred during the period researched. There were few fires during the period examined that involved more than a single room and its

contents. Human error cannot be eliminated and resources were not available to verify each narrative against the sum total of each electronic record of events.

Risk assessment tools were modified from standard form to meet the needs of this study. The author found no existing researchable basis for the adaptation. Therefore the risk assessment is intended to be supportive and not scientific in nature.

The survey provided representation from fire departments across the nation. The responses, however, do not include every fire department in the nation and, in fact, represent a reserved response. A total of 156 fire departments responded to the survey. It is assumed that the answers received were based upon department records and the opinions of chief officers. It is assumed that the respondents were in a position to represent their departments. Due to the limited response size, it is assumed that a margin of error exists. No effort was made to determine this margin.

It was assumed that participants in the WDF classes conducted by BBFR received similar but not exact information from the instructors that facilitated the lecture portion of the class. It is also assumed that each WDF experience varied with the fire-load offered as a result of the need to reuse the prop for multiple classes. This created the possibility for a variation in the size and intensity of the WDF as new wood was added to patch and reinforce burned wood.

Results

Research Question 1: How great a threat, if any, is the occurrence of a WDF event to firefighters in Boynton Beach? Injuries and fatalities discovered during the literature review establish that WDF has been responsible for firefighter casualties during emergency operations. National Institute of Safety and Health reports cite wind as a contributing factor in many LODD cases. Many of the negative outcomes took place during emergencies involving high-rise

structures. In at least one case, a firefighter was killed in single family structure where it was established that wind was a contributing factor. A review of historical weather information indicates that the Boynton Beach area experiences wind conditions similar to those described in many of the LODD reports that were examined. An SOG does not exist at BBFR that references a wind speed that excludes an emergency response by firefighters to a structure fire situation. Ray Carter, who is the deputy chief of operations for BBFR, stated that, during hurricane conditions, firefighters would generally be expected to respond to a fire emergency in sustained winds of up to 50 mph depending upon the situation. He further reported that there is no way to know when a gust of wind off the ocean might exceed 50 mph under non-hurricane conditions (personal communication with Ray Carter, June 4, 2009). Reports for fires that occurred in Boynton Beach over the past four years include 204 structure fires. Response records indicate that a firefighter working for BBFR may be involved in a structure fire up to 6.7 times per year. Meteorological records indicate the average daily wind speed near Boynton Beach is 10 mph, with average peak wind gusts being 53 mph. This compares to an average daily wind speed in Chicago of 10 mph with peak wind gusts at 60 mph for the same period of record. Wind gusts that were measured at New York's JFK Airport and in Toledo, Ohio were significantly higher than those of Boynton Beach and were calculated at 75 mph and 71 mph respectively. The average wind speed for each of these points, however, was in line with Boynton Beach's 10mph daily average (NOAA, 1998).

Structure Fires in Boynton Beach rarely involve much more than a room or two and their contents. Most of the structure fire records examined were of single story residences. Wind was never cited as a contributing factor in any fire report narrative over the period examined. Data from the NIST study, however, suggests that wind may have been a factor in more than 10 fires

that occurred in the State of Florida over the past 63 years. Additionally, the introduction of high-rise structures in the city of Boynton Beach, which first occurred in 2006, significantly changes the city's risk potential (personal communication with Jim Macintyre, Assistant Fire Marshall BBFR, 2009).

Survey results reveal the following information about fire departments in general: Fifty respondents, representing 32.1% of the sample group, reported that firefighters in their jurisdictions have experienced a WDF. Another 80 respondents, representing 51.3% of the sample group, reported firefighters in their jurisdictions are very likely to experience a WDF. Nearly 60% of respondents have high rise structures in their jurisdiction.

Risk identification and hazard assessment tools were adapted from the EASFSOM student manual to examine the risk of WDF to firefighters in Boynton Beach. Standard response guidelines were used as a predictor of how many firefighters would be involved in a typical fire response for each of the different occupancy classes. By using this information, it can be assumed that between 6 and 15 firefighters could be seriously affected by WDF event during a structure fire in Boynton Beach. The lowest number of firefighters at risk was 6 and was based on single and two-story structural response guidelines. The highest exposure to risk was in high-rise structures, with a possibility of at least 15 firefighters being at risk from a WDF event. A total score between eight and twelve indicated that firefighters in Boynton Beach were at least moderately vulnerable to the hazards of WDF. A risk disaster rating with a range of one to four was generated with one being the lowest and four being the highest risk. The result of the matrix reveals that WDF in high rise structures has the highest potential for disaster risks to firefighters in Boynton Beach. Two-story structures also pose some risk but the risk is lower in potential for

frequency and loss. Other structures have some risk to firefighters, but significantly less than the previous two categories.

Research Question 2: What strategies exist that specifically address the control of WDF in a structure? Literature reviewed for strategies related to the control of WDF revealed that controlling the wind was a major strategic objective. A second strategy discussed involved limiting any attempt at a direct attack on the fire until the fire has been darkened or knocked down by an indirect attack. Additionally, the pressurization of a structure using PPV was found within the existing research materials. Finally, locating an area of safe refuge for a shelter in place operation was cited as a strategy to ensure the safety of responders as well as victims.

Results of a survey requesting strategies in use by fire departments in the nation failed to add any significant strategic suggestions. Some suggestions that were submitted via the survey were excluded for reasons of non-relevance to WDF in the structural setting.

Research Question 3: What tactics exist that specifically address the control of WDF in a structure? Literature related to tactical considerations for the control of WDF that were validated via the NIST study at Governors Island was reviewed. Tactics for the control of wind included the use of a wind control blanket or K.O. Curtain over the windward side of the fire room. Additionally, a firefighter should be assigned to control the door leading into a potential WDF area. An indirect attack strategy can be supported by including the use of an aerial apparatus, HRN, or a wall breach maneuver to allow firefighters to darken down the seat of a fire before an entry team attempts direct extinguishment of a WDF. For the pressurization of the structure, the use of PPV or PPA fans was researched and validated by NIST. A shelter in place operation includes finding an area of safe refuge before entering the fire room.

Results of a survey requesting additional tactics in use by fire departments in the nation added the following tactical operation: The use of natural wind was suggested to pressurize the building and counteract a WDF. The survey respondent suggested that this could be accomplished by breaching windows on the same side as the fire room and channeling the wind to the fire-involved room by way of the hallway.

Research Question 4: What, if any, methods of training are being conducted that specifically address firefighting strategies and tactics for WDF? Respondents to the survey that reported having a WDF training program were in the minority. Survey results revealed that 144 jurisdictions representing 92.3% of the sample group deny any form of training program that specifically addresses firefighting strategies and tactics for a WDF event. Of the remaining 12 respondents, 7 reported that they had used a DVD from the NIST study as their training source, 4 were excluded for reasons of non-relevance to structural firefighting, and one respondent received training through the BBFR program. Firefighters at BBFR received no training specifically for strategies and tactics for the control of WDF prior to 2008. Starting in 2008 firefighters received lecture based training and a LFT component. Although there were lecture and LFT components, there were no hands-on exercises that reinforced the tactical skills of door control, deployment of a WCD, or the use of a HRN.

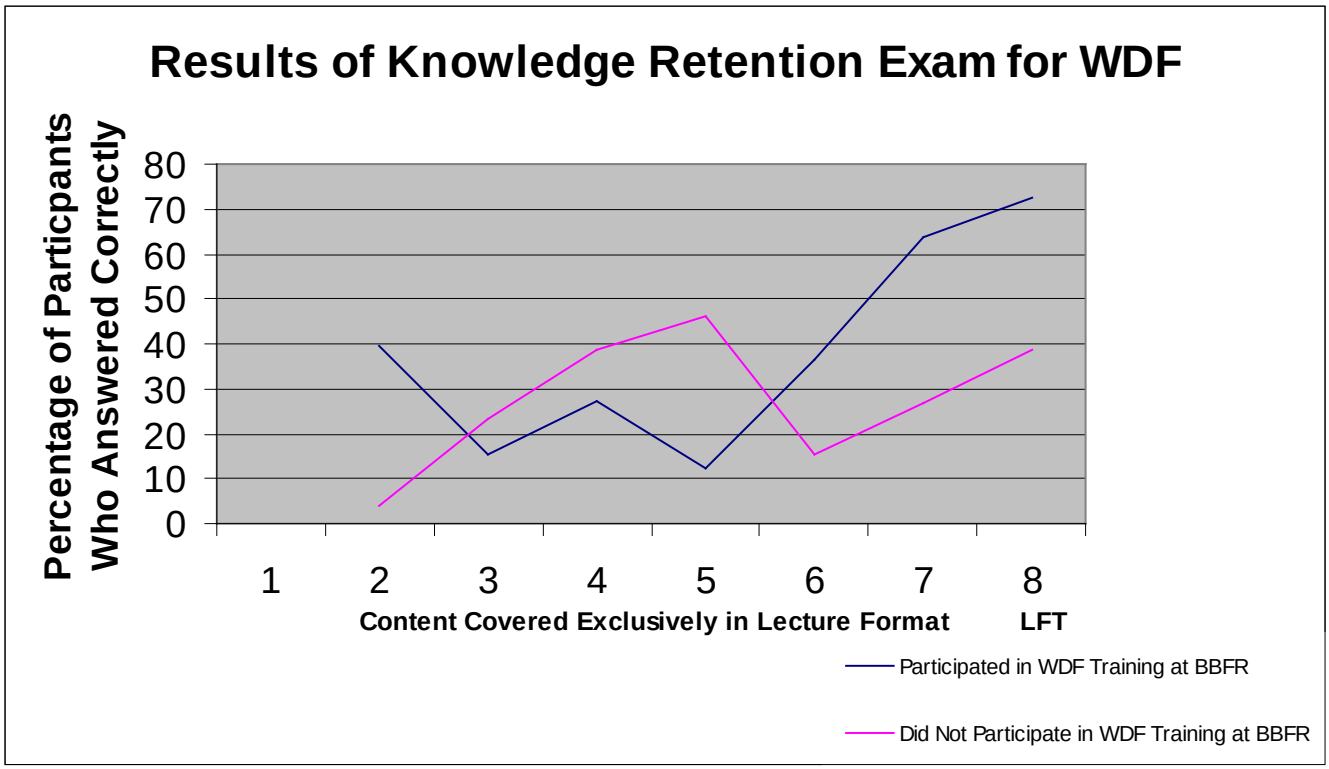
Some additional information was discovered as a result of interviews conducted with John Ceriello and Dr. Shane LO Siu-hang. According to Lt. Ceriello, FDNY was conducting lecture based and hands-on training for the control of WDF. He reported however, that there was no LFT component and stated that he believes that it would be helpful to have one, since he feels that most firefighters don't really understand how intense WDF can be without seeing it. He also reported that merely watching a video of the training might give them a false sense of security.

Dr. LO reported that the HKFD has not adopted many of the concepts researched on Governors Island. Dr. LO confirmed that the HKFD was very interested in the concept of stairwell pressurization. He also affirmed that, although it would not be practical in a fire department the size of his, he felt that LFT for the control of WDF would be the best method of delivery to reinforce strategies and tactics for WDF.

Research Question 5: What, if any, evidence is available to suggest that the methods being utilized to train firefighters at BBFR to control a WDF are safe for use in training firefighters? The results of the literature review revealed that the NFPA has written guidelines that address the design of an exterior prop used in LFT. They do not, however, have guidelines that address the design and use of a prop built for use inside a LFT structure. Given that there are no existing guidelines, the use of the prop was examined to see if it would conflict with any guidelines covering traditional use of the LFT center. Again, no conflict was found (NFPA 1402, 2002). Additionally, a standard exists which describes how LFT must be conducted. A records review of LFT events at BBFR produced documents that show LFT at BBFR is conducted in accordance with the standard.

Research Question 6: What, if any, evidence is available to suggest that the methods being utilized to train firefighters at BBFR to control a WDF will increase their level of safety and improve their likelihood of a success during an emergency operation? An exam was administered randomly to half of the firefighters who currently work for BBFR. Examination question 1 separates participants who attended the WDF class at BBFR (Appendix B). Examination question 2 refers to the participant's knowledge of the research conducted on Governors Island. A mere 3.8% of test participants who had not attended the WDF training program at BBFR were aware of the research conducted by NIST, while nearly 40% of those

who attended the training program knew of the study. Examination questions 3-6 are specific to strategies and tactics that were presented exclusively in lecture format. Firefighters who did not attend the WDF training scored higher in three of the four questions related to strategies and tactics for WDF. Examination question 7 identifies the participants' recognition of WDF potential from the identification of observable signs. This was also presented exclusively in lecture format in the WDF training. A majority of firefighters, more than 63%, who had attended the training, recognized the signs of WDF potential, while less than 27% of those who had not attended the training were able to identify signs of WDF in a structure. Examination question 8 references safety decisions based on an understanding of interior conditions experienced during a WDF. This information was covered in lecture and reinforced using a hands-on approach using LFT in a WDF. Of the majority of firefighters who answered question nine correctly, nearly 73% were from the group that had attended the LFT for WDF class at BBFR, notably less than 40% of test participants who had not attended the training arrived at the same conclusions.



In summary, conditions are favorable to support the existence of WDF in Boynton Beach, Florida. Firefighters at BBFR are likely to experience a WDF in the performance of their job as a fire suppression resource. Documented cases exist in which firefighters have died as a result of WDF. The recent addition of high-rise structures in the city significantly increases the risk to the life and safety to firefighters at BBFR. Firefighters have strategies and tactics available to them that have proven effective in the control of WDF in the structural setting. These strategies include mounting an indirect attack on the fire and initiating one of the many wind control measures which were utilized by FDNY during the Governors Island study. Safety strategies, such as providing a safe haven for the entry team prior to opening up the fire-involved apartment, have been field tested by FDNY and are also effective in the preservation of firefighters' life and health. Tactics for the implementation of these strategies have also been introduced, tested, and found to be useful in the control of WDF. One additional tactic, the use

of natural ventilation to pressurize the building, was discovered via the survey tool. Training for firefighters specifically targeted at the control of WDF is minimally occurring. When training occurs, it is generally being delivered via lecture format or by other means of passive learning systems such as the viewing of a DVD presentation. The program at BBFR is the only combination of lecture and LFT for the control of WDF that was discovered through the results of the nationwide survey. Results of a test administered proved that the combination of lecture based and LFT at BBFR did not provide an effective knowledge base for strategies and tactics for the control of WDF. The result, however, did provide evidence to support that firefighters who participated in this training were better able to recognize the signs of and conditions inside a structure subject to a WDF.

Discussion

There is an expectation by the general public that firefighters are highly trained individuals who willingly risk their lives to protect the public during emergency situations. Firefighters have an expectation that their officers will protect them through sound strategies, effective tactics, and quality training. Firefighters must be prepared to respond to a variety of high-risk situations that may pose a threat to their safety. Some high-risk assignments are regionalized and specific. Others are widespread and universal. It is therefore necessary for firefighters to know dangers specific to their area as well as those that are not. Research clearly indicates the firefighters at BBFR are at risk from WDF. Weather history in the Boynton Beach area is consistent with conditions that have produced documented occurrences of WDF in cities across America (NOAA, 2009). Standard risk assessment tools are of limited value in relationship to WDF, since they primarily focus on high dollar values and large numbers of casualties. Contrary to risk practices that focus primarily on risk to large populations, a focus of

the NFPA is to reduce firefighter LODDs by 25% (USFA, 2002). The loss of even a single firefighter to WDF is not acceptable and must be prevented. Although there has not been a LODD recorded for a firefighter in Boynton Beach, firefighters who work for the city are required to conduct many high-risk activities while in the performance of their duties. Along with other hazardous duties, firefighters at BBFR have a documented history of responding to structure fires six to seven times a year on average (BBFR, 2009 response records). Since conditions that could produce a WDF exist on a daily basis, data suggests that firefighters at BBFR should be considered an at-risk group from this phenomenon (NOAA, 2009). The need for an effective training program to deal with this risk would include the conveyance of strategies and tactics to minimize the risk.

Many of the strategies to control WDF which had previously been identified through the experiences of departments such as the OFD of Canada, the TFD, The CFD, and FDNY, were utilized by NIST in a WDF study which was conducted on Governors Island, New York (Kerber & Madrzykowski, 2009). These strategies included an indirect attack and the use of WCDs. Other strategies, such as building pressurization and the securing of a safe haven prior to making entry into a room with WDF potential, are current practice in many jurisdictions and have been credited by FDNY with saving lives (Daly Jr., Healy, 2006). Each of these strategies required the implementation of tactics specific to the control of a WDF.

Tactics utilized to execute these strategies included the use of a K.O. curtain, a wind blanket, the HRN, and door control (Kerber & Madrzykowski, 2009). The study published by NIST in 2009, which was conducted with the assistance of PI and FDNY, helped to validate many tactics for the control of WDF (Kerber & Madrzykowski, 2009). The research propelled the strategies and tactics used in the study their current status as industry standards. The need to

disseminate training for these industry standards is part of an ongoing challenge to the industry. Additional tactics that were not part of the WDF study at Governors Island, merit further examination. One suggestion discovered was to utilize the natural ventilation that feeds the WDF to counter the advance of fire. This would be accomplished by opening windows on the windward side of the building. No published research was available for this tactic. Lt. John Ceriello reported that this was not included in any of the research projects conducted on Governors Island. He further stated that it might have possibilities (personal conversation with John Ceriello, October 2, 2009).

Training that specifically addresses the strategies and tactics needed for the control of a WDF has begun across the country. The survey revealed however, that most of the training which is being conducted has been primarily limited to lecture format and to the viewing of the related NIST or FDNY DVDs. In contrast, the training program at BBFR includes a combination of lecture-based and LFT, the latter of which takes place in an engineered WDF prop. The WDF prop does not include any components that would place it in conflict with NFPA 1403 Standard on Live Fire Training Evolutions. It does in fact, offer the additional safety measure of a sprinkler system, which is utilized to control and extinguish fire remotely. The prop is designed so that firefighters do not need to enter the fire-involved room or hallway to view or extinguish the fire. Training records at BBFR confirm that there have been no injuries related to LFT in the past three years. This time period includes the duration that the WDF prop has been utilized in Boynton and the time period for which following NFPA 1403 has been a statutory requirement in the state of Florida (Florida State Statutes, 2006).

Surprisingly, the use of the WDF prop in training offered mixed results regarding whether the training could predict the effectiveness of firefighters during an actual WDF event.

Surprisingly, the results of testing indicated that firefighters who participated in the WDF training program at BBFR did not have an increased level of strategic and tactical knowledge for the control of WDF when compared to a control group. This result may be due to the fact that strategies and tactics were presented solely in lecture format. Further examination of this issue is warranted. Test results also revealed that firefighters who had experienced WDF in the training atmosphere were more accurate in recognizing the potential for and signs of WDF. They also had a more realistic view of the potential for survivability in a hallway involved in a WDF event.

Some intricacies of the training process should be discussed at this point. During the course of the training program, there were 11 separate deliveries of the course. Each lecture was conducted by one of three instructors. No attempt was made to compare lecture styles nor the comprehensiveness of content delivered. Additionally, hands-on training for participants was limited to exposure to WDF and did not include a hands-on practice for tactics used to control the fire. In fact, no hands-on training was offered which reinforced the use of WCDs, indirect attack methods, or the securing of a safe room.

It is interesting to note that in posttest discussions, some criticism of the testing tool was received. Question 8 referenced a firefighter's ability to survive in a hallway in which a WDF was occurring. Just over 63% of the participants who had participated in the WDF training at BBFR reported that the event would not be survivable. Almost 47%, however, indicated that they might be able to survive if they stayed low and retreated. This response would not be expected from anyone who attended the training. When asked why they chose to answer this way, the general consensus was that they answered the question based on fire behavior tactics learned in their original recruit training. The practice of staying low to escape from a fire is a basic survival tactic that was learned, and they believed that, if there was a way to survive, this

would be their best chance. This strategy is based on convection currents of fire that is not affected by wind. Many did not like the answer that left no option for survival. Most firefighters agreed that, during the training, they witnessed the thermal imbalance of the forced convection currents in the WDF prop. They reported that fire was present from floor to ceiling. Most firefighters agree with (Ceriello, 2009), that this condition is not compatible with life. However, during the test, most reported that they gave the answer that they felt we were looking for. In discussion however, nearly all firefighters who had experienced the WDF training admitted that being caught in WDF for any period of time would not be survivable. A few logical conclusions can be drawn from the testing and subsequent discussion. The first is that the testing mechanism alone may not be an accurate predictor of performance, since most firefighters who answered incorrectly admitted they were trying to answer the test based on prior performance in basic fire growth and behavior training. More significant is that those who answered that the scenario would be a non-survivable event most likely came to this conclusion by drawing from their recent training experience. Based on this assumption, these firefighters would be more likely to recognize a WDF phenomenon as it was forming. Additionally, they could be expected react to an emerging WDF fire as they had during their recent training experience. Most importantly, they would recognize and attempt to avoid the hazard and any attempt at a direct attack. There is sufficient information available in the literature review to support the belief that the hands-on-training experienced by firefighters in the engineered WDF environment would accurately predict their performance in a WDF emergency. It is therefore logical to assume, that a firefighter who was trained using LFT would be better equipped to respond to a WDF. They would be expected to use the correct strategies and with the correct tactics, if the strategies and tactics were incorporated into a hands-on training component.

Given the results of this study, BBFR now has sufficient justification to continue the WDF program and to make modifications to the program that will increase its effectiveness.

Recommendations

Recommendations for the training and education firefighters for the control of WDF include:

- A revision needs to be made to the component of the training program that covers strategies for the control of WDF.
- A hands-on training component needs to be added to the BBFR training program for the instruction of tactics that support strategies for the control of WDF.
- Further testing and standardization of the engineering and construction of the WDF prop should be attempted to ensure that each participant experiences safe, consistent, and realistic WDF training.
- After the suggested components have been instituted, the program needs to be re-evaluated to measure the effectiveness of the program modifications.
- The tactic of natural ventilation for building pressurization and wind control requires further study and validation.

The strategies that are currently delineated only in lecture format should be reinforced through discussion. The program should allow participants the opportunity to share their understanding of industry accepted strategies used in the control of WDF. The facilitator should ensure that each student understands the reasons why an indirect attack might save the lives of firefighters who are attempting an assault on a WDF. Firefighters should discuss the pros and cons of wind control. They also should consider and discuss the risks versus rewards of taking the time to open up a safe room near the fire-involved room.

A hands-on training component needs to be added to the BBFR training program for the instruction of tactics that support strategies for the control of WDF. This component should include the use of the HRN the K.O. Curtain, PPV/PPA fans, exterior attack and wall breaching techniques, and the use of door control.

The plans for the WDF prop should be redesigned for standardization of design, and to ensure maximum effectiveness and safety. The WDF prop used for the training was built to sustain multiple fires of extended duration. During the training period, it was necessary to repeatedly repair and ultimately rebuild the system, often using whatever materials were on site. This sometimes caused a variation in the timing and intensity of the WDF effect that was created. This occasional disparity could account for some variation in the results of the study. It also opened the door for instructors to customize the intensity of the WDF by increasing or decreasing the fire load to meet their individual preferences. In order to more accurately assess the effectiveness of this type of training, and to keep safety standards uniform, the fire load should be calculated and the prop should function from a standardized fire load that produces a calculated and acceptable range of British Thermal Units for each training event.

After the suggested components have been instituted, a second evaluation needs to be conducted to measure the effectiveness of the updated WDF control training program at BBFR. This evaluation should be conducted by an independent research agency and involve firefighters who have not received training on the topic. The program should also be evaluated for compliance to the standards utilized by FDNY, which is by virtue of its involvement in the research at Governors Island, considered to be an industry leader in the control of WDF.

The tactic of using natural ventilation to counter the effects of WDF can be examined using an engineered burn building set up for WDF. A building exists for regional use at the

Palm Beach County Fire Rescue training facility. Trainers from BBFR and Palm Beach County Fire Rescue, along with the assistance of Palm Beach State College, should take the lead in conducting testing of the effects of natural ventilation on WDF. Contact should be maintained with FDNY and NIST for assistance in the research. Standardization of the WDF prop should be made prior to any use for research purposes.

These recommendations were designed to increase the effectiveness of firefighter training for the control of WDF. The BBFR training program includes a hands-on LFT component that could serve as a model for other jurisdictions. In order for this to occur, the program must be reconstructed to include a hands-on training component using tactics that support accepted strategies for the control of WDF. Standardization of the engineered WDF simulator would allow the system to be built and utilized by fire departments throughout the United States and abroad. The inclusion of FDNY and NIST in the evaluation would help to ensure that the training is scientifically assessed and that industry standards for the control of WDF are being accurately represented.

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Appendix A

Course Name: Control of Wind Driven Fire in the Structural Setting.

Course Facilitator: Raymond Altman, Division Chief of Training and Safety for Boynton Beach Fire Rescue Fire Instructor III, LFTI # 123402

Course Duration: 2.0 hours
Block of Time allotted for Course 2.0 hours includes registration and pre and post vital sign acquisition.

Course Description: This course is designed to introduce the participant to strategies and tactics used to combat Wind Driven Fire (WDF). The course is delivered using a combination of lecture based and hands-on training. Lecture content includes tactics utilized by FDNY and validated through a study performed on Governors Island, NY which was published by NIST in 2008. During the component, Instructors are introduced to a Live Wind Driven Fire that is designed to safely allow the participant to experience the affect that a 5-10mph wind can have on a structure fire.

Course Background Information:

Purpose: This course provides instruction for persons who have need of information about wind driven fire in the structural setting.

Target Audience: firefighters, fire officers, and fire instructors

Instructor to Student Ratio 1:5 Max preferred ratio is 1:3

Enrollment limit 15 students

Course Objectives:

- The participant will be able to describe the signs that a structure is being impacted by wind driven fire.
- The participant will be able to discuss strategies that can be used to combat wind driven fire in a structure.
- The participant will be able to discuss tactics that can be used to combat wind driven fire in a structure.
- The participant will observe the changes that occur when wind impacts fire in a structural setting and he/she will establish this information as a baseline for recognition of wind driven fire in the uncontrolled setting of a structure fire.

Course Content:

- Lecture Information
  - History of WDF research
  - LODD related to WDF
  - FDNY/NIST study @ Governors Island
  - Pilot training programs for the control of WDF
- Training
  - Safety briefing
  - Visual observation of fire growth and behavior
  - Visual observation of the effects of 5-10 mph wind on fire growth and behavior
  - Training review and critique

Module #1	Course Overview and Lecture	(30min)
	Q/A	(10min)
	Break	(10min)
	Medical Prescreening	(10min)

Module #2 Exercise (60min)

Briefing and assignments	10min
Safety Walk-through	10min
Safety Check	5min
Attack Rotation	5min
Back up Rotation	5min
RIC Rotation	5min
Rehab	10min
Review	5min
Rotate	5min

Logistics Overview:

Water for Hydration
Ignition Source
Pandora's Box system see attached plans
Sprinkler System
8 sheets of 4x8 inch plywood to line the walls of the building will last through 4 days of burning with the first 2 pieces being replaced after every burn
Thermal Imaging Camera with temperature gauge
2 Engines, 1 ¾ attack line, 1 ¾ safety line
2 Training Instructors

5 Adjunct Trainers
1 each: entry officer, ignition officer, pump operator, ventilation officer

Facility Needs:

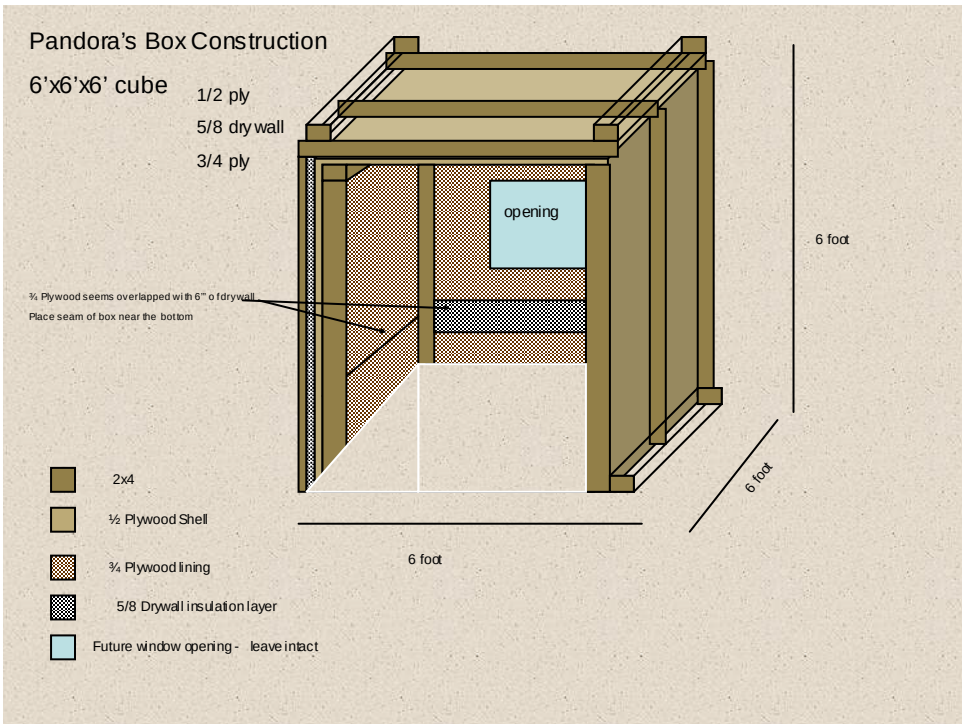
Engineered Burn Building, Conex Fire Prop, or acquired structure
Area for lecture and to show electronic visual presentation

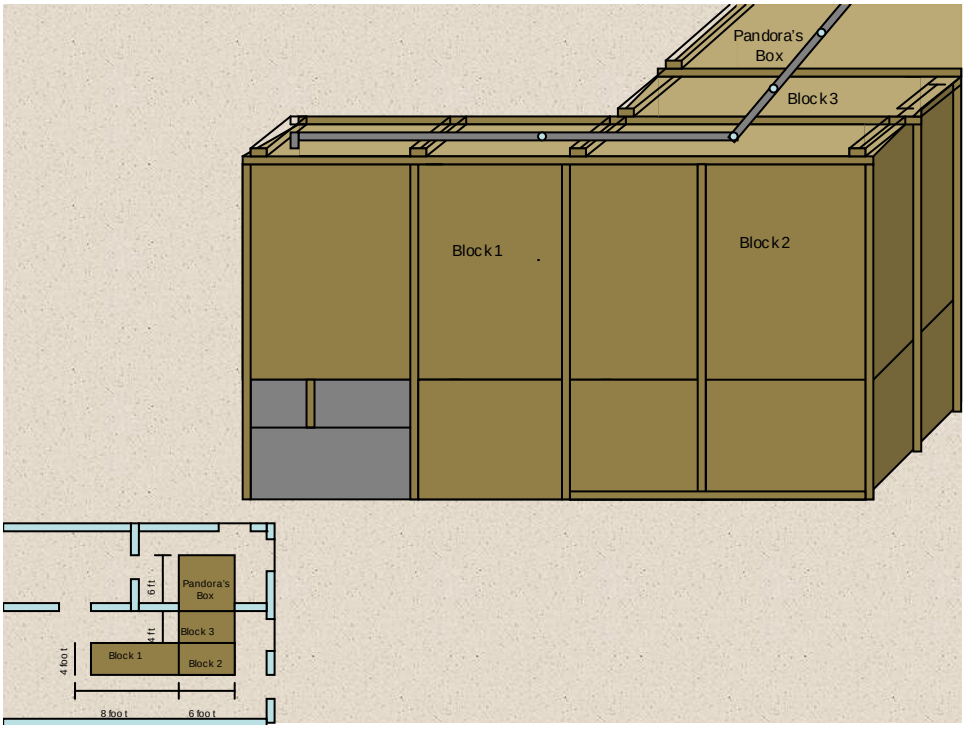
Course Materials:
Hand outs
Copies of NIST-GI study on CD

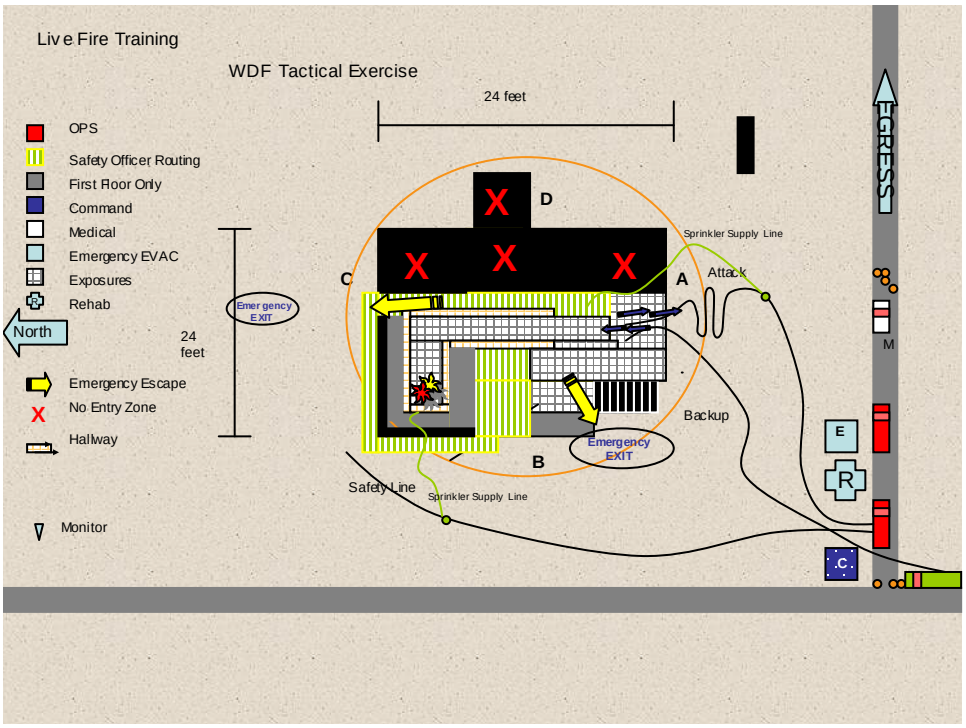
A/V Equipment Needs:

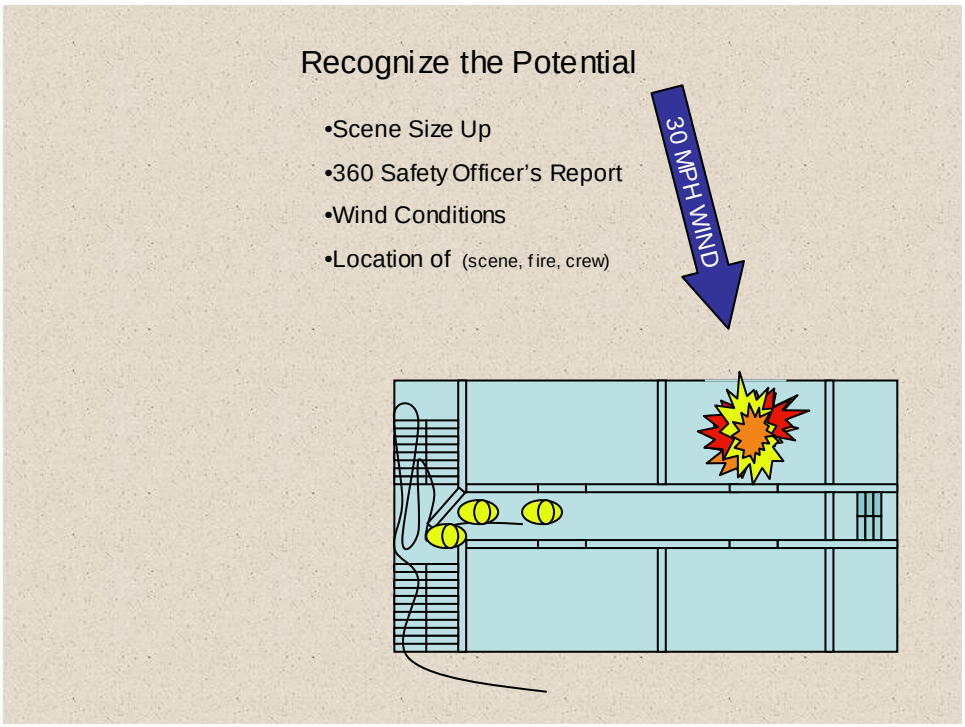
Computer, Projector, and screen

Appendix B


Pandora's Box Construction
6'x6'x6' cube
1/2 ply
5/8 dry wall
3/4 ply
opening
6 foot
¾ Plywood seems overlapped with 6" o f drywall
Place seam of box near the bottom
6 foot
6 foot
2x4
½ Plywood Shell
¾ Plywood lining
5/8 Drywall insulation layer
Future window opening - leave intact

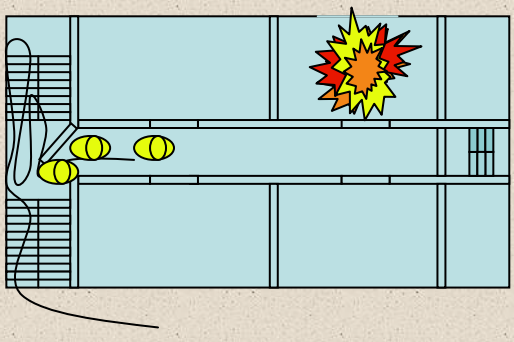

Pandora's Box
Block 3
Block 1
Block 2
6 ft
4 ft
4 foot
Pandora's Box
Block 3
Block 1
Block 2
8 foot
6 foot

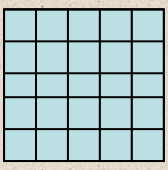

Live Fire Training
WDF Tactical Exercise
24 feet
OPS
Safety Officer Routing
First Floor Only
Command
Medical
Emergency EVAC
Exposures
Rehab
North
24 feet
Emergency Escape
No Entry Zone
Hallway
Monitor
Emergency EXIT
EGRESS
D
C
A
B
Sprinkler Supply Line
Attack
Backup
Emergency EXIT
Safety Line
Sprinkler Supply Line
M
E
R
C


Recognize the Potential
•Scene Size Up
•360 Safety Officer's Report
•Wind Conditions
•Location of (scene, fire, crew)
30 MPH WIND

Read The Fire

- Fire Presentation (is there a blow torch effect)
- Flames (are flames hidden within the smoke)
- Hot gases (are flames rapidly rolling or dancing slowly)





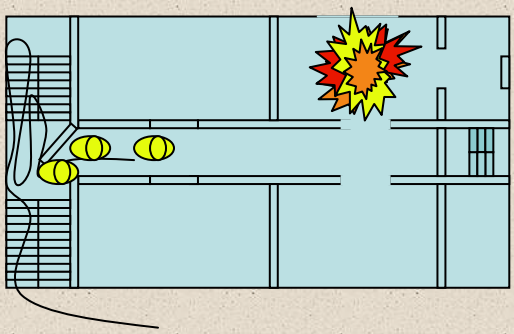
Other Considerations

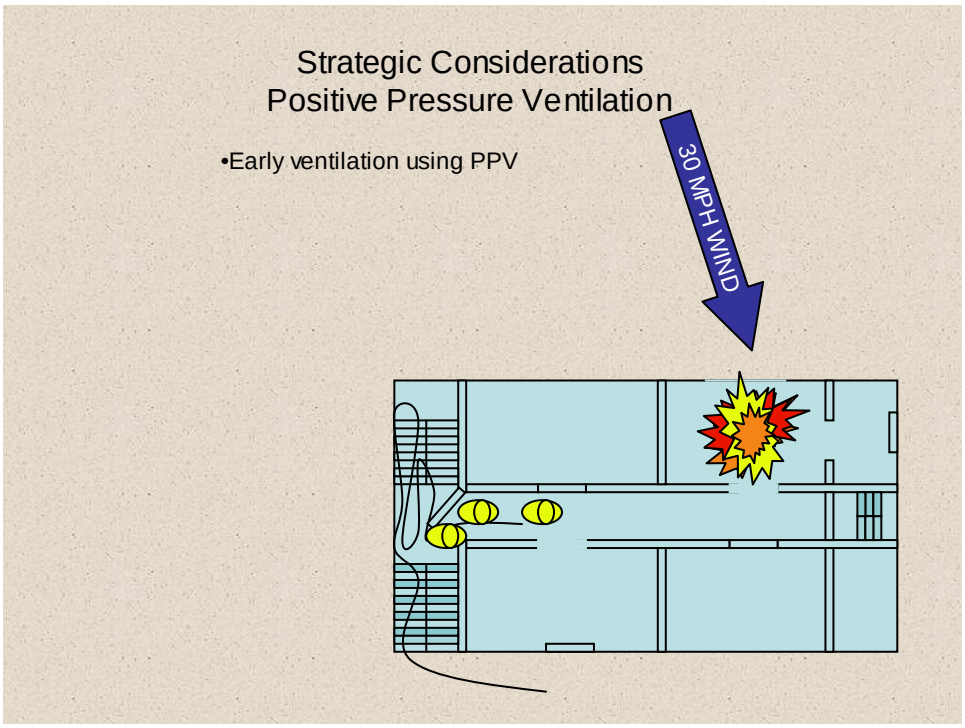
Wind Direction

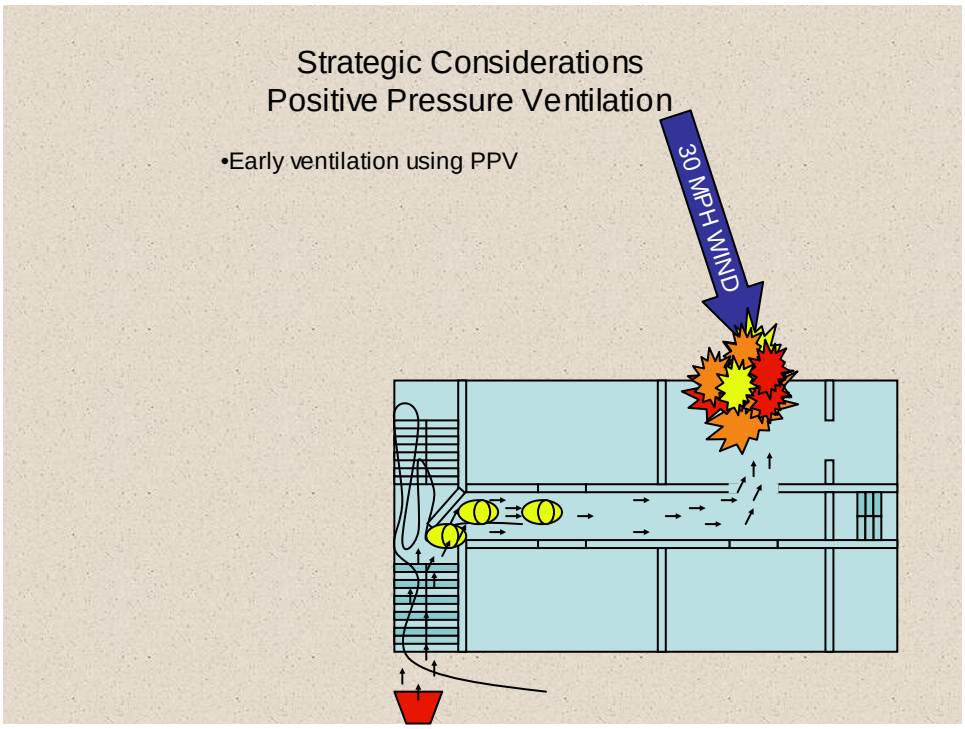
Wind Velocity

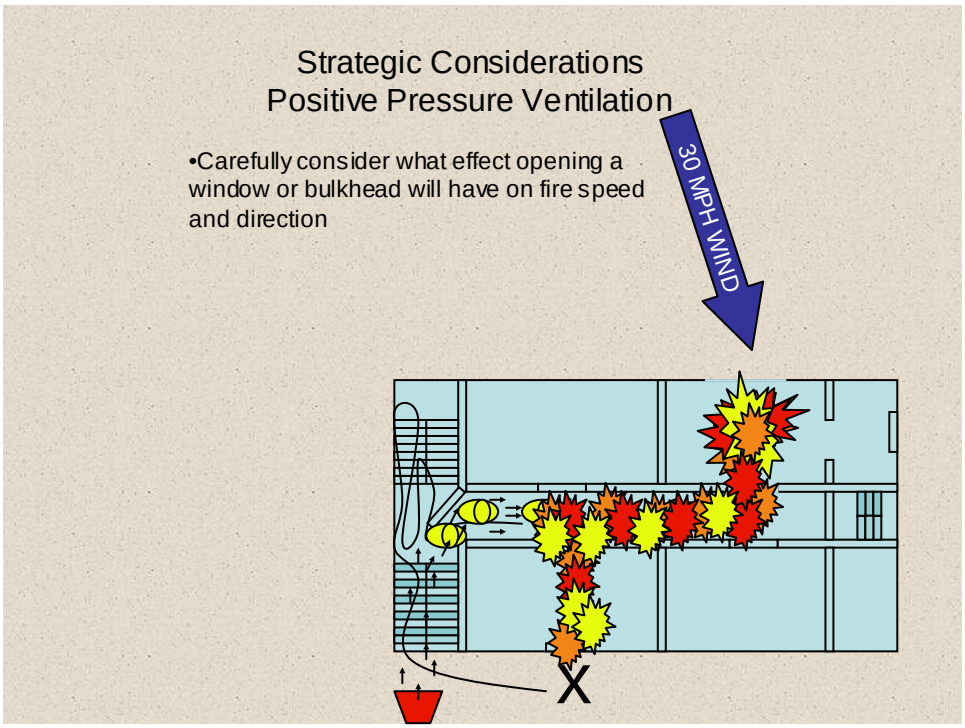
Wind Volume

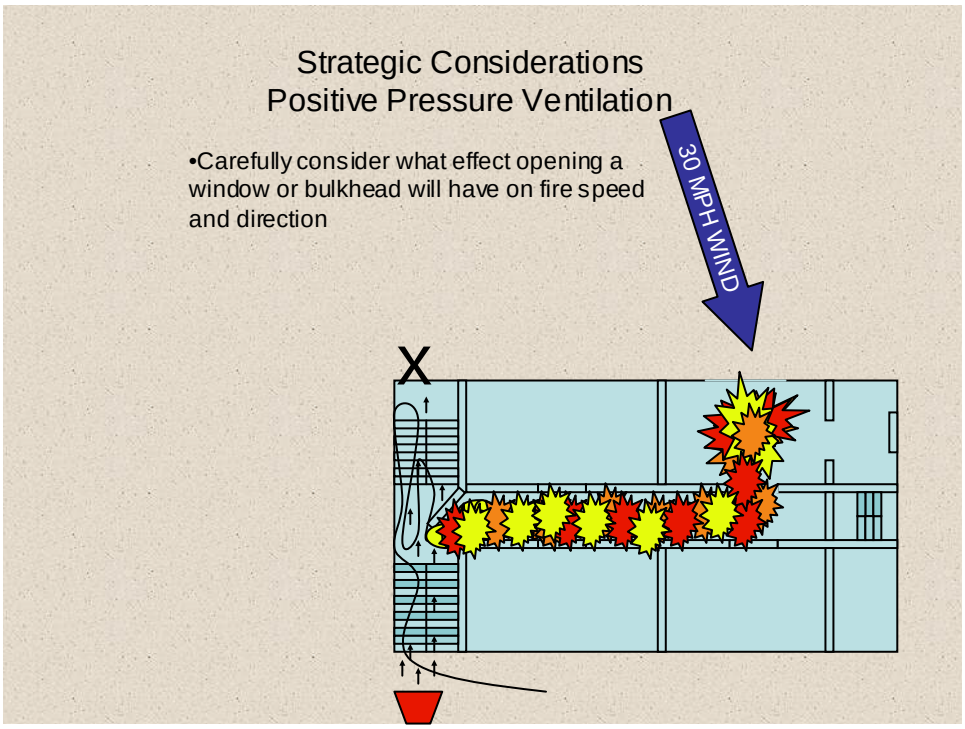
(consider the size of the windward openings)

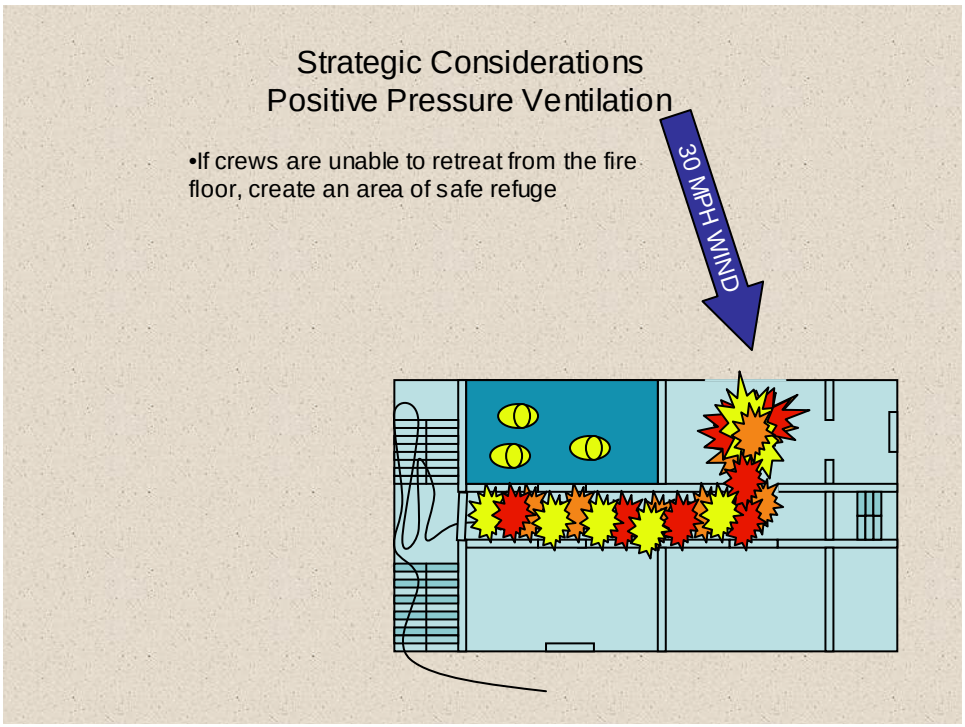


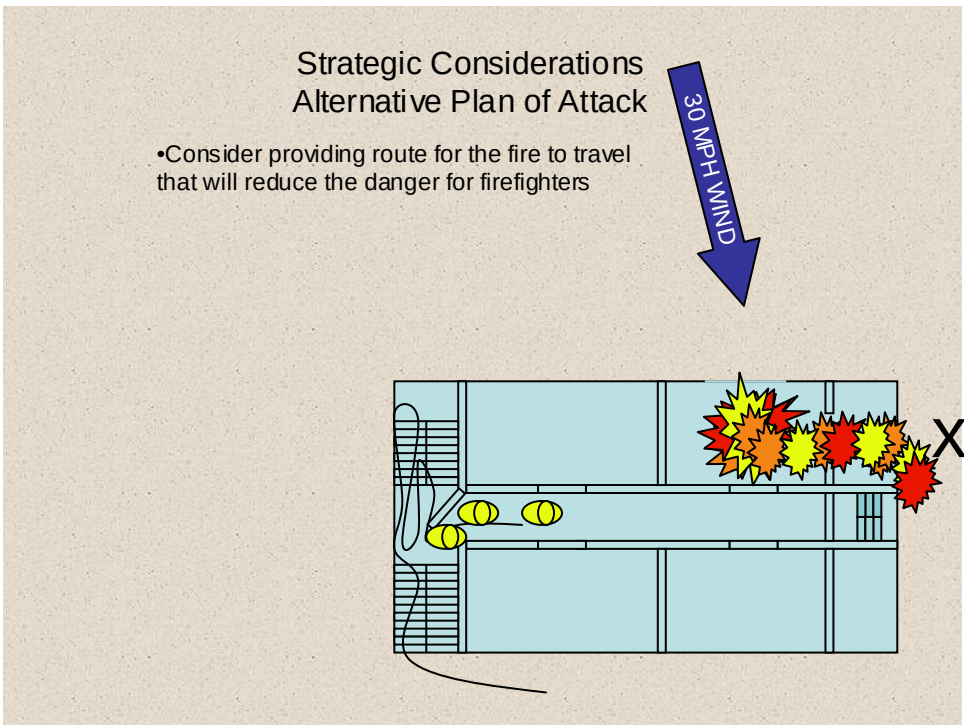

Strategic Considerations
Positive Pressure Ventilation
•Early ventilation using PPV
30 MPH WIND


Strategic Considerations
Positive Pressure Ventilation
•Early ventilation using PPV
30 MPH WIND


Strategic Considerations
Positive Pressure Ventilation
•Carefully consider what effect opening a window or bulkhead will have on fire speed and direction
30 MPH WIND
X

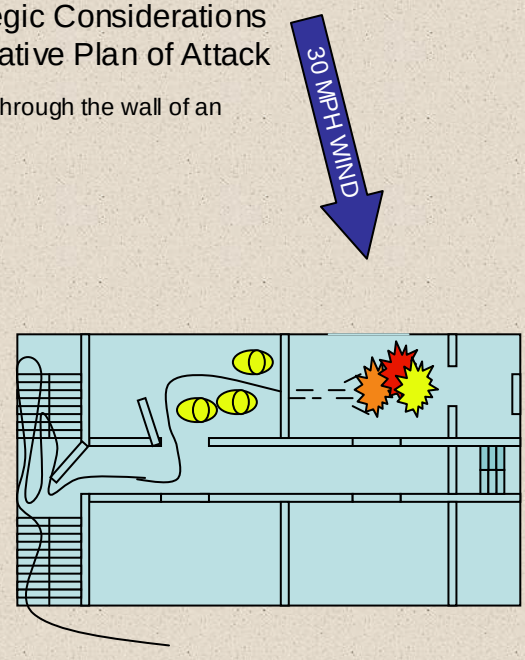

Strategic Considerations
Positive Pressure Ventilation
•Carefully consider what effect opening a window or bulkhead will have on fire speed and direction
30 MPH WIND
X


Strategic Considerations
Positive Pressure Ventilation
•If crews are unable to retreat from the fire floor, create an area of safe refuge
30 MPH WIND


Strategic Considerations
Alternative Plan of Attack
•Consider providing route for the fire to travel that will reduce the danger for firefighters
30 MPH WIND
X

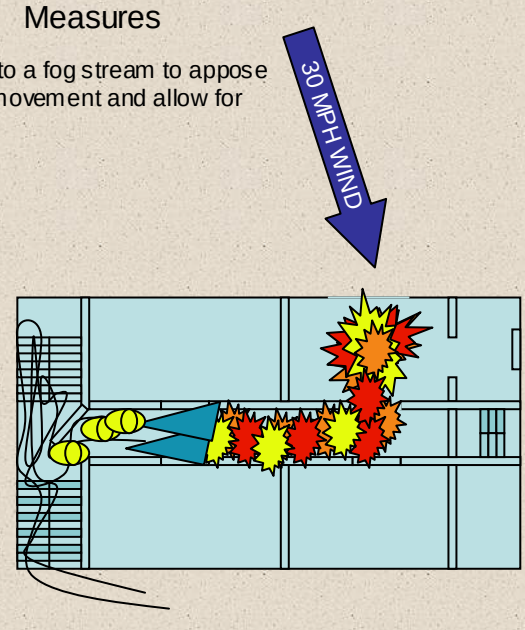
Strategic Considerations
Alternative Plan of Attack

•Consider attacking through the wall of an adjacent room



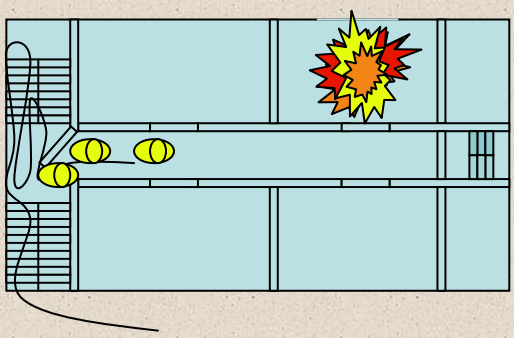
Emergency Evacuation Measures

•Consider switching to a fog stream to appose the wind driven fire movement and allow for safe egress.



Strategic Considerations
Alternative Plan of Attack

- Recognize the need for BIG Water early
- Report that you suspect a wind driven fire to command.
- Ask for additional resources
- Know when to back out of a fight



Appendix C

Survey #1 Examining Firefighter Training Under Wind Driven Conditions

This survey is being conducted as part of the National Fire Academy course, Executive Analysis of Fire Service Operations in Emergency Management. The data acquired from this survey is collected anonymously. This data will be used as part of an applied research project, the results of which should be available through the Learning Resource Center after January of this year. Thank you in advance for your contribution of time and your interest in the advancement of fire service safety and education.

Please feel free to contact the author of this survey with any questions, concerns, or additional comments.

Ray Altman
Division Chief of Training and Safety
Boynton Beach Fire Rescue
2080 High Ridge Road
Boynton Beach, FL 33426
almtanr@bbfl.org
561-602-1230 cell
561-742-6326 office
561-742-6334 fax

1. Please select the description that best fits your primary title or responsibility for your agency.

__ Fire Chief / Director of Emergency Services
__ Asst., Dept., or Bat. Chief / Operations
__ Asst., Dept., or Bat. Chief / Safety
__ Asst., Dept., or Bat. Chief / Training
__ Asst., Dept., or Bat. Chief / Administration
__ Asst., Dept., or Bat. Chief / EMS
__ Asst., Dept., or Bat. Chief / Prevention
__ Other

2. A wind-driven fire occurs when air moving with sufficient velocity and volume is introduced into the free-burning stage of fire development. This causes the fire to increase in size and intensity, thereby creating a blowtorch like effect.

How likely is it that your firefighters will experience this phenomenon while working a structure fire in your jurisdiction?

Please rate the likelihood of this condition occurring at a structure fire within your jurisdiction.

__ Firefighters in my jurisdiction have already reported experiencing this phenomenon.
__ Firefighters in my jurisdiction are very likely to experience this phenomenon.
__ Firefighters in my jurisdiction are unlikely to experience this phenomenon.

3. Jurisdictional Data - Population Information

__ 1-10,000 people
__ 10,000 to 100,000 people
__ 100,000 and above

4. Jurisdictional Information - Primary Property Usage

__ Wildland with limited structures
__ Wildland with urban interface
__ Rural residential
__ Rural commercial
__ Mixed rural / urban
__ Urban residential
__ Urban residential with high rise structures
__ Urban mixed residential / commercial
__ Urban mixed residential / commercial with high rise structures
__ Urban commercial
__ Urban commercial with high rise structures
__ Urban city environment with high rise structures

5. If you have high rise structures in your jurisdiction, please indicate the tallest structure.

__ All buildings in my jurisdiction are less than 15 stories
__ 15 to 20 stories
__ 21 to 50 stories
__ 50 and above

6. Is your jurisdiction frequently threatened by severe wind events? If so, check all that apply.
Note: For the purposes of this research, "threatened" will be defined as "conditions are right and a watch is issued."

Note: For the purposes of this research, "frequent" will be defined as "one or more event within the chosen category occurring at least annually."

__ My jurisdiction is not frequently threatened by wind events
__ Hurricane

__ Nor'easter
__ Tornado
__ Typhoon
__ Other wind event

7. If you have an SOG/SOP that defines the maximum wind speed in which a fire suppression unit will respond to a call, please indicate the maximum wind speed closest to your procedure.

__ We do not have an SOG/SOP that addresses this issue
__ Wind Speed below 45mph
__ Between 46 and 55mph
__ Between 56 and 65mph
__ Between 66 and 75mph
__ Above 75mph
__ It is the company officer's discretion
__ It is the shift commander's discretion
__ It is the fire chief's discretion

8. Does your agency have a training program that specifically addresses firefighting strategies and tactics for wind driven fire events?

__ Yes
__ No
__ If yes please give a brief description of the training

9. Please describe any strategies used for the control of wind driven fire which your agency employs that differ from those listed below.

Exercise control of wind entry and exit points
Exercise positive pressure ventilation
Indirect fire attack

_____
_____
_____
_____

10. Please describe any tactics used for the control of wind driven fire which your agency employs that differ from those listed below.

Place a window curtain on the windward side of the fire room
Dedicate a firefighter to door control
Place a PPV/PPA fan in the doorway to pressurize the building or stairway
Use a Navy or shipboard-style extension fog nozzle
Use a wall, floor or ceiling breach for an indirect attack

_____
_____
_____
_____

11. If you would like a copy of this research paper, please include your email (for a link to the document) or postal address for a hard copy) in the box below.

If you wish to remain anonymous this step is optional.

_____
_____
_____
_____

Appendix D

Examination #1 Strategies and Tactics for Wind Driven Fires

This Examination is being conducted as part of the National Fire Academy course, Executive Analysis of Fire Service Operations in Emergency Management. The data acquired from this examination survey is collected anonymously. This data will be used as part of an applied research project, the results of which should be available through the Learning Resource Center after January of this year. Thank you in advance for your contribution of time and your interest in the advancement of fire service safety and education.

1. Did you attended training for Wind Driven Fires (WDF) conducted by Boynton Beach Fire Rescue (BBFR)?

__ Yes, as a student
__ Yes, as an instructor
__ Yes, as a student and then as an instructor
__ I attended the event but did not participate in the training due to the duties assigned to me
__ I did not attend this event

2. Are you familiar with the findings of the study conducted on Governors Island, for control of WDF? The study was published by the National Institute of Standards and Technology (NIST) in 2009?

__ Yes
__ No

3. Which suppression strategies are best to use when it has been determined that you are dealing with a WDF within a structure?

a. “Darken down” the room of origin on a WDF. Begin at the room of origin and proceed from the burned side toward the unburned side. After the fire is “darkened down” order interior crews to enter and extinguish the fire using a direct attack

b. Have interior crews control the fire using a direct attack from the unburned side to avoid pushing the flames deeper into the structure

c. Attack from the floor below

d. Attack Through a wall breach

__ a, b, c, d
__ a, c, d
__ b, d

__ b, c, d

4. Which strategies are best to use to control smoke and heat, when it has been determined that you are dealing with a WDF within a high rise structure?

a. Control the wind entering the windward side of the structure

b. Ventilate the stairwell via positive pressure ventilation

c. Ventilate stairwell via smoke ejector fans

d. Ventilate stairwell via the bulkhead

__ a, b, c, d
__ a, c, d
__ a, b, d
__ a, b

5. Which fire suppression tactics have been proven effective against a WDF and have been validated in the study which was published by NIST?

a. An indirect attack from the exterior using a high rise nozzle.

b. An attack through a wall breach from an adjacent room toward the windward side of the building

c. A direct attack through the hallway to the fire apartment using dual 30 degree fog nozzles

d. An indirect attack using a tower or aerial apparatus

__ a, b, c, d
__ a, b, d
__ b, c, d
__ b, d

6. Which smoke and heat reduction tactics have been proven effective against a WDF and have been validated in the study which was published by NIST?

a. Use of a positive pressure fan in the doorway of the attack stairwell

b. Use a smoke ejector fan at the opening of the bulkhead

c. Deploy a fire blanket or curtain from the window above the room suspected of housing a WDF

d. Deploy a fire blanket at the doorway of the room suspected of housing a WDF

__ a, b, c, d
__ a, b, c,
__ a, c
__ c, d

7. Signs of a WDF include:

a. Smoke blowing out of the open window of a room on fire

b. Fire visible through the open window of a room on fire without smoke visibly exiting the window

c. Fire that appears to be pulsating in an out of an open window

d. Smoke that appears to be puffing in and out of a closed window

__ a, b, c, d
__ a, c
__ b, c
__ b, d

8. After a trigger event, such as the collapse of a window on the fire floor, a routine fire may become a Wind driven Fire. Which description best fits the conditions a firefighter would encounter in the hallway by the fire-involved apartment?

a. Fire would travel through the hallway staying at the ceiling level. A firefighter crawling at the ground level would stand a good chance of surviving the event if he/she stayed low.

b. Fire would engulf the hallway with swirls of fire reaching floor level. Survival is unlikely even if the firefighter stayed down at floor level.

c. The fire would stratify and the wind would cool the flames and help clear the smoke.

D. Fire would intensify but the hallway would be tenable as long as the firefighter stayed against the leeward wall.

__ a
__ b
__ a, c

__ a, c, d

Please include a brief explanation of your answer

_____
_____
_____
_____

Appendix E

Wind Driven Fire Threat to Firefighters in Boynton Beach Florida

Hazards	What is the possibility an event will occur at this hazard?	What is your best estimate of firefighters that may be affected seriously by this hazard?
WDF in a in a single story residential structure	Possible	6
WDF in a two story residential structure	Possible	6
WDF in a high rise residential structure	Likely	15
WDF in a commercial structure	Possible	9
WDF in a light industrial structure	Possible	9

Hazard Identification Matrix

Adapted from EOEFSOM Student Manual page SM 4-15

Appendix F

Vulnerability Assessment of Firefighters from a WDF Event

Hazard	WDF in a single story residential structure	WDF in a two story residential structure	WDF in a high rise residential structure	WDF in a commercial structure	WDF in a light industrial structure
Impact Rating					
Danger to Firefighters (High=3; Moderate=2; Low=1)	1	2	3	1	1
Economic (Permanent=3; Temporary=2; Immediate Short Term-1)	2	2	2	2	2
Environmental (High=3; Moderate=2; Low=1)	1	1	1	1	1
Social (High=3; Moderate=2; Low=1)	3	3	3	3	3
Political Planning Level (Local=3; Regional=2; Local=1)	1	1	1	1	1
Total Vulnerability Rating (Sum of All Factors)	8	9	10	8	8
Rank 5-8--Low 9-11--Moderate 12-15--High	Low	Moderate	Moderate	Low	Low

Vulnerability Assessment Matrix

Adapted from EOEFSOM Student Manual page SM 4-20

Appendix G

Risk Rating Matrix for Wind Driven Fire in Boynton Beach Florida

	Hazards Probability of Occurrence			Vulnerability Danger Factor			Risk Disaster Rating Probability x Danger
Hazards	High (3)	Moderate (2)	Low (1)	High (3)	Moderate (2)	Low (1)	Rating (*)
WDF in a single story residential structure			1			1	1
WDF in a two story residential structure			1		2		2
WDF in a high rise residential structure		2			2		4
WDF in a commercial structure			1			1	1
WDF in a light industrial structure			1			1	1

Risk Rating Matrix

Adapted from EOEFSOM Student Manual page SM 4-23