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The attached document provides expanded documentation of my oral presentation at the 2008 Firefighter Fatality Investigation and Prevention Program public stakeholder meeting.

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NIOSH FIREFIGHTER FATALITY INVESTIGATION AND PREVENTION PROGRAM: RECOMMENDATIONS FOR IMPROVEMENT

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Public Stakeholder Meeting

On 22 March 2006, the National Institute for Occupational Safety and Health (NIOSH) held a public stakeholder meeting in Washington DC to gather input on the Firefighter Fatality Investigation and Prevention Program. At this meeting, NIOSH received Input from a diverse range of fire service stakeholders. Feedback was extremely supportive of the program, but provided input on potential improvements to this extremely important program. In 2006, I gave a brief presentation that focused on several key issues:

- The upward trend in the rate of firefighter fatalities due to trauma during offensive, interior firefighting operations.
- Failure of NIOSH to adequately address fire behavior and limited understanding of fire dynamics as a causal or contributing factor in these fatalities.

The issues that I raised at the 2006 stakeholder meeting continue to be a significant concern. In 2007, extreme fire behavior was a causal or contributing factor in 17 firefighter line of duty deaths (LODD) in the United States. Where these incidents were investigated by NIOSH, the investigations, subsequent reports, and recommendations did not substantively address the fire behavior phenomena involved nor did they provide recommendations focused on improving firefighters and fire officers understanding of practical fire dynamics.

Ongoing Challenges

In the 20 months since the 2006 meeting, NIOSH has implemented a number of stakeholder recommendations. However, Death in the line of duty reports continue to lack sufficient focus on fire behavior and human factors issues contributing to traumatic fatalities during offensive, interior firefighting operations.

Where these reports could provide substantive recommendations for training and operations that would improve firefighter safety, they continue to provide general statements reflecting good practice. While the recommendations contained in NIOSH Death in the line of duty reports, are correct and critically important to safe and effective fireground operations, they frequently provide inadequate guidance and clarity.

In incidents involving extreme fire behavior, investigators frequently fail to adequately address the fire behavior phenomena involved in the incident and the implications of the action or inaction of responders. In addition, while training is addressed in terms of national consensus standards of standard state fire training curriculum, there is no investigation as to how the level of training in practical fire dynamics, fire control, and ventilation strategies and tactics may have impacted on decision making.

Presentation of these issues in general terms does not provide sufficient clarity to guide program improvement. Examination of a recent death in the line of duty report will be used to illustrate the limitations of these important investigations and reports in incidents where extreme fire behavior is involved in LODD.

Death in the line of duty... F2007-29

There are many important lessons to be learned from this incident and the limited information presented in this report. However, this analysis of report F2007-29 focuses on fire behavior and related tactical decision-making. This analysis is completed with all due respect to the individuals and agencies involved in an effort to identify systems issues related to the identification and implementation of lessons learned from firefighter fatalities.

On August 3, 2007 Captain [redacted] and Firefighter [redacted] of the Noonday Volunteer Fire Department lost their lives while fighting a residential fire. Neither this information nor any reference to the report released by the Texas State Fire Marshal's Office was included in NIOSH Death in the line of duty report F2007-29. This is critical to locating additional information regarding the incident. Even more importantly, it is important to remember that firefighter LODD involve our brother and sister firefighters, not simply "Victim #1" and "Victim #2".

Reading the Fire

This incident involved a 2700 ft², wood frame, single family dwelling. The fire was reported at 0136 and the first unit arrived on scene at 0150. The crew of the first arriving engine deployed a 1-3/4" hoseline and positive pressure fan to the door on Side A. NIOSH Report F2007-29 reported that the attack team made entry at 0151 but backed out a few minutes later due to flames overhead just inside the front door and that positive pressure was initiated at 0156 prior to the attack team re-entering the building.

However, the Texas State Fire Marshal's report FY 07-02 indicated the following:

Flint-Gresham Engine 1 arrived on scene at 01:50:21 positioning short of side "A" and reported, "On location, flames visible."

Firefighters [redacted] and [redacted] of the Flint-Gresham VFD pulled rack line 2, a 200' 1.75" line, to the front door on side "A." Flint-Gresham VFD Firefighter [redacted] conducted a quick survey of the north side and then positioned the vent fan at the front door to initiate Positive Pressure Ventilation (PPV). [redacted] stated that the PPV was set and operating prior to entry by the first attack team. [redacted] stated that he started to survey the south side and noted heavy black smoke from the top half of a broken window. He stated that he reported this to the IC...

Flint-Gresham Firefighters [redacted] (nozzle) and [redacted] (backup) entered through the open front door and advanced 8-10 feet on a left hand search. This attack team noted flames rolling across the ceiling moving from their left to their right as if from the attic. [redacted] stated that flames were coming out of the hallway at the ceiling area and around the corner at a lower level. [redacted] reported the hottest area at the hallway. The interior attack team then backed out to the front doorway and discussed their tactics. After a brief conversation, [redacted] took the nozzle with [redacted] backing him and they re-entered. They entered approximately 10 feet and encountered flames rolling from their left to their right. They used a "pencil technique" aimed at the ceiling to cool the thermal layer. [redacted] reported in interview that there was an increase in heat and decrease in visibility as the thermal layer was disrupted and heat began to drop down on top of them.

There is an inconsistency between the NIOSH and Texas State Fire Marshal's reports regarding the timing of the positive pressure ventilation. The NIOSH report indicates that positive pressure was applied between the first and second entries by the attack team. However, in the Fire Marshal's report,

Firefighter [redacted] is quoted as stating that positive pressure was applied before entry. This seems to be a minor point, but if effective, positive pressure ventilation would have significantly changed the fire behavior indicators observed from the exterior and inside the building. Recognition of this discrepancy along with a sound understanding of practical fire dynamics would have pointed to the ineffectiveness of tactical ventilation and potential for extreme fire behavior.

The NIOSH report did not identify the fire behavior indicators initially observed by Firefighter [redacted] or the attack team, nor did they draw any conclusions regarding the stage of fire development, burning regime (fuel or ventilation controlled), or effectiveness of the positive pressure ventilation.

NIOSH Report F2007-29 did not speak to the fact that none of the first arriving personnel verified the size and adequacy of the existing ventilation opening, the potential implications of inadequate exhaust opening size, and the need to verify that the positive pressure ventilation was effective prior to entry. In addition, the initial attack crew observed flames moving toward the point of entry, which would not be likely if the positive pressure ventilation was effective. However, no mention was made in the NIOSH report regarding conditions inside building and the observations of the attack team.

Window size is not specified, but it is likely that the opening was significantly less than the area of the inlet being pressurized by the fan. Inadequate exhaust opening area leads to excessive turbulence, mixing of hot smoke (fuel) and air, and can lead to extreme fire behavior such as vent induced flashover or backdraft. Recognition of this discrepancy along with a sound understanding of practical fire dynamics would have pointed to the ineffectiveness of tactical ventilation and potential for extreme fire behavior.

In reading this case study, it would be useful for the reader to be able to make a connection between key fire behavior indicators, the decisions made by on-scene personnel, and subsequent fire behavior. The NIOSH report did not identify the indicators initially observed by interior or exterior crews, nor did it draw any conclusions regarding the stage of fire development, burning regime (fuel or ventilation controlled), or effectiveness of the positive pressure ventilation, all of which were likely factors influencing the outcome of this incident.

NIOSH Report F2007-29 indicated that the attack team exited the building at 0213 due to low air and reported that the fire was knocked down, identified the location of a few hot spots, and that smoke conditions were light. The report follows to indicate that one of the chief officers did a walk around two minutes later and observed smoke in all the windows and smoke coming from the B/C and C/D corners of the structure. However the Texas State Fire Marshal's report stated:

Firefighters [redacted] and [redacted] penciled the rolling flames in the thermal layer until low air alarm sounded...The Incident Commander, Captain [redacted] and Firefighter [redacted] met Firefighters [redacted] and [redacted] at the front door and a briefing occurred... Firefighters [redacted] and [redacted] reported to Asst. Chief [redacted] they had the hot spots out. Rawlings stated in a later interview that they told [redacted] and [redacted] they knocked down the fire and only overhaul was needed.

At 02:13, Captain [redacted] and Firefighter [redacted] entered the structure as attack team 2, using the same line previously utilized by Firefighters [redacted] and [redacted]...

Exterior crews from Noonday and Bullard started horizontal ventilation by breaking a window out on side "D" (north side). Noonday Chief [redacted] performed a walk around, then

reported heavy smoke from the "B"- "C," and "C" -"D" corners and at **02:15:51** asked if vertical ventilation had been started. Command then gave the order to begin vertical ventilation...

Understanding what occurred in this incident requires more than the cursory information provided in the NIOSH report. Developing the understanding of critical fire behavior indicators is essential to situational awareness. Discussion of fire behavior indicators and their significance in NIOSH reports would provide an excellent learning opportunity. For example, in this incident, the difference between "smoke" as described in the NIOSH report and "heavy smoke" as reported in the Texas State Fire Marshal's report is likely a significant difference in assessment of conditions from the exterior of the building (particularly if this is a change in conditions).

NIOSH Report F2007-29 made brief mention of smoke discharge from the point of entry which was being used as the inlet for application of positive pressure. "At 0236 hours, heavier and darker smoke began pushing out of the entire front door opening and overriding the PPV fan". However, the report does not speak to the significance of this indicator of impending extreme fire behavior.

The Texas State Fire Marshal's report included a series of photographs provided by the Bullard Fire Department which provided a dramatic illustration of these key smoke and air track indicators. Inclusion of these photographs in the NIOSH report would have aided the reader in recognizing this key indicator of ineffective tactical ventilation and imminent potential for extreme fire behavior.

NIOSH Report 2007-29 addresses the need for the **incident commander** to conduct a risk versus gain analysis prior to and during interior operations. However, the report does not address the foundational skill of being able to read fire and predict likely fire behavior as a part of that process. In addition, reading the fire and dynamic risk assessment are not solely the responsibility of the incident commander. Everyone on the fireground must be involved in this process within the scope of their role and work assignment. For example, the initial and subsequent attack teams were in a position to observe critical indicators that were not visible from the exterior.

While there is no way to tell, it is likely that if Captain _____ and Firefighter _____ recognized the imminent probability of extreme fire behavior or the significance of changing conditions they would have withdrawn the short distance from their operating position to the exterior of the building. Likewise, if the incident commander or others operating on the exterior recognized deteriorating conditions earlier in the incident it is likely that they would have taken action sooner to withdraw the crew working on the interior.

Understanding practical fire dynamics, recognition of key indicators and predicting likely fire behavior is a critical element in situational awareness and dynamic risk assessment. Fire behavior and fire dynamics receive limited focus in most standard fire training curricula. It is important that NIOSH examine this issue when extreme fire behavior is a causal or contributing factor in LODD.

Tactical Ventilation

The NIOSH report makes a general recommendation that "fire departments should ensure that **proper** ventilation is done to improve interior conditions and is **coordinated** with interior attack" [emphasis added]. However, the report is misleading and fails to address key issues related to tactical ventilation, its effective application, and its tremendous influence fire behavior.

NIOSH Report F2007-29 indicated that positive pressure ventilation was initiated prior to the second entry by the initial attack crew (a significant difference from the information provided in the Texas State Fire Marshal's report). However, no mention is made of any action (or lack thereof) to create an adequate exhaust opening for effective horizontal positive pressure ventilation. While advising that ventilation needs to be **proper**, it would be helpful to provide more specific guidance. Lack of an adequate exhaust opening prior to pressurizing the building has been a major factor in a number of incidents in which application of positive pressure resulted in extreme fire behavior such as ventilation induced flashover or backdraft. *Positive Pressure Attack for Ventilation and Firefighting* (Garcia, Kauffmann, & Schelble, 2006), *Fire Ventilation* (Svensson, 2000), and *Essentials of Firefighting* (IFSTA, 2008) all emphasize the importance of creating an adequate exhaust opening prior to application of positive pressure.

The NIOSH report pointed out that smoke pushed out the inlet and overrode the effects of the blower, but attributed this to the presence of an attic floor that interfered with vertical ventilation rather than the lack of an adequate exhaust opening for the initial horizontal ventilation.

The PPV fan and vertical ventilation had little effect due to an attic floor being installed. At 0231 Chief #2 had horizontally vented the window on the D side near the AD corner.

In this incident, ventilation was being performed while the interior attack crew was already inside working. When the ventilation was completed, minimal smoke was pushed out of the vent hole but dark smoke pushed out of the front door, in spite of the fact that a PPV fan was set up at the front door. *Note: The dark smoke pushing out the door indicated that the conditions were worsening and the vertical ventilation was not impacting the fire.*

In addition, the report fails to note that the opening made on Side D near the AD Corner placed the attack team between the fire and an exhaust opening. As with lack of an adequate exhaust opening, this has been demonstrated to have the potential for disastrous consequences (see NIOSH Death in the Line of Duty...F2004-02).

Extreme Fire Behavior

Command ordered companies to abandon the building at 0234 hours using three air horn blasts as an audible signal. The NIOSH report indicated that heavy fire "continued to roll out the front door" but it is unclear how soon this occurred after smoke conditions at the doorway changed.

NIOSH Report F2007-29 does not clearly identify that extreme fire behavior was a causal or even contributory factor in the deaths of Captain [redacted] and Firefighter [redacted]. It simply states that they died as a result of smoke inhalation and thermal burns.

NIOSH Recommendations

NIOSH made six recommendations based on analysis of the incident in which Captain [redacted] and Firefighter [redacted] lost their lives. Several of these recommendations focused on factors that may have contributed to these two LODD. These included radio communications equipment and procedures, accountability, rapid intervention, and the importance of mutual aid training. In evaluating the significance of these recommendations it is useful to ask if these actions had been taken would the likely outcome of the incident in question have been different.

Two recommendations were more directly related to causal factors, the importance of ongoing risk assessment and use of proper and coordinated ventilation. However, these broad recommendations miss the mark in providing useful guidance in minimizing the risk of similar occurrences.

Ensure that the IC conducts a risk-versus-gain analysis prior to committing to interior operations and continue the assessment throughout the operation.

This statement is necessary but not sufficient. Size-up and risk assessment is not only the responsibility of the incident commander. All personnel on the fireground must engage in this process within the scope of their role and assignment. Understanding practical fire dynamics is critical to firefighters' and fire officers' ability to recognize what is happening and predict likely fire behavior and the influence of tactical operations. To effectively address this issue, NIOSH death in the line of duty reports must be explicit and detailed with regards to key fire behavior indicators observed, subsequent fire behavior phenomena, and the influence of the action or inaction of responders on fire development.

Fire departments should ensure that proper ventilation is coordinated with interior attack.

NIOSH Report 2007-29 focused on the ineffectiveness of the vertical ventilation, but failed to recognize the impact of the sequence of action (i.e. pressurization of the building and creation of exhaust openings), inadequacy of initial exhaust openings, and eventual location of exhaust openings in relation to the operating position of Captain ' and Firefighter

As with situational awareness, effective tactical operations are grounded in training, education, and experience. The incident commander and crews tasked with carrying out tactical ventilation must understand how these tactics influence the fire environment and fire behavior. As with size-up and risk assessment, this is dependent on an understanding of practical fire dynamics.

Other than indicating that ventilation must be coordinated with interior attack, the NIOSH report did not speak to fire control operations conducted during this incident. From the building floor plan and information presented in the reports by NIOSH and the Texas State Fire Marshal, it appears that the fire was shielded and direct attack was not possible from the position of the first attack team or the position reached by Captain and Firefighter .. The Fire Marshal's report indicated that the initial attack team "penciled" the ceiling to control flames overhead and experienced disruption of the hot gas layer and an increase in temperature at floor level.

Just as ventilation must be appropriate and coordinated with interior fire attack, fire control must also be appropriate and coordinated with tactical ventilation. Cooling the hot gas layer is an appropriate tactic to create a buffer zone and increase the safety of the attack team as they access a shielded fire. However, penciling (use of an intermittent application of a straight stream) the ceiling is an ineffective method of cooling the hot gas layer and results in excessive steam production. In addition, cooling the hot gas layer is not an extinguishment technique; it must be integrated with other fire control methods such as a direct attack on the seat of the fire.

NIOSH death in the line of duty reports must explicitly address the effect of tactical operations, particularly where effectiveness or ineffectiveness was a contributing or causal factor in the LODD.

The Way Forward

While this assessment has been quite critical of NIOSH's investigation of traumatic fatalities involving extreme fire behavior, it is important to emphasize that with all its faults, the Firefighter Fatality Investigation and Prevention program is a tremendous asset to the fire service.

The following recommendations are made to further strengthen and improve the quality of this program and the utility of recommendations made to reduce the risk of firefighter line of duty deaths as a result of extreme fire behavior during structural firefighting operations:

- Emphasize the criticality of understanding fire behavior, causal factors in extreme fire behavior, and the influence of tactical operations such as fire control and ventilation.
- Increase attention to building, smoke, air track, heat, and flame indicators when investigating incidents which may have involved extreme fire behavior as a causal or contributing factor in LODD.
- Examine training in greater detail, with specific emphasis on fire behavior, situational assessment, realistic live fire training, and crew resource management.
- Provide fire behavior training to all NIOSH investigators to improve their understanding of fire development, extreme fire behavior phenomena, and the impact of tactical operations.
- Include a fire behavior specialist on the investigation team when investigating incidents that may have involved extreme fire behavior as a causal or contributing factor.
- Initiate investigations quickly to avoid degradation of the quality of information obtained from the individuals involved in the incident and other witnesses.

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