Initiative

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Safety must be a primary consideration in the design of apparatus and equipment.

Executive Summary

Today's fire service leaders whether they are fire chiefs, other chief fire officers, equipment committees, or equipment manufacturers have a vested interest and a legal responsibility to provide for the safety of firefighters. Yet, each day these groups struggle with the issue of preventable firefighter injuries and deaths, and the need to incorporate safety as a primary consideration in the design of fire service apparatus and equipment.

New technologies and innovations are available that can significantly reduce the potential for injury and deaths related to fire service apparatus and equipment failures or shortcomings. This paper will identify the driving force behind the push for safety in design, and explore the technologies and innovations available today. We will also look at stakeholder best practices that can be implemented to improve fire fighter safety, thereby reducing the potential for injury and death.

The 16th Initiative ratifies the belief that no firefighter should die in the line-of-duty due to apparatus or equipment-related issues.

Problem

As is well known in our industry, approximately 100 firefighters are killed in the line of duty each year and this largely preventable loss has been occurring for far too many years. As fire service leaders know, firefighting is an inherently hazardous profession. However, the continued loss of 100 of our co-workers is fast becoming an expected annual statistic. It has become routine for the United States fire service to experience a firefighter line of duty death (LODD) rate three to four times the total of the fire services in the rest of the world—about one every 76 hours.

Statistics provided by the National Fire Protection Association (NFPA)[1] and the United States Fire Administration (USFA) [2,3] indicate that in 2004 and 2005 approximately 50 percent of LODDs could be attributed to cardiac-related issues, and another 25 percent are directly attributable to fire apparatus mishaps. The statistics also indicate that the problem with LODDs is not strictly a career or volunteer issue, although volunteer members comprise more of the line of duty deaths annually. The issues regarding LODDs have been allowed to continue for too long, and have become part of the fire service's culture.
According to the United States Fire Administration, 106 firefighters died in the line of duty in 2006. Responsible fire service leaders have a duty to sub-ordinates to keep them as safe as possible from apparatus and equipment—related failures, and one option available is to eliminate or correct the problem before it occurs with safety in the design phase. Whether it is a vehicle accident or a cardiac arrest, very often equipment played a contributing role; therefore, safety must be considered as design factor when fire apparatus is designed and purchased.

Recommendation # 1*: When looking at accidents and near-misses, departments should try to identify design flaws or for places where design support could have intervened for a different outcome.*

Driving Force

To solve a problem, there has to be a driving force or an important emotional event that drives change. Safety is no different. In the spring of 2004, under the leadership of National Fallen Firefighters Foundation (NFFF), fire service leaders from across the nation were invited to Tampa (FL), to participate in a summit to design a blueprint for eliminating preventable firefighter fatalities. More than 200 fire service professionals gathered to begin the process of finding answers to how we can stop killing 100 firefighters annually in the United States. The first Firefighter Life Safety Summit produced a national agenda of 16 value statements which have become known as the 16 Firefighter Life Safety

Initiatives. The initiatives are benchmarks for the nation's fire service leadership to commit to and strive to achieve in a proactive approach to reducing LODDs. In conjunction with the Tampa Summit in 2004, the US Fire Administration published definitive reduction objectives for the fire service to attempt to achieve to lower the LODD figure:

• The reduction of firefighter deaths by 25 percent in five (5) years.
• The reduction of firefighter deaths by 50 percent in ten (10) years.
The NFFF believes these to be obtainable outcomes **if** the US fire service works in unison, and if all major fire service organizations commit to the 16 Firefighter Life Safety Initiatives. Although efforts to date have not yet dramatically impacted on lowering the LODD rate, it is hoped that continuing efforts will be able to do so.

Recommendation #2: *Encourage your fire service organization to commit to the Life Safety Initiatives by developing action plans for implementation.*

Fire Service Apparatus

Fire apparatus is used everyday by thousands of fire departments and firefighters across this nation. But the question remains, "Has safety been a primary consideration in the design of your apparatus?" Based on statistics from the NFPA and USFA, which indicate that 25 percent of LODD incidents involve fire apparatus, we would have to draw the conclusion that the answer to this question is **NO**. A recently released research paper published by the International Association of Fire Fighters (IAFF) [5] determined that equipment, including fire apparatus and related firefighting equipment, is the second leading cause of firefighter fatalities behind cardiac-related causes.

One of the most effective ways to reduce or eliminate risks associated with fire apparatus is to design or engineer safety features into them. This could possible increase the margin of safety when human factors contribute to a vehicle accident. When an accident does occur, it is generally the result of a sequence of events that culminates in, for example, a vehicle crash. If, however, somewhere in the chain of events the sequence is altered due to an engineered safety intervention, the outcome can be prevented or altered in favor of the firefighting crew.

During the research for this paper, communication was made with many of today's fire service's safety advocates regarding increased apparatus safety through design. The individuals consulted included: Deputy Fire Chief Billy Goldfeder, EFO (Loveland-Symmes, OH), Fire Chief and Emergency Management Director I. David Daniels, MHRM, MIFireE (Renton, WA), Dr. Harry Carter, Mr. R. J. "Bob" Barraclough (who has served as president of the Fire Apparatus Manufacturers' Association), Mr. Stephen Austin (Project Manager, www.respondersfety.com), Charlotte Fire Dept. Health Officer Robert Tutterow

(Charlotte (NC) Fire Department), and Lieutenant Mike Wilbur (FDNY) for their thoughts on "best practice" safety features that should be part of the design of apparatus.

All agreed that any vehicle used for fire service operations, whether purchased new, rehabbed, or constructed locally, should comply with the most current edition of National Fire Protection Association (NFPA) Standard 1901. What follows is a list of other features recommended by these experts (see also Appendix A). To organize this list, best practice design features are discussed as those pertaining to the interior portion of apparatus, and then exterior features.

Interior Features

Seatbelts: This feature was mentioned by every person contacted as an absolutely essential feature of every fire department vehicle—including ambulances. Not only should they be included, but they must be of sufficient length and design to secure your largest fully-equipped firefighter. Additionally, the seats should be alarmed so that the officer and driver know when they are not being utilized. A number of seat and fire apparatus manufacturers have made great strides in developing new seats that allow for ease of operation for both custom and commercial chassis. A major fire apparatus seatbelt study is expected to occur during 2007 and 2008; this study should answer many of the lingering questions about seat and seatbelt design.

Recommendation # 3: *Seat belt use by firefighters responding to or returning from the emergency scene should be non-negotiable in terms of policy and custom within the organization. Safety committees need to support this by ensuring that every department vehicle (including ambulances) is equipped with working seat belts and that all employees are trained in their proper use.*

Crash Tested Cabs: Every fire truck in the United States should be built with a cab that has been crash tested. The current standard being used by a number of leading apparatus manufacturers is the European Occupant Protection Standard ECE Regulation No. 29. This certification gives the end-user an assurance the cab will remain intact if the apparatus is involved in an accident.

Air Bags: Air bags have become the industry standard for passenger vehicles in all privately owned vehicles. At least one of the major apparatus manufacturer is now offering frontal air bags as an option on custom chassis and a variety of fire apparatus makers offer optional side air bags.

Recommendation # 4*: Air bags should become mandatory on all emergency response vehicles within five years.*

Electronic Stability Control and Rollover Protection: As with other features,

consumers are finding stability control and rollover protection a standard option on their privately owned vehicles. At least one fire apparatus manufacturer offers these options where a computerized system is engineered to assist the driver if an unsafe condition is sensed. These would be particular helpful on any emergency vehicle, but particularly on tankers/tenders where roll-over accidents are more prevalent.

Independent Front Suspension with Disc Brakes: This feature is becoming more standard, and rightly so, on fire apparatus. One of the leading fire apparatus manufacturers recently introduced two new model lines which feature independent front suspension (with disc brakes) as standard. Independent third-party testing reveals that all fire apparatus similarly equipped could stop 60 feet shorter than similar apparatus equipped with a straight axle. (see www.piercemfg.com/pdfs/Pierce_TAK-4_stpru.pdf)

Tire Monitoring Systems: A relatively new feature available is a system that monitors tire pressure. Sensors mounted to each wheel send information regarding tire pressure and temperature to a display inside the vehicle, alerting the crew when a tire needs attention. Some tire monitoring systems also provide a riding surface to prevent the vehicle from becoming uncontrollable if a blowout occurs.

Center of Gravity: One of the factors associated with many tanker/tender LODD incidents is that these vehicles have a higher center of gravity which makes them more susceptible to rollovers. By designing a vehicle with a lower center of gravity, the driver would have better control of the vehicle. Two methods that can be used is extending the length of the tank so that it is not so tall, or lowering the tank mounting on the vehicle so that it is not so high off the chassis.

Recommendation # 5: A*pparatus & equipment purchasing committees in every department have the duty to learn about safety features available on and in fire apparatus.*

Exterior Features

Retro-Reflective Material: The fire service needs to make its fire apparatus more visible, especially in three critical locations. It is recommended that chevron striping be applied to all fire vehicles on the rear of the apparatus to comply with the ASTM D 4956-06 *Standard Specifications Retro-Reflective Sheeting for Traffic Control*. A second area would be on the sides of fire apparatus in the center of the rub rails. By installing reflective striping in this location there would still be some reflectivity to the side of the vehicle if the roll-up doors are up or the swing-out doors are open. The last area would be to ensure that reflective material is installed inside of cab doors and inside of swing-out doors so that the reflective material and the door are apparent to oncoming drivers. All apparatus manufacturers are capable of providing this feature.

Lighting: It was suggested by several consulting authorities that a more extensive use of LED lighting on apparatus would make them safer. They also suggested the uniform practice of flashing headlights during response, the use of daytime driving lights, and traffic control lighting devices on the rear and perhaps the side of apparatus. Fire apparatus does not need to be blinding, but must be seen by civilian drivers and others using the roadways in order to be safe.

Fire Apparatus Color**:** A tradition within the fire service has been the red fire truck. For many, the red truck is synonymous with the local fire department and there is tremendous hesitancy to interfere with this symbolism. However, there is ample evidence from the scientific and testing community that indicates colors such as lime-green and yellow are more visible to the human eye. For a good discussion on this, see an article in the Journal of Safety Research (Spring 1995), *Influence of Color on Fire Vehicle Accidents*, by Dr. Stephen S. Solomon and James G. King.

Recommendation # 6: *Keep up with the latest technology regarding simple fixes such as providing retro-reflective striping or apparatus color for best visibility. Make decisions based on science, not sentiment.*

The fire service can be hopeful that changes in apparatus design will improve the outcomes, or even break the chain of events, which lead to apparatus-related injuries and deaths. Recent email correspondence with Robert Tutterow (a member of the NFPA 1901 committee) indicates that the NFPA is seriously considering the inclusion of a number of these best practice features as part of a revision of NFPA Standard 1901. This is certainly a step in the right direction.

Personal Protective Equipment

Cardiac related issues account for approximately 50 percent of all LODDs. Most of the deaths are due to the fact that a firefighter is out of shape, is too heavy, or suffers from an idiopathic condition. Personal Protective Equipment (PPE) has made tremendous advances in the last 20-30 years and provides considerable protection from heat and the products of combustion, two forces which can contribute to heart attacks and even cancer. Today's fire service leaders have a myriad of outer shell materials, thermal barriers, moisture barriers, face clothes and reflective materials to choose from when outfitting today's firefighter.

PPE should be selected with due diligence and through considerable research using a definitive process of identifying products designed to improve firefighter safety. The first step any department should take when purchasing PPE is to conduct a hazard and risk assessment. The risk assessment will allow fire service leaders to determine PPE needs based upon types of response and specific hazards (i.e. exposures). A risk analysis need not be the daunting task it appears to be. In fact, once a department or a safety committee is aware of its

members' needs, they can take advantage of a free computer program, Turnout Gear Selector (ToGS ™) Software Tool, offered by the National Institute of Standards and Technology (http://www2.bfrl.nist.gov/software/TOGS/). The ToGS program will assist departments in identifying characteristics of turnout gear to match its needs based on a risk assessment tool. Important attributes of PPE to consider include wear characteristics of the outer shell, thermal layer protective performance and bending stiffness, as well as breathability of the moisture barrier.

All of these features of PPE are discussed at length within the ToGS format. Within the program there are a total of 41 ensembles available for evaluation. Each ensemble is a system of components: there are 9 different outer shells, 5 moisture barriers, 8 thermal liners and 7 face cloth materials.
Once a decision is made regarding PPE, it is recommended that wear testing the article or ensemble will lead to correct decisions regarding purchasing. Many local distributors will support this request and provide a set or two of PPE or equipment in the hopes of securing a future (i.e. larger) order. PPE that does not fit, that is too cumbersome to don, or does not properly align with the exposure levels of a department is useless. Money wasted on equipment that is not used wastes precious resources most fire departments cannot afford.

Recommendation # 7*: Take a look at your department and see what PPE or equipment* ***isn't being used*** *as it was intended and try to find out why. This will be an important clue to future purchase decisions.*

Once field-testing starts, it will be readily apparent what firefighters like and don't like based on interviews and observation. After discussing PPE with a number of manufacturers, all those consulted for this paper agreed that departments should ensure personnel are fitted individually for their PPE to ensure for the critical factors of flexibility, range of motion, and breathability. The bottom line is if PPE does not fit properly and comfortably, it will remain unused and firefighters will continue to be hurt The last step is to develop detailed specifications based upon the needs of a department, research, the ToGS program, and field testing. Armed with the above information, a safety or purchasing committee should be able to formulate a list of specifications for each protective ensemble or equipment it really needs. Reputable dealers and manufacturers will appreciate when a department has done its homework and will be more willing to work with them to meet safety mandates.

Even with the best PPE possible, firefighters can still become thermally stressed by PPE which could lead to cardiac related problems. As the firefighters exert themselves in PPE, they lose body fluids and their body's core temperature increases. **It is essential departments institute on-scene rehab procedures**. Research conducted by the Defense R & D Canada[6] has determined that passive rehab measures (drinking cold liquids, removing clothing and resting) are not in themselves sufficient to reduce body core temperatures. Heart rate

decreases while in rehab should not be the only indication firefighters are safe to return to physical activity[7]. What must be required is an active approach to include such measures as submersion of hands and forearms into water to lower the core temperature for 30 minutes or more[8]. This can be accomplished by using plain plastic buckets, or the use of specially designed folding chairs with pockets that can be filled with water for the submersion of hands and forearms. If the firefighter's core temperature is not decreased, it will continue to rise to dangerous levels and the firefighter is likely to experience cardiac-related life threatening problems.

Fire service professional can be kept abreast on research and new advances with PPE by signing up with the NIOSH National Personal Protective Technology Laboratory (NPPTL) at www.cdc.gov/NNIOSH/npptl/sub-NPPTL.html.

Recommendation # 8*: Use the technology and support offered by allied organizations with a stake in firefighter safety, such as the National Institute for Occupational Safety and Health, and the National Institute of Standards and Technology.*

Miscellaneous Equipment

The fire service has become like all of our society—more and more reliant on electronic parts and devices to perform our jobs. Increasingly, self-contained breathing apparatus (SCBAs) have integrated personal alert safety systems (PASS) alarms that involve electronics. Portable radios routinely comply with OSHA regulations which involve advanced electronics; and thermal imaging cameras used for rapid intervention teams rely on electronic technology. The fire service however, is beginning to discover that these tools (many of which we now take for granted) have a serious downside in that they can be seriously degraded by heat exposure.

For instance, recently fire service concerns were raised by NIST testing that highlighted essential equipment failures when exposed to elevated temperatures expected in environments where firefighters routinely operate. In December 2005, the International Association of Fire Chiefs warned the fire service about testing by NIST[10] that highlighted PASS alarm signal volume failure at temperatures as low as 300° F. These were devices certified as complying with NFPA 1982 Standard on Personal Alert Safety Systems. PASS alarms are considered by most fire service professionals as the linchpin and last line of defense in the safety of individuals working in hazardous environments. The NFPA is considering the inclusion of a requirement for a redundant device on SCBAs as part of the revision process for future editions of the standard. Another lifeline for firefighters in hazardous areas has been their portable

radios. Firefighters operating under current OSHA guidelines in “Immediate Death and Life Hazard” (IDLH) environments are permitted to be there with radio contact.

A recent NIST report has revealed that radios in use today have a maximum operating temperature range of 140° F which is well below the heat range encountered by interior operating firefighters. The NIST report showed that exposing radios to temperatures of 320° F/160° C for 15 minutes affected the operating conditions them. Furthermore, radios exposed to temperatures above 320° F/160° C for only 5 minutes were unable to pass the test with serious degradation. Suggestions by the NIST include requiring radios be protected inside PPE pockets or under PPE to ensure their continued operation. The NIST believes the technology is available today to offer radios capable of withstanding elevated temperature and expected conditions. Lastly, thermal imaging cameras have become essential tools in today’s firefighters’ arsenal. These units are used to search for incapacitated victims, for hidden fire, lost firefighters and a multitude of other tasks. They too however, are subject to heat degradation due to on-board electronics, and complaints of finicky batteries and limited battery life. The best practice to follow is sound search procedures so that if a TIC fails you do not find yourself trapped. Manufacturers are working on both the battery and heat related problems.

Recommendation # 9: *Technology can improve safety, but it is imperative to train personnel to sustain their own safety should they experience a technology failure.*

Conclusion

Fire service fire apparatus and equipment can be associated with over 75 percent of firefighter LODDs in the United States. It is essential that the fire service take a proactive approach to reducing firefighter deaths and injuries. This proactive approach must focus at preventing one death or injury at a time within our departments, and on the broader issue of developing a LODD-reduction blueprint at the national level. A method to accomplish this task is to eliminate or change one of the events in the complex sequence of events leading up to an incident that result in an injury or death. This paper has provided a list of items for fire apparatus and ideas for personal protective equipment for individuals and departments. The fire service as a whole look critically at all proposed changes to apparatus standards, particularly the NFPA 1901. We must also insist, through our purchasing power, that safety features on fire apparatus are not luxuries.

Some of these features must include: tire protection systems, independent front suspensions, front disc brakes, front and side air bags, seatbelts that fit, highly reflective markings exterior striping, visible paint and warning lights. Fire departments must make informed decisions on personal protective clothing and

equipment ensuring it fits individual firefighters, while providing superior protection, allowing mobility and breathability, and use active rehab techniques and procedures. Finally, safety equipment that relies upon state-of-the-art electronics (portable radios, pass alarms, and thermal imaging cameras), must be better researched and developed to allow their use by firefighters in firefighting environments without degradation. If they don't work in our environment, they are of no use Improvements in apparatus design and equipment (particularly PPE) are responsible for most of the decrease in firefighter deaths over the past thirty years or so. The widespread use of turnout gear, gloves, properly designed helmets and especially SCBA have saved thousands of lives. However, those big fixes are behind us. What is needed now, to carry us far below the barrier of 100 firefighter deaths per year, are more subtle design changes involving apparatus and equipment. And we must be sober in our knowledge that no apparatus design is going to make a driver-operator drive sensibly, or ensure that an overly excited firefighter dons all his or her protective ensemble. Design and technology can only be handmaidens to firefighter safety. In the end, it is up to each and every one of us to make the commitment to safety, health and wellness.

Recommendation # 10*: Recognize that design improvements will not be enough to turn around the LODD situation in the United States. Improvements in design must be viewed in partnership with culture and human behavioral changes.*

Recommendations

Recommendation # 1: When looking at accidents and near-misses, departments should try to identify design flaws or for places where design support could have intervened for a different outcome.
Recommendation #2: Encourage your fire service organization to commit to the Life Safety Initiatives by developing action plans for implementation.
Recommendation # 3: Seat belt use by firefighters responding to or returning from the emergency scene should be non-negotiable in terms of policy and custom within the organization. Safety committees need to support this by ensuring that every department vehicle is equipped with working seat belts and that all employees are trained in their proper use.
Recommendation # 4: Air bags should become mandatory on all emergency response vehicles within five years.
Recommendation # 5: Apparatus & equipment purchasing committees in every department have the duty to learn about safety features available on and in fire apparatus.
Recommendation # 6: Keep up with the latest technology regarding simple fixes such as providing retro-reflective striping or apparatus color for best visibility. Make decisions based on science, not sentiment.
Recommendation # 7: Take a look at your department and see what PPE or equipment **isn't being used** as it was intended and try to find out why. This will be an important clue to future purchase decisions.

Recommendation # 8: Use the technology and support offered by allied organizations with a stake in firefighter safety, such as the National Institute for Occupational Safety and Health, and the National Institute of Standards and Technology.

Recommendation # 9: Technology can improve safety, but it is imperative to train personnel to sustain their own safety should they experience a technology failure.

Recommendation # 10: Recognize that design improvements will not be enough to turn around the LODD situation in the United States. Improvements in design must be viewed in partnership with culture and human behavioral changes.

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Appendix A

Apparatus Safety Feature List

• Seatbelts that fit and allow the firefighter room enough to prepare for operations while responding
• Seatbelt monitoring system for driver and operator to know when a crew member is not belted in for both custom and commercial chassis
• Highly visible reflective striping on the sides and rear to meet or exceed ASTM D 4956-06 Standard Specifications Retro-Reflective Sheeting for Traffic Control
• Rub rails with reflective striping in the center
• Reflective striping or panel inside cab and forward opening side doors
• Daytime running light and headlight wig-wag flashers
• Traffic control warning lights on sides and rear
• Require all apparatus to carry traffic control devices (cones, flares, advanced warning devices)
• White lighting to illuminate all four (4) sides of the apparatus
• Brightly colored non-slip edging on areas where firefighter frequently get up or down
• Crash Tested Cab
• Roll stability system
• Rollover protection system (side air bags)
• Frontal air bags
• Tire protection system (in case of blowout)
• Independent front suspension
• Front disc brakes
• Lower Center of Gravity especially for Tankers and Large Aerial Devices
• Heated remote control mirrors
• Heated windshield wipers
• Rear-view camera
• Ergonomic pump controls
• Class A or compressed air foam system with electric pump for refill