Executive Leadership

Electromechanical System to Ensure all Occupants are Wearing Seat Belts when Fire Apparatus are in Motion

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Abstract

The problem was there was no way to ensure firefighters always wear seat belts while riding fire apparatus. The research purpose was to assess the potential for an electromechanical monitoring system capable of guaranteeing seat belt usage. Descriptive research described systems currently used on fire apparatus, systems that were available but not used by apparatus manufacturers, pros and cons of the unused systems, and improvements that could be made in seat belt monitoring systems. Using a literature review and interviews, it was determined that a system can be designed to ensure firefighters wear seat belts. It is recommended that a coalition of fire service agencies pool their resources to fund the research and development of such a system.
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Introduction

Eighty-nine firefighters died in the line of duty during 2006. Cardiac arrest (38%) and motor vehicle crashes (21%) were the two leading causes of death. According to National Fire Protection Association (NFPA) statistics dating back to 1977, cardiac arrest as a cause of firefighter death has been on a steady decline (NFPA, Fire Analysis and Research Division, 2007). Conversely, over the same time period, the percentage of firefighters killed in motor vehicle crashes has remained steady. Data from 1997 to 2006 show two-thirds of these deaths occurred in fire department apparatus (NFPA, 2007). According to research by the National Highway Transportation Safety Administration, seat belts prevent a fatality in about 50 percent of the cases where the vehicle occupant would otherwise die (2005). The more alarming statistic is that 76% of the firefighters who died in motor vehicle crashes during 2006 were not wearing a seat belt (NFPA, Fire Analysis and Research Division, 2007). It appears that the fire service’s current methods of getting firefighters to wear seat belts are falling short.

Thirty-two states mandate seat belts for front-seat occupants and 17 states, plus the District of Columbia, mandate seat belts for all occupants riding in motor vehicles (National Highway Transportation Safety Administration, 2004). Ninety-one percent of fire service executives who responded to a survey for this research reported that their fire department has a policy requiring seat belt use when any vehicle is in motion. Yet, with the laws and policies, plus repeated shouts from fire service leaders, there has been no reduction in the proportion of firefighters killed annually in motor vehicle crashes.

The research problem is that without a way to ensure firefighters are seated and wearing seat belts when fire apparatus are in motion, there is a greatly increased potential for serious firefighter injury or death in the event of an apparatus crash. With historical data revealing the current methods of mandating seat belt use have not proven effective, the purpose of this
research is to assess the potential for an electromechanical monitoring system capable of ensuring fire apparatus occupants are wearing seat belts when apparatus are in motion. Descriptive research will be used to answer the following research questions by examining seat belt monitoring equipment available from fire apparatus manufacturers and third-party equipment suppliers, researching existing technologies such as sensors, monitors, and interlocks that might be used to detect when firefighters are seated with seat belts properly fastened, and through interviews with engineers, product specialists, and any current end-users that can be identified. The research questions are:

1. What seat belt monitoring systems are currently available for fire apparatus?
2. What seat belt monitoring systems exist which have yet to be used on fire apparatus, but may be available for such applications?
3. What are the pros and cons of current and available systems?
4. What improvements can be made to seat belt monitoring systems to enhance their effectiveness?

Background and Significance

Carrboro Fire Department was officially chartered as a volunteer organization in 1927. Early apparatus consisted only of a hose reel and some nozzles mounted on a cart that was manually pulled to the scene of a fire. In 1940, an enterprising member of the Department modified a 1937 model Chevrolet pickup truck by outfitting it with ladders, hose, and a pump; this resulted in the Department’s first motorized fire “apparatus.” Changes in the way people lived after World War II, including a move from agrarian to professional lifestyles, caused the roster of the Carrboro Fire Department to slowly dwindle. Five paid personnel were hired in the mid-1970s: a chief, a fire marshal and three apparatus drivers. By the late 1990s, there were no longer enough volunteers turning out for fires, and the department became fully career. In 2006,
the Department received a light rescue franchise from the North Carolina Department of Insurance and changed its name to Carrboro Fire-Rescue Department. Today, the Department is the smallest career Department in North Carolina, with authorization for 33 personnel and a typical annual operating budget of about $2 million. With ten personnel per shift, the Department staffs two engines, a ladder truck, and a command vehicle, which operate from one fire station. In fiscal year 2007, the Department responded to 1,397 requests for service. Counter to national trends, by a narrow margin, Carrboro Fire-Rescue answers more fire than medical requests for service.

The Town of Carrboro is situated just west of the Research Triangle in the piedmont of North Carolina. Carrboro is 89% residential, with a population of about 19,000 and an area of 5.8 square miles; it is the most densely populated municipality in the state. In addition to protecting the area inside the corporate limits, Carrboro Fire-Rescue provides service to the South Orange Fire District, which consists of 18 square miles of mostly rural area in unincorporated Orange County. The South Orange Fire District was once populated with a number of dairy farms and some are still in operation. While all areas inside the town limits are supplied with a water system and fire hydrants, the Department relies on water shuttles when conducting fire suppression operations in the South Orange Fire District. All Carrboro Fire-Rescue apparatus are equipped as water tenders or tankers. According to NFPA research, tenders or tankers account for nearly 23% of all fire apparatus crashes (NFPA, Fire Analysis and Research Division, 2007). While rural roads, like those in the South Orange Fire District, account for only 35% of the total miles driven in the United States each year, the rate of fatalities is two and a half times higher than that for more urban roadways (United States Department of Transportation, Bureau of Transportation Statistics, 2005). The combination of congestion in
Town, winding country roads in the South Orange Fire District, and apparatus that carry a minimum of 1,000 gallons of water is a recipe for an apparatus crash.

Spot checks of Carrboro Fire-Rescue crews leaving the station for calls show that the Department’s mandatory seat belt usage policy is always followed. Even so, there exists the potential for personnel to forget to buckle their seat belts in the wee hours of the morning, during water shuttle operations, or during times of high stress. Given this potential, and the dismal firefighter death statistics associated with apparatus crashes, there is an obvious need for a device that can accurately monitor and ensure seat belt usage. Statistically, such a device would save the lives of eight firefighters per year; this fits neatly into the United States Fire Administration’s goal to reduce by 25% the number of firefighters killed annually in the line of duty.

Literature Review

The 2003 edition of the NFPA’s 1901 Standard for Automotive Fire Apparatus addressed seat belt usage by requiring the seat belts to be easily distinguishable from the straps of self-contained breathing apparatus. The standard requires all seat belts to be red with the intent being that a crew supervisor can quickly and easily determine if crew members are wearing seat belts (Cavette, 2003).

Seat belt monitors are now available which are capable of determining if a seat in the cab of a fire apparatus is occupied and if the occupant of that seat has his or her seat belt properly buckled (Wilmoth, 2007). Such devices sound audible and/or visible alarms when sensors determine there is sufficient weight in the seat (about 60 pounds) and the seat belt is not buckled. Crimson Fire, Ferrara Fire Apparatus, Marion Body Works, Pierce Manufacturing Company, and Smeal Fire Apparatus Company report that they offer a seat belt monitor that senses a firefighter in a seat and whether or not the corresponding seat belt is buckled (personal communications, August 31 through September 8, 2007). An engineer from Elite Fire Apparatus responded that
they did not have a seat belt monitor (J. Wesenberg, personal communication, September 4, 2007). However, Carrboro Fire-Rescue Department took delivery of an Elite pumper in September of 2006 and it has a seat belt monitor complete with an alarm and display screen within the driver’s view.

Rick Fix with Fire Research Corporation (FRC) advised that his company is in the process of releasing a seat belt monitoring system in response to the 2008 edition of NFPA 1901, which is due to be voted upon in October 2007 (personal communication, September 6, 2007). The new standard will likely require a vehicle data recorder that will record, among other things, the status of seat occupancy and seat belt use. Fix stated that the FRC device will be capable of “seeing” the correct sit and buckle sequence and will send a warning when a seat is occupied but the seat belt is not buckled or when the sequence is out of order (seat belt is buckled before the seat is occupied).

In an effort to identify seat belt monitoring systems that are available, but not currently used by fire apparatus manufacturers, email requests to five sensor system manufacturers garnered responses from three. HBM, Incorporated (J. McNeil, personal communication, September 4, 2007) and Sensortechnics, GmbH (J. Fazli, personal communication, September 4, 2007) stated that they did not offer sensors or a system of sensors for applications such as monitoring seat belt usage. An inquiry to Futek Advanced Sensor Technology resulted in a telephone call from Javad Mokhbery, the company’s president. Mokhbery stated that he knew of no turnkey system that could monitor seat belt usage that was not already being used for such a purpose (personal communication, September 10, 2007). Mokhbery took some interest in the potential for a seat belt monitor that could guarantee 100% accuracy and stated that he could design one for a cost of $25,000 to $30,000. He recommended a matrix of sensors in the seats, on the seat belts, and in the floors. The system would monitor seat occupancy, determine if seat
belts were buckled properly (in front of the wearer), and ensure that firefighters were not standing. Mokhbery initially suggested that the system control the ignition of apparatus. After some discussion that oriented Mokhbery about fire service procedures and the way fire apparatus are used, he decided that it would be better if the sensor system controlled the transmission rather than the ignition. All sensors in the system would have to agree that occupants were seated and belted properly before the transmission would engage. In such an arrangement, it would not preclude starting an apparatus engine to warm it or build air pressure while firefighters were getting dressed on the ground. Additionally, if a seat belt were unbuckled while the vehicle was in motion, it would not kill the engine and associated systems such as power steering.

A patent has been issued to Thomas Kowalick for a seat belt monitoring system that is tied to a global positioning system and has a recorder for documenting seat belt usage by the driver and passengers. The claim is that this system is capable of recording seat belt usage in real time with the aid of infrared technology and indicator lights that are visible through both the front and rear windshields (Patent Storm, 1999). The proposed system includes an infrared emitter that would be located in the cab of a vehicle and infrared reflectors that would be placed appropriately on shoulder belts. The system would determine, through lack of an infrared reflection, that the driver and any passengers were not properly wearing seat belts. When the system’s sensors are satisfied that all occupants are properly seated and belted, it will illuminate lights that project through the front and rear windshields for view by other motorists and law enforcement officers.

There are a number of seat belt monitors in use or patented by the various automobile manufacturers that can detect the presence of the driver and any passengers and determine if they are properly buckled. One such system, the Seat Belt Status Monitoring System, was designed by
General Motors engineers and is not unlike those systems currently in use on some fire apparatus (Free Patents Online, 2004).

Orlando Robinson has been issued a patent for his *Seat Belt Shifter Lock System* (Free Patents Online, 2003). The system requires that the vehicle have an automatic transmission and would monitor the vehicle’s ignition, the position of the gear selector, and sensors on the seats, seat belts, and brake pedal. If the system does not see that seated passengers are properly buckled, it will not allow the gear selector to be moved from the park position to a drive gear position. After the system’s requirements have been met and the vehicle’s transmission is in a drive gear, unbuckling a seat belt will result in an audible chime until either the belt is re-fastened or the transmission is placed in park. The system has an override feature, whereby if the gear selector is in park, the brake pedal is depressed, and the hazard flashers are activated, the driver will be allowed to move the gear selector from park into a drive gear.

Yet another patent for a system to encourage seat belt use has been issued to Brian Finger (Free Patents Online, 2006). His *Apparatus and Method to Encourage Seat Belt Use* monitors seat occupancy and seat belt usage. When a seat is occupied but the seat belt is not fastened, the system deactivates one or more non-essential vehicle systems, such as the air conditioner or radio.

John O’Neill developed the *Seat Belt Sensing for Vehicle Occupant Load and Misuse* (Free Patents Online, 2005). This seat belt monitoring system is designed to detect accidental or intentional misuse of the seat belt such as fastening it behind the occupant’s back or behind the seat. This is accomplished through sensors situated between the seat belt webbing spool and the spool housing that monitor how much webbing has been pulled off the spool. The system alarms when it detects a seat belt has been pulled out, but insufficient webbing has been removed from the spool for the seat belt to be buckled in front of the user.
The systems described above fall into two groups: those that have been developed and are in use and those that are little more than ideas. Dr. Burton Clark is a 36-year veteran of the fire service and is the Management Science Program Chair at the National Fire Academy. He is a Certified Fire Officer and a graduate of the Executive Fire Officer Program. Clark has a Bachelor of Science in Business Administration from Strayer University, a Master of Arts in Curriculum & Instruction from Catholic University and a Doctorate of Education in Adult Education from Nova Southeastern University. Dr. Clark is perhaps the fire service’s most vocal proponent of firefighters wearing seat belts. He is adamant that the problem with firefighters not wearing seat belts is not an engineering problem, but a culture and policy enforcement problem (B. Clark, personal communication, October 1, 2007). While he has some appreciation for the intent of this research, he was clear that he believes this research should be unnecessary, and would not be a research topic if fire administrators would enforce seat belt policies. However, Dr. Clark agreed to give input about the potential usefulness of seat belt monitoring systems that are in use and those that could be used in a fire apparatus application. He stated that the red seat belts required by the 2003 edition of NFPA 1901 were good, but acknowledged that they only promoted increased seat belt usage when an officer was willing to require members of his or her crew to wear them. Dr. Clark was of the opinion that the current monitoring systems that detect a seated firefighter and a fastened seat belt were very good systems and should be required equipment. He added that similar systems capable of detecting a proper sit-and-buckle sequence would be a good extension of the current design. In regard to the potential system proposed by Futek Advanced Sensor Technology, Dr. Clark liked the fact that the system would prevent firefighters from standing, but was of the opinion that it is an expensive and complicated technology. He expressed concern that the system would take a long time to design and implement and that a number of firefighters would die in apparatus crashes before the system
was in widespread use. Dr. Clark said he felt unqualified to comment on any other proposed systems uncovered by this research.

Janet Wilmoth is editor of *Fire Chief*, where she has worked for over 20 years. She is active with the Fire & Emergency Manufacturers & Services Association, the International Association of Fire Chiefs Foundation, the National Fallen Firefighters Foundation, and the Fire Department Safety Officers' Association. About the red seat belts currently required by the NFPA 1901 standard, Wilmoth said that they do encourage seat belt use by calling attention to the equipment, but expressed concern that the intent of the red belts is easily circumvented (J. Wilmoth, personal communication, October 1, 2007). Regarding systems that detect an occupant in the seat and whether or not the corresponding seat belt is buckled, she was of the opinion that the systems were good because they encourage seat belt use, but bad because not all apparatus have them—they are currently optional equipment. Wilmoth said the systems capable of detecting the proper sit-and-buckle sequence have a lot of potential; she does not know of any cons because she has not yet seen that type of system. Discussing the Futek system, Wilmoth thinks it is a good proposal, but does not support the system controlling the transmission, especially while the vehicle is underway. Alternatively, she proposed a recording device as a component of the system to encourage firefighters to use seat belts. Further, she suggested the recording device could transmit a signal to a console at the fire department’s communications center as a real-time means of monitoring seat belt usage. About the system that monitored seat belt usage via infrared light, Wilmoth stated that it sounded like it had good potential as long as it proved reliable on fire apparatus. A system that would not allow the gear selector on the transmission to shift out of neutral would probably increase seat belt usage significantly, in Wilmoth’s mind. She expressed concern that it needed an override in the event of a failure so that a sensor or other electrical problem did not prevent the apparatus from moving. She opined
that a sensor system that shut down non-essential functions in the apparatus cab when seat belts were not worn was a good attempt at increasing usage, but wondered what systems on fire apparatus would be shut down. She could not think of any non-essential system on fire apparatus important enough to firefighters to make them fasten seat belts. These systems usually are tied to the stereo, air conditioner, or entertainment devices; few fire apparatus have these. Surely, such systems would not have control of sirens, two-way radios, warning lights, or other equipment essential to firefighter and the public’s safety. Because Wilmoth is in tune with the potential for firefighter circumvention, she liked the idea of the monitoring system that was designed to detect misuse of a seat belt. She could not think of a drawback to such a system, saying that it sounded like a good, economical idea.

Bob Baraclough is a consultant to fire equipment and apparatus manufacturers. He has worked for E-One, Class 1, Incorporated, Hale Products, Incorporated, and National Foam. He is past president of the Fire Apparatus Manufacturers’ Association and has served on the NFPA 1901 committee for the past 22 years. Asked about improvements that would make seat belt monitoring systems more effective, Baraclough had several suggestions. First, on current commercial chassis fire apparatus, there is no monitoring system available for rear-seat passengers (B. Baraclough, personal communication, October 3, 2007). The front seats have factory-installed seat belt monitors and apparatus manufacturers are reluctant to add sensors in the rear and tie them into the existing front-seat system. Baraclough said he was reasonably certain that this problem was going to be addressed in the 2008 edition of NFPA 1901 Standard for Automotive Fire Apparatus, but he was uncertain as to whether or not it would be completely cured. The likely fix will be that all seats will have the apparatus manufacturer’s sensor system and the front seats will have both the apparatus manufacturer’s system and the chassis manufacturer’s system. Baraclough stated it had been proposed in meetings of the NFPA 1901
committee that a seat belt sensor system be tied to the apparatus transmission and that this had always been met with adamant opposition from the fire service members on the committee. He said similar interlocks appeared on passenger cars several decades ago and were met with so much opposition that they were removed in subsequent model years. Baraclough’s opinion was that the fire service might not be ready for such a system. He went on to say that the technology exists to have a system in place that controls the apparatus transmission, and he estimated that it would not cause an expense appreciably greater than what the 2008 edition of NFPA 1901 will require. He indicated that to get such a system through the NFPA 1901 committee, it would have to have some type of override in the event that the apparatus had to be moved and all conditions required by the sensor system were not met. His suggestion was an override that could be actuated relatively quickly by the apparatus driver, but was too burdensome to be used every time the apparatus was placed in gear.

Michael Wilbur is a Lieutenant for the Fire Department of New York and serves on the Department’s apparatus purchasing committee. He is a contributing editor to Firehouse and Fire Apparatus Journal. He has served on the International Fire Service Training Association validation committees for their manuals on pumping and aerial apparatus operation. Wilbur said that there are three reasons firefighters do not wear seat belts (personal communication, October 5, 2007). First, seat belts do not work well. There is not enough room in the seats for firefighters in full bunker gear and it is difficult for firefighters to buckle the belts and to manipulate the seat belt in conjunction with the straps of self contained breathing apparatus. Wilbur indicated that much of the fault for the poor design of seats and seat belts is the result of insufficient communication between apparatus builders and parts suppliers. Further, little effort is put into research for fire apparatus seat belts because it is an insignificant portion of the automotive market. The second reason Wilbur gave for why firefighters do not wear seat belts is
that the fire service hires risk takers. Firefighters are hired and asked to take risks in order to save lives and property. Yet, we ask them to buckle their seat belts and be safe on the way to risking their lives. Wilbur characterized this as doublespeak that was going to have to be addressed with a change in the fire service’s culture. Finally, agreeing with Dr. Clark, Wilbur said the fire service has an enforcement problem and that fire administrators are going to have to be bold enough to require firefighters to wear seat belts. Wilbur stated that he does not believe the fire service will ever reach 100% compliance with seat belt laws and policies. He does believe a rate of 90% will be achieved in the future. He feels that the vehicle data recorder (VDR) proposed in the 2008 edition of NFPA 1901 is enough to bring compliance up as high as is achievable. Wilbur believes the legal system will ultimately be the catalyst that makes firefighters wear seat belts because of data the VDR will provide. The VDR’s record of the status of seats and seat belts before and after an apparatus crash will be used by plaintiffs to file suits against fire administrators who do not enforce seat belt policies and against apparatus drivers who do not ensure all occupants are properly seated and belted prior to moving the apparatus. Wilbur also suggested that insurance companies may cause an increase in seat belt use as they use data from VDRs to refuse payouts to beneficiaries of firefighters that were not utilizing all the safety devices available to them.

Procedure

Research for this project began with a Google Internet search in order to get a general idea of what sort of information might be available regarding firefighters and seat belt use. The author prefers to use the “Advanced Search” feature of Google in order to receive a more focused result. “Advanced Search” allows one to search for specific phrases, select an “and/or” option, and to omit certain words in the search string. The Internet search revealed several valuable pieces of information. One was an editorial from the May 2006 Fire Chief. The
editorial led to three telephone interviews with experts in the field of seat belt design and use. A second was Globalspec.com, an engineering search engine. Using Globalspec.com led the author to five companies that are in the business of manufacturing or designing sensors or sensor systems. A third piece of information revealed by Google was the United States Department of Transportation’s website, www.dot.gov. Many of the statistics concerning death rates, highway miles traveled, seat belt usage, and seat belt laws were gleaned from that website. Google was also useful in finding websites that catered to entrepreneurs and listed a number of seat belt monitoring systems that have been designed but never built.

A search of the National Fire Academy’s Learning Resource Center Online Card Catalog turned up two articles of interest. One was delivered electronically via interlibrary loan through D. H. Hill Library on the campus of North Carolina State University. The other was requested, via email, from the author. The author responded but the article was not received before this research was completed.

On October 1, 2007, Dr. Burton Clark and Janet Wilmoth were interviewed by telephone. The purpose of the interviews with Dr. Clark and Ms. Wilmoth was to answer research question 3. Each was asked to list pros and cons of seat belt monitoring systems uncovered in the literature review. Specifically, they were asked, “What are the pros and cons of the following seat belt monitoring systems?” The systems they were asked to comment on included: (a) red seat belts as they are now required by NFPA 1901; (b) systems that monitor seat occupancy and seat belt use, such as those that are now available as an option from some custom fire apparatus manufacturers; (c) those that detect the correct sit and buckle sequence, send a warning to the driver and/or front seat passenger, and record the data; (d) systems that use sensors to monitor the seats, floors, and seat belts and would not allow the transmission to engage when all sensors did not agree that occupants were correctly seated and belted; (e) those that monitor the seat and
the seat belt with infrared light, record the data, and illuminate a light that can be seen through the windshield; (f) those that monitor the seats and the status of the seat belt buckle, and will not allow the transmission to be placed in drive until seat belts for occupied seats are buckled; (g) those that deactivate non-essential vehicle systems such as the radio or air conditioning when seat belts in occupied seats are not fastened; and (h) those that detect if a seat belt is misused by sensing how much webbing has been pulled from the belt’s spool.

Bob Baraclough was interviewed on October 3, 2007 and Michael Wilbur on October 5, 2007 in order to answer the fourth research question. After both interviewees had listened to an explanation of the intent of this research, each was asked “What improvements can be made to seat belt monitoring systems to enhance their effectiveness?”

As a result of the information provided by globalspec.com, five companies were contacted via email to determine if they produce seat belt monitoring systems or could produce systems to monitor seat belts that might guarantee firefighters wear their seat belts. Four of these companies responded by email and one responded by telephone to the question “Does your company sell or build, or could it design a sensor system capable of ensuring firefighters are seated and wearing seat belts anytime fire apparatus are in motion?”

Two email surveys were used in conducting research. One was sent to about 40 of the author’s colleagues in the fire service. The survey had a single question: “Does your fire department have a policy that requires all occupants of fire apparatus to be seated and belted when the apparatus is in motion?” The second survey was sent to 11 apparatus manufacturers and again, had a single question: “Does your company offer a seat belt monitoring system on the fire apparatus it builds?” Seven of the companies responded.

There are several limitations of this research. One is that it does not consider the psychology underlying the apparent difficulty getting firefighters to wear seat belts. Machismo,
poor seat belt design, lack of policy enforcement, habit, or some combination of these things may be the culprit, or it might be some completely different reason or reasons. Another limitation is that the research for this project was conducted under the constraints of a six-month time period. Sixty-four percent of the apparatus manufacturers responded to the question about what seat belt monitoring systems are currently offered. While conventional wisdom suggests the manufacturers that did not respond do not have a monitoring system, there is no proof of that; more time would have allowed the author to follow up with more manufacturers. A third limitation is that this research only considers the death statistics associated with lack of seat belt use. Consideration of injury statistics may make the need for a system to guarantee seat belt usage by firefighters even more apparent.

Results

While there is not great amount of diverse information available, the author found sufficient information to answer the four research questions.

Question 1: What seat belt monitoring systems are currently available for fire apparatus?

There are essentially two means to monitor seat belt use that are available on fire apparatus today. One is the red seat belts required by the 2003 edition of NFPA 1901. The theory behind the red belts is that, because they are easily distinguishable from darker-colored self contained breathing apparatus straps, crew leaders on fire apparatus can more easily check to see if seat belts are properly in place across the chest of firefighters (Cavette, 2003). The second means of monitoring seat belt usage is via a sensor system that detects when a firefighter is in a seat and whether or not the seat belt buckle is fastened. Most of these systems display seat belt status in the front of the cab, either via indicator lights, liquid crystal display, audible alarm, or some combination thereof (Marion Body Works, personal communication, August 31, 2007; Smeal Fire Apparatus Company, personal communication, August 31, 2007; Ferrara Fire
Fire Research Corporation has developed a prototype seat belt monitoring system that they expect to start installing on fire apparatus very soon. The device is in response to the proposed 2008 edition of NFPA 1901. The device will record a number of things, including proper sit and buckle sequence and seat belt status at the time of an apparatus crash (R. Fix, personal communication, September 6, 2007).

Question 2: What seat belt monitoring systems exist which have yet to be used on fire apparatus, but may be available for such applications?

A system could be designed to ensure firefighters were properly seated and belted before the transmission would be allowed to engage (J. Mokhbery, personal communication, September 10, 2007). The proposed system would incorporate an array of sensors in the floors, seats, seat belt buckles, and the seat belt webbing spools on fire apparatus. There would be an interlock between the sensor system and the transmission. Only after the sensor array was satisfied that firefighters were seated and properly buckled, would the transmission be allowed to shift into a drive gear. The system would be able to detect standing firefighters and a condition where a seat belt was buckled behind the seat or behind the wearer’s back.

A system has been theoretically designed that would use global positioning system and infrared technologies to determine if vehicle occupants were properly buckled (Patent Storm, 1999). An infrared transceiver would emit a light and capture its reflection from reflectors on shoulder belts. Tied to seat sensors, if the system detected an occupied seat but did not “see” a proper corresponding infrared reflection, it would signal a fault. When proper reflections are received from all occupied seats, the system would illuminate a light visible from the exterior of the vehicle.
For apparatus with automatic transmissions, a system has been proposed that will not allow the transmission to shift into a drive gear until seat belts are fastened on all occupied seats (Free Patents Online, 2003). If, after being satisfied and allowing the transmission to be placed in a drive gear, one or more seat belts become unbuckled, the system would alarm until either the seat belt or belts were re-fastened or the transmission was taken out of a drive gear. The system has an override: with the gear selector in park, the brake pedal depressed, and the hazard flashers activated, the driver would be allowed to place the transmission in a drive gear.

At least one seat belt monitoring system has been theorized that is designed to detect accidental or intentional misuse (Free Patents Online, 2005). Along with sensors in the seats to detect occupancy, the system has sensors on the seat belt webbing spool. The purpose of these sensors is to determine if the user has pulled enough webbing from the spool to go in front of the user rather than behind the seat or behind the back. If the sensor is not satisfied with the amount of webbing removed from the spool, it sounds an audible alarm.

Question 3: What are the pros and cons of current and available systems?

Sensor systems that detect the proper sit and buckle sequence and record the status of seat belts at the time of an apparatus crash have a lot of potential (J. Wilmoth, personal communication, October 1, 2007) and will be a good extension of the current design that only senses occupied seats and fastened buckles (B. Clark, personal communication, October 1, 2007). A flaw of these systems is that they are a technology that is not yet available; it will be many years before all apparatus have it (J. Wilmoth, personal communication, October 1, 2007). A system that is capable of monitoring floors, seats, seat belt buckles, and webbing, and is tied to the transmission is good because it can keep firefighters from standing, but is likely an expensive and complicated technology (B. Clark, personal communication, October 1, 2007). Allowing such a system to have control of the transmission may prove to be a problem if there is no way to
override it, especially if the system can disengage the transmission when the apparatus is underway (J. Wilmoth, personal communication, October 1, 2007). Monitoring shoulder belts with infrared light has potential so long as it is a reliable system (J. Wilmoth, personal communication, October 1, 2007). It is unlikely that a seat belt monitoring system that is able to disengage non-essential vehicle systems would have much effect on seat belt usage because fire apparatus have few systems that would be considered non-essential (J. Wilmoth, personal communication, October 1, 2007). Finally, Wilmoth liked the idea of a seat belt monitor that can determine if a seat belt is being properly worn. She stated that this type of system appears to have good potential as an economical solution to the problem of firefighters fastening seat belts behind their back or behind the seat.

Question 4: What improvements can be made to seat belt monitoring systems to enhance their effectiveness?

A means must be developed to monitor all seats on commercial chassis fire apparatus (B. Baraclough, personal communication, October 3, 2007). Commercial cabs and chassis are delivered from their manufacturer to the apparatus builder with sensors installed on the front seats only. Apparatus manufacturers have been reluctant to tie rear seat sensors into the existing front seat system (B. Baraclough, personal communication, October 3, 2007). Baraclough believes the 2008 edition of NFPA 1901 will address this problem, but he is unsure if it will be a perfect fix. He also stated that, on numerous occasions, a sensor system had been proposed to the NFPA 1901 committee that would not allow the transmission to engage if sensors did not detect that all occupants were seated and belted. Such a system has always been met with opposition from fire service committee members. Baraclough says technology exists to have a seat belt sensor system control the transmission at a minimal cost. The most likely way to get such a system through the committee was to incorporate an override that was a compromise
between being simple enough to engage the transmission if necessary, but too complicated to use on a regular basis. While seat belt usage will likely never reach 100%, the vehicle data recorder (VDR) proposed in the 2008 edition of NFPA 1901 will be enough to get the rate to 90%, likely as high as it will ever be (M. Wilbur, personal communication, October 5, 2007). Wilbur believes that because the VDR will show whether or not firefighters were properly wearing seat belts at the time of a crash, the data will be used by litigants to file suit against fire administrators for not enforcing policies and against fire apparatus drivers for not ensuring all occupants are properly belted before moving the apparatus. This, coupled with the potential for insurance companies reviewing VDR information and refusing to pay beneficiaries when deceased firefighters were found not to be wearing seat belts at the time of a crash, will make all but the most rebellious firefighters properly wear their seat belts (M. Wilbur, personal communication, October 5, 2007).

Discussion

Conducting the literature review and investigating facts and opinions that are the results of this research led the author to several interesting revelations. Fire apparatus make up a statistically insignificant portion of the fire apparatus market (M. Wilbur, personal communication, October 5, 2007). As such, there is little incentive for private-sector automotive component manufacturers to research and design seats and seat belts that work well when installed on fire apparatus. As a rule, seats and seat belts on fire apparatus are taken or adapted from those used on medium and heavy-duty trucks. As an extension of these facts, the author was surprised to find that the available means of monitoring seat belt use are few. Essentially, all that currently exists is red seat belts (Cavette, 2003) and an electronic sensor system that can determine if a fire apparatus seat is occupied and whether or not the corresponding seat belt is fastened (Marion Body Works, personal communication, August 31, 2007; Smeal Fire Apparatus
A number of designs for systems to increase the frequency of seat belt use have been proposed, but, so far they are only proposals (Free Patents Online, 2004, 2005, 2006; Patent Storm, 2006; Javad Mokhber, personal communication, September 10, 2007). The author agrees with the assertions of Dr. Burton Clark (personal communication, October 1, 2007) and Lieutenant Michael Wilbur (personal communication, October 5, 2007): the quickest and easiest fix for the problem of firefighters not wearing seat belts is for all fire departments to have seat belt policies and for administrators to enforce those policies. Research shows a high percentage of fire departments have policies. However, with 30 years of data for support, enforcement of these policies is lacking in effort (NFPA, 2007). Clearly, something has to be done to force firefighters to wear their seat belts. Wilbur makes a good argument that seats and seat belts are poorly designed. Both Clark and Wilbur make good arguments that there has to be a culture change in the United States fire service so that wearing seat belts becomes a routine procedure. New seat and seat belt design is going to take time to make it into the fire apparatus market. Cultural change is going to take time. Even then, there will be renegade firefighters unwilling to wear seat belts and the success rate will likely never top 90% (M. Wilbur, personal communication, October 5, 2007).

The author believes that an electromechanical system that does not allow the fire apparatus to move until sensors show all personnel are seated and properly buckled is the only way to reach 100% compliance and that such a system will take no longer to accomplish its objective than engineering new seats and seat belts or changing the culture of the fire service. An engineered device to ensure firefighters always wear seat belts is not a quick fix, but the fire service has made no progress in 30 years and a move toward the goal of ensuring firefighters wear seat belts
100% of the time has to start at some point. The technology to design, test, and implement such a system is available at an affordable cost (J. Mokhbery, personal communication, September 10, 2007; B. Baraclough, personal communication, October 3, 2007). Such a system, with sensors in seats, floors, on seat belt buckles, and on seat belt webbing spools that control the engagement of the apparatus’ drive line is the only method currently proposed to guarantee firefighters wear their seat belts every time (J. Wilmoth, personal communication, October 1, 2007; B. Baraclough, personal communication, October 3, 2007). The implications of such a seat belt monitoring system are that, after the technology has made it to market and into all fire apparatus, firefighter deaths occurring from lack of wearing seat belts will be eliminated for Carrboro Fire-Rescue Department and all other fire departments.

Recommendations

The problem of firefighters not wearing seat belts is a significant one, and currently, there is no means of ensuring firefighters are always buckled. The vehicle data recorder that is proposed for the 2008 edition of NFPA 1901, at best, will only encourage a 90% compliance rate (M. Wilbur, personal communication, October 5, 2007). The Carrboro Fire-Rescue Department should take the lead in assisting with the design and testing of a sensor system to ensure firefighters wear seat belts 100% of the time. As a small organization, scheduling and call volume is conducive to apparatus fitting and trials. Further, because the author is an administrator at Carrboro Fire-Rescue, support for such a project already exists. Systems similar to the one favored by the author have been proposed to the NFPA 1901 committee in the past and have not been supported by fire service members on the committee (B. Baraclough, personal communication, October 3, 2007). The Department should designate a representative to pursue a seat on the committee for the 2013 edition of the automotive fire apparatus standard in an effort to educate and persuade other committee members of the benefits of an electromechanical seat...
belt monitoring system. Further, the Department should take a lead role in pursuing funding for project development through sources such as the United States Fire Administration, the International Association of Fire Fighters, the International Association of Fire Chiefs, and the National Fallen Fire Fighters Foundation.

For those conducting similar research in the future, it is recommended that the latest ideas and technologies be considered, as they are always being proposed and developed. In the next five years, the traditional three-point seat belts now accepted as standard on fire apparatus may be replaced with more secure harnesses that could incorporate self contained breathing apparatus straps (M. Wilbur, personal communication, October 5, 2007). The system proposed by this research is heavily based on technology. It will be critical that future research investigates industries on the cutting edge of restraint technology such as the space program and motor sports.
References


