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Prototype Air Bag Restraint for Use in Patrol Vehicles

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ABSTRACT

An air bag has been designed and laboratory tested for use in existing police vehicles that will restrain a person if he or she becomes violent. The device will prevent self-injury and protect the vehicle and officer. The device does not pose a suffocation hazard and can be quickly and easily inflated or deflated by the officer from the front seat. The device is ready for field testing.

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INTRODUCTION

It is not infrequent that a person placed in the rear seat of a police vehicle in an initially calm state later erupts into violence. Such a person can cause self-injury, damage the vehicle, and endanger the officer. The air bag restraint is intended to prevent or reduce the seriousness of property damage to the vehicle (smashed windows, dented doors, etc.), self-inflicted injury to the transported subject, and assault on the officer.

The objective of the vehicle air bag restraint system is to prevent a person or persons from continuing violence while being transported in a patrol vehicle without requiring immediate physical contact by a law enforcement officer. The air bag is rapidly but not explosively deployed by the officer from the front seat. It exerts sufficient pressure to restrict the physical activity of the rear seat occupant(s) of the vehicle, allowing the officer to safely stop the vehicle and to have additional time to get backup personnel if necessary before subduing the occupant(s). The officer has control of the system and can inflate the bag or deflate the bag as desired. Air permeable sections of the bag and the

low pressure of the bag minimizes the risk of suffocation. Modular design permits easy removal of the bag for cleaning or for replacement with a new unit, minimizing vehicle down time. The device is designed for installation in existing patrol vehicles with cages to best use current vehicle resources.

At a 1992 needs assessment workshop sponsored by the National Institute of Justice, law enforcement attendees expressed a need for addressing the problem of violent outbursts from subjects during transport. The Idaho National Engineering Laboratory (INEL) was funded under an Interagency Agreement to provide a proof-of-principle design for a rear seat air bag restraint system for a patrol vehicle. After consulting with a variety of law enforcement groups, we developed a set of design requirements from the basic need originally identified, and completed a proof-of-principle design in 1993. A second-phase award was made in 1994 to develop a prototype of the system that could be evaluated for field testing. We designed, fabricated, evaluated this prototype as a mockup, and then installed it in a patrol vehicle.

DESIGN REQUIREMENTS

The design requirements established in 1993 are still valid and were applied to the prototype development. The requirements are as follows:

1. *The air bag will be activated manually.* The officer needs to initiate any action regarding the air bag. The officer is the person responsible and liable for mishap; thus, he or she needs to be able to determine when an air bag should be deployed. A manually activated system is also typically less expensive and less likely to malfunction than an automated system. Sensors can be placed in, and around, the rear seats to automatically activate the air bag based on motion or force criteria if such is determined later to be useful or desirable.
2. *The system must restrain person for at least two minutes.* This is the minimum time that officers believe would be adequate to get their vehicle safely out of traffic and evaluate the situation at hand.
3. *Inflation time in tens of seconds is adequate.* A very rapid inflation time (less than 1 s) poses design and safety concerns. The officers consulted believe that the time required to inflate the air bag is not critical as long as it is not in minutes.
4. *The system must be inexpensive.* Law enforcement is budget constrained. Developing the greatest device in the world is of little use if it is too expensive for agencies to purchase and implement. Ideally, the air bag restraint could be installed on all patrol vehicles, and the cost of the system be no more than current commercially available restraint seats.
5. *The system must install in existing patrol vehicles.* We envision the system as being installed in patrol vehicles as time and costs allow; thus, the air bag restraint must be designed as an add-on device. This allows new, as well as old, vehicles to be outfitted with the restraint device. Possibly, the air bag restraint could be offered as an option directly from the automotive dealers, but that is not the present intent.
6. *The air bag system must accommodate various seating arrangements (i.e., persons with or without seat belts and handcuffs, one person or two, large person or small, etc.).* Since no unique seating configuration exists upon which to base the design, the air bag must serve all possible body configurations. Persons sitting, lying on the seat, lying on the floor, kneeling, or standing on the seat will all have to be considered in the design.
7. *The air bag must restrain without suffocating or being a physical hazard to the person(s) being restrained.* Since the minimum restraining time is two minutes, suffocation is a possibility. The air bag must, therefore, prevent its occurrence. Restraint does not mean a person must be pinned with all the air knocked out of him or her. Research shows that a pressure of 1 to 2 psig (27.7 to 55.4 in. H₂O) will not cause physical harm. However the restraint system should exert the minimum pressure to restrain persons. The amount of pressure will need to be determined through testing.
8. *The air bag must be washable or replaceable and not rip or tear easily.* It is assumed that blood and saliva will end up on the air bag. To answer any health concerns associated with this, the air bag must either be washable or so inexpensive that replacing it is trivial. The air bag must also be rugged and not tear or rip easily. If a sharp belt buckle, or blow with the fist, could render the system useless, it probably is not worth the cost of installing it.

SYSTEM DESIGN AND MOCKUP

The work completed in 1993 demonstrates that the concept of a semipermeable air bag inflated by a constant air supply was a viable system to restrain persons in the rear seat of patrol vehicles. This is where the 1994 effort began. Two subsystems had to be designed: the air bag itself and the air supply system. These two subsystems then had to be integrated into a working system that could be mounted and operated in a law enforcement patrol vehicle.

Development of the air bag was tackled first. Unknowns that existed were the amount of pressure the bag should exert, the surface area and location of permeable and nonpermeable materials, and the size, and geometry of the bag. The pressure the bag exerts is related to the surface area of permeable and nonpermeable material, so those two aspects were considered together. From the design requirements, a threshold pressure of 1 psig was evaluated as being reasonable; it would restrain but not pose a threat to persons. Ideally, the pressure should be as low as possible since this reduces the possibility of injuring someone, but the exact value for pressure was still undefined. Having no published data identified that would shed light in this area, we decided that a full size mockup of the rear seat of a patrol vehicle would be used to help define the low pressure value. One of the small air bag demonstration setups used in 1993 was retrieved for some pressure measurements. This demonstration setup consisted of a small air bag (less than 2 ft².) with canvas on the front surface placed inside a plywood box. A leaf blower was connected to the air bag and the bag inflated. Hands placed inside this box are pinned by the air bag when it is inflated but can still push into the bag a moderate distance. This was measured at a pressure of about 0.1 psig. Since this value was well below our threshold of 1.0 psig and had a reasonable restraining feel to it, we scaled it up as the model for a full-size mockup.

A plywood box approximately the size of the back seat of a typical patrol vehicle was constructed. The top and one side of the box was made of

Plexiglas with the side panel being a slide-in removable section. The rear seat from a Chevrolet Caprice was placed in the box. For mock up, we decided that standard PVC pipe would suffice as the ducting into the air bag. Two, one-horsepower leaf blowers were used in this system as the air supply. Figure 1 shows the mockup. An air bag was then fabricated using the insights gained from the small air bag setup. This bag when fully inflated would easily fill the entire volume of the mockup. Canvas, the permeable material selected, was placed on the front side (facing a passenger in the seat) and on the bottom surface of the bag. We assume these surface would contact the locations a person would most likely be since a person is almost always seat belted. The rest of the air bag was made from rip stop nylon (a nonpermeable material). Both materials were selected for their durability, low cost, and ease of cleaning.

The air bag was inflated using the two blowers in approximately five seconds and completely filled the volume of the mockup exception for the foot space between the seat and the wall of the mockup. Measurements of the pressure exerted by the bag were attempted, but the pressure was below what the instrumentation would measure. This meant that the pressure was less than 0.1 psig, which, again, was well below the threshold limit of 1.0 psig. The permeable material covered the seat area of the mockup, so regardless of whether an person was sitting upright or lying down on the seat, the possibility of suffocation is highly unlikely since air will be blowing into their face in those locations.

The next question to be answered was whether this larger, lower pressure bag would restrain an person adequately. Safety Engineering was called in to evaluate the set up and determine if a person could test the mockup. The power control for the blowers was routed inside the mockup so that the person inside could turn off the blowers at any time. As soon as the blowers loose power, the bag deflates and completely loses its pressure. Upon approval from Safety Engineering, testing began with a person inside the mockup.

Figure 1. The mockup of the prototype air bag restraint.

Tests in the mockup were initially conducted with persons very familiar with the system, who could best evaluate the air bag. A person sat inside the mockup with the power control for the blowers in his or her lap. The air bag was simply rolled up and held in place with tape. When the person was ready, the blowers were turned on with the power control, and the tape was released. Tests began with a duration no longer than ten seconds and then slowly increased in ten-second increments until the person was in the mockup for over two minutes.

These tests revealed that the canvas portion of the air bag let sufficient air pass through that breathing was never affected by the bag. The pressure of the bag was also evaluated favorably. A person could push into the bag with moderate ease but it was a pretty exhausting process. When the person was allowed to use hands to attack the bag,

which simulates a person not in handcuffs, it was possible to overcome the pressure and collapse it. When the person's hands are held behind as they would be if handcuffed, the pressure is sufficient to hold him or her for a minute or two. The design engineers believed that the neck was the most vulnerable part of the body that could be used to defeat the bag and evaluated how the neck could move against the bag. The pressure from the mockup was low enough that the neck and head were able to push into the bag without being snapped back. We decided that the pressure should remain at this low value to prevent injury, even though it meant that the bag would be less effective when persons are transported without being handcuffed. Our limited funding did not allow physiological testing, and the information obtained from the mockup is from observations of the design engineers. Complete physiological tests should be

conducted by experts in that discipline prior to field testing this technology.

The last area of the design to be developed was deployment of the bag and the latching system. PVC pipe had been used to house the air bag and provide the ducting from the blowers to the bag, owing to its durability and low cost. Our budget constrained us to use commercially available shapes such as pipe and channel rather than specially designed shapes. This limitation led to the replacement of PVC with sheet metal for the air bag housing since it could be easily shaped as needed. We anticipate that in a production model the sheet metal will be replaced with injected molded plastic, but for prototype development the sheet metal was better.

Several shapes were evaluated for the housing of the air bag. The primary requirements were (a) a small profile so that the viewing area into the rear seat of the vehicle was as large as possible, (b) a sturdy and somewhat tamper proof design for the housing, and (c) a housing that would allow the air bag to be removed and installed as easily and quickly as possible. The latching system was also investigated. A paddle wheel type release mechanism was tested. This system relied on the air from the blowers rotating the paddle wheel and physically hitting the release. Although this worked well and required no power, we believe that potential maintenance for the paddle wheel and possible alignment concerns make a more typical electrical latch a better choice.

INSTALLATION OF THE PROTOTYPE IN A PATROL VEHICLE

The information obtained from the mock up was used in completing the design of the final prototype air bag restraint system. The Arapahoe County Colorado Sheriff's Office was extremely generous and lent the INEL a 1993 Chevrolet Caprice Patrol Vehicle. By having a police vehicle available for hardware installation, not only did it facilitate the design effort but it also verified that the prototype could be installed in an existing vehicle with minimal modification to that vehicle.

The air supply for the air bag restraint was installed in the trunk of the vehicle. Commercial blowers were used, and their size precluded installation under either the front or rear seats of the vehicle. It is plausible that blowers with sufficient output can be packaged such that they will fit underneath a seat, though installation in that location may be more time consuming and costly than trunk installation. These commercial blowers are a.c., not dc, power; dc will be needed for the final produc-

tion system, and dc-powered blowers will probably have to be specially designed for this use.

From the trunk, the air from the blowers is directed to the air bag housing via PVC ducting through the speaker penetrations in the rear window ledge. The PVC ducting is run along the ceiling in the back seat and connects to the air bag housing at the ceiling line. The air bag housing directs the air from the vertical ducting horizontally into the air bag. The air bag housing is bolted to the extruded metal partition of the patrol vehicle. A solenoid latch in the housing is activated by a switch in the console in the front seat of the vehicle to deploy the air bag. Another switch on the console turns the blowers on and off. Figure 2 displays the various hardware components as they are installed in the patrol vehicle from the Arapahoe County Colorado Sheriff's Office. The entire installation of the hardware required very little modification.

Figure 2a. The air supply for the air bag restraint.

Figure 2b. The air bag housing and ducting located in the rear seat area of the vehicle.

Figure 2c. The switch plate control for inflating and deflating the air bag.

The housing for the air bag is triangular and fabricated out of sheet metal. Several shapes and latching mechanisms were considered, including spring loaded configurations and rounded shapes. The triangle configuration has the least vertical space; thus, it has the least impact on the visibility into the rear seat from the front seat. The solenoid latch was selected over an air-activated spring-loaded system because it provides better tamper proof design.

We anticipate that a production model of the housing would be injection-molded using a thermoplastic. The air bag is easily installed in the housing by threading the welts on the bag through

the molding in the housing. Figure 3 shows the air bag installed in the housing. Once the air bag is secured to the housing, the bag is rolled up similar to a window shade, and the housing door is closed. Prepackaged air bags would be used in a production model; for the prototype design only one air bag exists, so it must be rolled up after every use.

For safety during testing, a power-kill switch was added to the system. This is a hand-held device given to anyone testing the air bag in the back seat of the vehicle. The person evaluating the air bag restraint system can turn off the blowers at any time should any discomfort be felt.

Figure 3. The air bag installed in the housing.

SUMMARY

This work has demonstrated that an air bag restraint system can be designed such that it can restrain a person(s) without posing a suffocation hazard. We have also demonstrated that the installation and removal of air bags can be quick and easy. Installation of the hardware for the system does not require major modification to the vehicle. Any existing vehicle can be fitted with the system. Although only laboratory tests were conducted, the results were very positive, and field tests should be considered as the next step.

A technical area still to be developed is to provide dc-powered blowers. The production model air bag restraint system will need blowers powered from the vehicle's electrical system, and dc power is probably best. Field testing under typical use scenarios will help finalize the specific performance curves for the blowers. Once this

information is obtained, the final design for the blowers can be completed by any of a number of organizations such as universities, private industry, or national laboratories. Field testing will also provide the necessary input to optimize other areas of the design. The air bag housing must be rugged enough to survive residing in the rear seat of a patrol vehicle. It must be tamper resistant and not block too much of the view of the officer driving the vehicle. The air bag itself must also be evaluated for durability, pressure, and breathing adequacy by persons that can test it under more realistic conditions. Law enforcement personnel should be involved in all steps of the field testing to ensure that the system will perform to their needs. Upon successful completion of field testing, we anticipate that the system can undergo final design modifications and then be ready for commercial production.