WHEELCHAIR
RESTRAINT SYSTEM

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INNOVATIONS DESERVING EXPLORATORY ANALYSIS (IDEA) PROGRAMS MANAGED BY THE TRANSPORTATION RESEARCH BOARD

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EXECUTIVE SUMMARY

A prototype wheelchair restraint system was designed, developed and tested. The wheelchair restraint system is compatible for operation with buses, light rail commuter cars, and multi-passenger call-and-ride vehicles. The design incorporates features that eliminate the need for docking hardware permanently attached to the chair, does not require the transit vehicle driver/operator to attach securement devices to the wheelchair, and is tolerant of positioning errors with the wheelchair. The system is cost-effective and easy to operate and enhances the potential for reducing passenger injuries and consequent medical and liability costs.

The wheelchair restraint system can accommodate commercially available wheelchairs which vary in width from 66 cm (26 in) to 81 cm (32 in). The restraint system limits chair movement to less than 1.5 cm (0.59 in) during forces that are representative of accelerations experienced during normal driving maneuvers. The design ensures that the restraint mechanism will not contact the occupant of the wheelchair and that activation of the restraint does not require the operator to invade the wheelchair user's personal space.

A novel mechanism will prevent the wheelchair frame being subjected to stress levels which could cause a folding wheelchair to collapse or reduce the life expectancy of the wheelchair frame due to fatigue loading. The mechanism can be deployed in about 1 min—a period acceptable by both transportation system operators and passengers.

The wheelchair restraint system uses pneumatically driven bristles that engage the wheels and frame of the chair to stabilize it against movement during acceleration and braking and help reduce the risk of injury in case of collisions. The bristles are actuated by a compressor installed on the vehicle and by a vacuum line to rapidly disengage the restraint from the wheelchair and to stow the restraint in the least amount of space. The pneumatic system includes release valves for quick release and evacuation in case of a power failure after collision. The restraint design incorporates sensors that will detect when the restraint contacts the side of the wheelchair and will act to limit subsequent travel of the bristles so that the chair will not collapse or bend from the force of the restraint.

A prototype wheelchair restraint system was constructed from aluminum and Delrin rods, and consists of four modules, two on each side of a wheelchair (see figure 1). The transit rider backs into the restraint system, and the device actuates to capture and hold the wheelchair. The modules are operated with compressed air which can be supplied by the vehicle. The outer boxes of each module contain movable inner boxes to accommodate varying wheelchair widths. The inner boxes are deployed and retracted by a pneumatic drive system. Each inner box contains a bristle plate into which the bristle assembly is inserted (see figure 2). The bristle plate is deployed by inflatable bladders and retracted with constant force springs. The bristles slide freely within their assembly when the bristle plate is deployed, extending until they contact a component of the wheelchair. Each bristle moves independently to create a custom mold that mates with the frame of the wheelchair. Once capture is established, the wheelchair is secure and can be subjected to loading.

The finished prototype was mounted on a test platform and subjected to force applications of increasing magnitude until the restraint released the wheelchair. In static testing, the prototype restraint was able to secure the wheelchair against loadings that are comparable to those experienced during routine driving; however, the prototype system was not able to withstand crash level loadings (loads greater than 8 G's). The static testing confirmed the feasibility of the concept and that the system can be made crashworthy. The limitation in the prototype was caused by relative motion between the boxes that move the bristles. This motion allowed the inner box to tilt under crash level loads and the wheelchair was able to slip within the restraint. This motion could be eliminated in a second generation prototype as it was caused by the construction technique.

This study accomplished its goal of demonstrating the feasibility of using a novel, pneumatically actuated system to secure wheelchairs in mass transportation vehicles. The study resulted in a set of design specifications for a public transportation wheelchair restraint system, the design and fabrication of a pneumatically operated securement prototype device that uses air driven bristles to restrain the movement of a wheelchair under load levels that could occur during normal driving, and static testing of the prototype system to prove the feasibility of the concept.

Preliminary contacts have been made with manufacturers of wheelchairs and suppliers of other wheelchair restraint systems to identify potential partners in the commercialization of the IDEA product. Wheelchair manufacturers have expressed interest in the wheelchair restraint system.

IDEA PRODUCT

A new and innovative wheelchair restraint system was developed and tested. The pneumatically operated wheelchair restraint system is compatible for operation with buses, light rail, and multi-passenger call-and-ride vehicles. The system is cost effective and easy to operate and enhances the potential for reducing passenger injuries and consequent medical and liability costs. The design accommodates a wide variety of commercially available wheelchairs, eliminates the need for docking hardware permanently attached to the chair, does not require the transit vehicle driver/operator to attach securement devices to the wheelchair, and is tolerant of positioning errors with the wheelchair.

CONCEPT AND INNOVATION

The system uses pneumatically driven bristles that engage the wheels and frame of the chair to secure it during acceleration and braking and to help reduce the risk of injury in case of collisions. The bristles are actuated by a compressor installed on the vehicle and by a vacuum line to rapidly disengage the restraint from the chair and to stow the restraint in the least amount of space. The pneumatic system includes release valves for quick release and evacuation in case of a power failure after collision. The restraint design incorporates sensors that will detect when the restraint contacts the sides of the chair and will act to limit the subsequent travel of the bristles so that the chair will not collapse or bent from the force of the restraint.

INVESTIGATION

GUIDELINES FOR WHEELCHAIR RESTRAINT SYSTEM DESIGN

Information about commercially available products was collected to ensure that no similar products already existed and to verify that a need existed for improved restraint systems. An advisory board composed of representatives from the transportation industry, wheelchair users, and design engineers was organized to provide the project investigators with information needed to design the system and to assist in evaluating alternative designs to assure that they were practical and acceptable to all who will have to interface with the device. Table 1 lists the advisory board members. The advisory board held several meetings to discuss the various issues considered when designing a restraint system. Important deliberations of the first meeting which were instrumental in forming the preliminary design are summarized below:

- Although it is important that restraints in Metro-lift vans be improved, the primary focus for the first stage of the project was to improve restraints for use in buses. The need for improved restraints in buses is important because 1) bus drivers seem to have less experience securing wheelchairs than van drivers and 2) scheduling constraints and driver and passenger attitudes are such that shorter stopping times are viewed as more necessary for buses than for vans. A system that works equally well in both buses and vans is the most desirable

- The most common complaints with current restraints are that they take too much time and that they require too much invasion of personal space. Tie-down times vary from an estimated 30 seconds, not including positioning, to 3-5 minutes, including time for positioning of the chair.

- The Americans with Disabilities Act (ADA) requires that chairs must be either front or rear facing in a minimum of 76 cm x 122 cm (30 in x 48 in) free floor space with either a two- or four-point tie down. Once restrained, the chairs can slide no more than 3.75 cm (1.5 in). Although belts are required on Metro-lift, belts are optional on the full-size buses because they are not required for other users. Because the wheelchair lifts are 76 cm x 122 cm (30 in x 48 in), any chair that will not fit in this space does not need to be accommodated by the proposed restraint, since such a chair will not be able to enter the bus.

Table 1 Project Advisory Board Members and Qualifications

Member	Qualifications
J. Frieden	Wheelchair user who has extensive experience with mass transit transportation and serves on the local transit board to represent the needs of persons with disabilities.
M. Nosek	Wheelchair user who is active with consumer issues in the community and has extensive experience with independent living issues.
J. Loughlin	Houston Metro management representative who uses a wheelchair.
R. Levy	Texas Rehabilitation Commission employee responsible for use of technology by persons with disabilities. He has extensive experience with vehicle modifications and wheelchair restraints.
D. Rossi	Wheelchair user who uses the Houston MetroLift system.

- The driver should be removed from the loop as much as possible. Although for liability reasons the driver must verify that the wheelchair is properly secured, it is desirable to minimize the both the driver's time and invasion of the rider's personal space.

WHEELCHAIR RESTRAINT SYSTEM DESIGN

To meet the project goals of developing and studying the feasibility of a pneumatically actuated wheelchair restraint, a set of design goals was derived from the literature and interaction with the advisory board. In a recent study of the engineering requirements for a transit vehicle mobility aid securement system (1), the importance of several variables was noted. The study also delineated a number of human factors considerations and suggestions that were incorporated in the design developed in this project. The human factors design considerations included:

- *Minimizing the time required to train the passenger*. The system was designed to use a minimal set of picture based instructions to guide the user in how to roll up to the securement system and activate the device. The goal is to make the system operable by a person with third-grade level cognitive skills.

- *Minimizing the time needed for transit operator training*. The instructions for using the system can be packaged into an in-service program of 20 minutes or less. The program would be designed to be used in new-operator orientation and on an annual basis by operators and drivers. The training includes information about routine operation, maintenance (not repair), and problem solving for non-routine operation.

- *Minimizing the need for the operator to invade the passenger's personal space*. With this design, the only necessary invasion is during non-routine operation of the device. The operator can be informed via remote signal when the securement system is properly deployed and engaged; however, in most instances, the operator checks the system visually to satisfy liability requirements.

- *Minimizing the need for tools to connect or disconnect the securement system*. The system designed in this study does not require tools to operate under routine conditions. The device can be deployed by either a user activated switch or a driver-operated switch that utilizes the pneumatic power available on the vehicle.

- *Reducing positional accuracy requirements for docking*. Small lateral adjustments and small angular adjustments to the wheelchair position are very time consuming and often frustrating for everyone involved. The chair does not have to be centered within or aligned along the modules that define the operating space of the securement system.

- *Minimizing the number of steps required to secure and disconnect the wheelchair.* The system has been designed to accommodate the differences that currently exist between wheelchairs. Adjustments for different chair widths, depths and heights are made automatically as the bristles contact the chair.

- *Minimizing the need for fine motor control to activate the securement device*. The design is activated by the transit operator and requires no passenger intervention beyond rolling into the designated area. Activation can be done remotely when the operator has checked to make sure the chair is within the stall and ready to be secured.

- *Minimizing interference with other passengers*. The system was designed so that when it is not being used by a wheelchair user, one of the aisle-side units swings up over the other one for storage so that the space in the stall of the device will be available to passengers who are not who are not in wheelchairs.

- *Minimizing activation time*. The system has been designed to activate in under three minutes. The activation time includes the time required to move into the stall and secure the wheelchair or disengage the chair and roll out of the stall in a motorized chair.

- *Minimizing the modifications needed on the wheelchair*. The device does not require any modifications or attachments to the wheelchair.

Maximizing passenger security. The lateral, longitudinal, and tilt motions experienced by the loaded wheelchair were primary concerns addressed by the design. Members of the advisory board who use wheelchairs were queried to determine the magnitude of motions that cause them discomfort. Under normal driving conditions, motions were limited to less than 2 cm (0.79 in); however, under crash conditions, allowable motion of the chair was increased to 5 cm (1.97 in) to control the accelerations experienced by the user and thus reduce the potential for injuries.

The investigators met with Jim Loughlin at the Houston Metro Bus Barn to inspect the various vehicles that have been fitted to carry persons who use wheelchairs. A number of photographs were taken and sketches were made of vehicle layout and the space available for wheelchairs. Several preliminary designs for the wheelchair restraint system were developed on the basis of input from the advisory board, from trips to inspect the vehicles, and from information provided by Drs. McDermott and Koppa. The final design implemented in the IDEA project, uses a combination of air filled bladders and pneumatic pistons to operate the wheelchair restraint system.

Pneumatically actuated bristles provide the restraining force needed to stabilize the wheelchair without causing a residual sideward force on the wheelchair frame which could cause the chair to collapse. The current design for the restraint uses a double-staged activation to engage the bristles with the wheelchair. The first stage of activation extends the bristles in preparation for contact with the wheelchair frame. The second stage of activation moves each section of bristles forward to engage the chair. During the second stage of activation, the bristles slide freely when engaging the wheelchair frame and wheels. The maximum sideward force that can be caused by a bristle is the weight of the bristle times the coefficient of friction between the bristle and the metal plate which holds it; this force is calculated to be less than 0.2 N (0.05 lb.). Any bristle contacting the side of chair will be retracted when the force is greater than 0.2 N (0.05 lb.); however, neighboring bristles will continue to advance and further engage the chair. Once the deployment is complete, the bristles are locked in place and only forces which constrain the chair parallel to the motion of the vehicle are present. The bristles are locked in place by inflating rows of elastomeric tubing fitted between the rows of bristles. The bristles form a custom mold of the frame that maximizes the area available to restrain the chair and thus keep the stresses in the wheelchair wheels and frame as low as possible while limiting the movement of the wheelchair to less than 5 cm (1.97 in) when loaded to the design load of 26,700 N (6,000 lb.).

To satisfy the space constraints imposed by current buses, a sliding mechanism was designed to permit the restraint system to be stored as part of the passenger seat and a linkage was designed to minimize the floor footprint required to store the restraint system when not in use. When a wheelchair user needs to use the restraint system, the seat bottom can be raised and the restraint slid into the aisle to provide adequate maneuvering room for the wheelchair. Once the wheelchair is positioned in the restraint area, the modules along the aisle move toward the wheelchair to reduce the box travel required for capture and to maintain aisle width.

The advisory board met again to discuss and evaluate the proposed design for the wheelchair restraint system. The consensus of the board was that the current design should be constructed. The board was pleased with enhancements in the design which eliminated direct contact between the air bladders and wheelchair which was part of an earlier design. This refinement reduced the possibility of causing claustrophobia. The board also recommended that the restraint have solid sides to improve users' feelings of security and confidence in the device. The board cautioned that, in a production model, care must be taken with aesthetics to reassure users that the bristles will not scratch the surface of their wheelchairs. When the design considerations were accepted by the advisory board, line drawings were created using Auto Cad and the dimensions and assembly plans were finalized. A foam core model was constructed and positioned on a Metro bus to verify the design and demonstrate the concept for the local transit authority before a metal prototype was constructed.

WHEELCHAIR RESTRAINT SYSTEM PROTOTYPE

In the prototype system the frame was constructed from aluminum and the bristles from Delrin rod. The prototype system consists of four modules, two on each

each side of the wheelchair. The outer boxes of each module contain movable inner boxes to accommodate varying wheelchair widths. The inner boxes are deployed and retracted by double-acting pneumatic pistons. Each inner box contains a bristle plate in which the bristle assembly is inserted. The bristle plates are deployed by polyurethane-coated nylon air bladders and retracted by constant-force springs. Figures 2, 3, 4 and 5 show the innovative features of the wheelchair restraint system including:

Bladder-Actuated Bristle Plates (see figure 2).
During the first stage of system activation, the well-protected, hidden bladders inflate, bringing the bristle plates to the "ready" position. During the second stage, the bristles slide to form a custom mold of the wheelchair wheels and frame, thereby restraining the wheelchair. Upon deactivation, the bristle plates are retracted, resetting the bristles to a neutral configuration. The bristle plates are in the reset position.

Pneumatic Piston-Actuated Boxes (see figure 3).
After the bristle plates are extended forward during the first stage of activation, telescoping boxes move the bristles forward to engage the wheelchair during the second stage. In this way a greater range in wheelchair widths can be accommodated and accessibility of the wheelchair to the restraint is enhanced. The boxes are shown in both the activated (see figure 4) and in the retracted (see figure 5) configuration.

STATIC TESTING OF PROTOTYPE

The finished prototype was mounted on a test platform and subjected to force applications of increasing magnitude until the restraint released the wheelchair. Wheelchair displacement was recorded at every 1112 N (250 lb.) until the wheelchair moved excessively (movement greater than 5 cm (1.97 in)). Four separate pull tests were performed. Each of the four tests began with capture of the chair at the same position in the restraint system. Dials and plumb bob were zeroed, and then force was applied via the hydraulic actuator. Force was applied in 1112 N (250 lb.) load increments. At each level of force, the test proceedings were stopped to observe chair movement, quality of chair capture, and to make photographs and record the results.

A camcorder was used to provide overall coverage of the test proceedings and verbal commentary by the test engineers. Supplemental still photographs were taken of the test. A dial indicator with a 2.54 cm (1.00 in) stroke was used to measure longitudinal displacement of the wheelchair. Longitudinal measurements were supplemented by a simple plumb bob on a string fastened to the back of the chair brace. The actuator pump was equipped with a pressure gauge, and the pressure readings were converted to drawbar pull force by multiplying the applied pressure by the area of the hydraulic cylinder piston.

The testing frame was constructed of 3/4 inch plywood and "2 x 6" timbers, with supplementary bracing to withstand up to 17,800 N (4,000 lb.) internal loading from the upright structure tot he wheelchair. The upright is equipped with heavy aluminum plates through which the steel bar used as the actuator anchor is passed. The hydraulic actuator is a Blackhawk Pull Ram Model RC640 capable of 17,800 N (4,000 lb.) force application. The stroke of the actuator is over four inches. The pump used to power the cylinder is a Blackhawk Porto-Power Hand Pump Model p-76 rated at 70,000 KPa (10,000 psi). Double chains from the actuator were connected to two pieces of steel square tubing bolted together to form a single unit. The bar was placed behind the seat back uprights of the wheelchair, and taped in place.

The manually powered wheelchair was equipped with a plywood seat base and back to better resist deformation during the pull test. A "2x4" brace was located just below the rear of the seat to provide additional rigidity. Later, for the third and fourth tests, an additional brace was placed across the lower horizontal tubes of the chair. The wheelchair was occupied by a 50th percentile crash dummy.

At no time did the chair ever come out of the restraint system; however, at high force applications (greater than 8 G's), the wheelchair slipped forward within the restraint and it was immediately recaptured at a new position within the restraint. Because the motion within the restraint was greater than the 5 cm (1.97 in) allowed in our testing paradigm, the restraint system did not withstand the forces that are generated during a crash situation. The applied force on the wheelchair at the point of slippage ranged from 3960 N (890 lb.) to 5400 N (1214 lb.) with an average value of 4561 N(1025 lb.) which corresponds to an acceleration loading of 8 G's.

The chair moved forward under the loading before it slipped due to normal bristle bending action, bending of the wheelchair hubs, and bending of the four boxes which form the modules of the restraint system. Examination of the modules after the pull tests did not reveal any damage or permanent deformation in either the boxes or bristles. The wheelchair was somewhat damaged by the test protocol, but not to the point of becoming unusable.

Damage was confined to the hubs of the main wheels, which remained bent downward and rearward after the tests were completed.

RESULTS

Based on the results of the static testing, it was concluded that the prototype is able to restrain a wheelchair when the wheelchair is subjected to loads similar to those possible during normal driving and that with a modification in the construction techniques used to fabricate the restraint, the system can successfully hold a wheelchair under crash-like loading. The feasibility of the concept has been demonstrated. The practicality of fabricating a wheelchair restraint that can accommodate a wide variety of wheelchair sizes, not require hardware be permanently mounted to the wheelchair, nor require the transit operator to invade the personal space of the wheelchair occupant in order to secure the wheelchair or release it, has been shown.

During the investigation, several important findings were made that directly affected the design and feasibility of the pneumatically activated wheelchair restraint system. The findings and their significance are listed below:

- A two stage activation system can accommodate the range in width of commercially available, non custom wheelchairs, from 66 cm (26 in) to 81 cm (32 in). The width variability required the restraint system to be able to change significantly its width without losing effectiveness. The required flexibility was accomplished using a two stage activation system. The first stage adjusted the width between the modules to fit the width of the chair. The second stage activated the bristles that engaged the chair to restrain it.

- Wheelchair users become uncomfortable when their chairs move more than 2 cm (0.79 in) during normal driving. In order for the restraint to be acceptable to most people who use wheelchairs, the chair must not move more than 1.5 cm. (0.59 in) during normal driving maneuvers. This is a more strict requirement than the specification cited in the original proposal.

- The maximum height that the restraint can be is 43 cm (17 in). In order to be sure that the person in the wheelchair is not contacted by the restraint system, the height of the system was made less than 43 cm (17 in). Height was an important consideration when assuring the stability of the restrained wheelchair.

- Mass transit operators require that the restraint operation be overseen by the vehicle operator. The driver of the mass transit vehicle must check the operation of the restraint each time that it is used in order to satisfy liability issues. Since the restraint would always have the supervision of a trained operator and did not have to be capable of user-controlled operation, the control system was simpler than originally envisioned.

- Acceptable ingress/egress times vary significantly from the perspectives of the passenger and the vehicle operator. While both parties desired a system that operates quickly, the definition of "quickly" is different for the two parties. Passenger representatives state that less than three minutes is acceptable for system activation while operators say they will be pleased if the proposed restraint can be activated in less than five minutes. Also, both parties desire that the system not require the vehicle operator to enter into the personal space of the passenger. If the drivers do not have to bend and twist to connect the restraint system to the chair, it is felt that they will be less subject to on the job injuries. The passenger representatives feel better if the drivers do not have to climb over them and touch them in "rather intimate places". The prototype system as constructed met the desired goals of both passengers and drivers, since it took less than one minute to engage and required only that the operator stand nearby with a switchbox rather than enter the personal space of the passenger.

- The sideward force required to collapse a foldable wheelchair is small enough to make it impossible to adequately secure the wheelchair using air filled bladders which require a residual force to be applied to the wheelchair frame in order to generate the restraining force. In an early design stage, it was proposed to use bladders in direct contact with the sides of the wheelchair to generate the restraining forces. However, testing revealed that foldable wheelchairs were prone to collapse under the forces necessary for adequate restraint. Therefore the design was modified to eliminate forces against the sides which would tend to collapse the wheelchairs. Instead of bladders alone, a combination of pneumatic pistons, pneumatic bladders, and retracting springs were used to actuate the restraint system.

- The novel bristle design is a feasible method of providing restraint. No movement of the wheelchair was observed when the test engineers applied forces corresponding to loads experienced during normal driving maneuvers. Slippage under high loads was not catastrophic, but rather represented a gradual release potentially capable of absorbing considerable energy. At no time did the chair ever come out of the restraint system or become loose within the four boxes; however, at high force applications, the wheelchair slipped forward within the restraint and was immediately recaptured at a new position.

CONCLUSIONS

The IDEA project demonstrated the feasibility of a pneumatically operated wheelchair restraint system compatible with buses, light rail commuter cars, and multi-passenger call-and-ride vehicles. Although the model prototype fell below expectations in some respects, the testing confirmed the practicality of the concept and illustrated areas for improvement.

One of the novel features of the restraint system is the use of pneumatically driven bristles that engage the wheels and frame of the chair to stabilize it against movement during acceleration and braking and help reduce the risk of injury in case of collisions. This design eliminates the need for docking hardware permanently attached to the chair, does not require the transit vehicle driver/operator to attach securement devices to the wheelchair, and will be tolerant of positioning errors with the wheelchair. The bristle mechanism insures that the wheelchair frame is not subjected to stress levels which could cause a folding wheelchair to collapse or reduce the life expectancy of the wheelchair frame due to fatigue loading. The mechanism deploys in about 1 min—a period acceptable by both transportation system operators and passengers.

The goals and objectives of the project were accomplished in a manner which demonstrates the effectiveness of the wheelchair restraint system. The testing results indicate that the wheelchair restraint system is a workable approach to providing a tiedown for a wheelchair user on a public transit vehicle. No movement of the wheelchair was observed as the test engineers manually pushed and pulled to verify capture using loads of approximately 223 N (50 lb.) . Moreover, slippage under high loads was not catastrophic, but rather represented a gradual release potentially capable of absorbing considerable energy. The maximum force applied to a wheelchair before gradual release commenced was 5400 N (1214 lb.). Limiting factors of the restraint system appear to be the forced retraction of the inner boxes and not the finger design. Potential improvements to the wheelchair restraint design were brought to light by the testing:

More powerful pneumatic cylinders should be used for positioning the inner boxes, or perhaps a bladder and retraction spring combination could be used for the inner boxes as it is for the bristle plates. A more secure method of attaching the restraint to the test frame should be employed. Some of the bending of the restraint was at the connection point between restraint and test frame rather than within the restraint itself. The boxes used to hold the bristles tilted under loading, causing the wheelchair to slip forward in the restraint. This is a limitation of the construction which could be remedied in a second generation prototype.

The IDEA investigation accomplished the compilation of design specifications for a public transportation wheelchair restraint system, the design of a pneumatically-operated bristle engagement securement prototype, and demonstration of design concept feasibility based on static testing. The design should provide transit companies with the basis for a cost-effective, easy-to-operate restraint system that can accommodate the wide variety of wheelchairs currently on the market. This device could be fitted in all vehicles that are used to transport passengers who use wheelchairs, reducing passenger injuries and consequent medical and liability cost as well as personal pain and suffering for the rider and operator.

GLOSSARY

Box — A metal enclosure used to hold and position the bristles in proximity to the side of the wheelchair frame and wheels.

Bristle — One of the Delrin rods which mesh with the wheels, hubs, and frame of the wheelchair to create a custom mold of the side.

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APPENDIX

Construction Plans for Wheelchair Restraint System Components

FIGURE 1 Wheelchair Restraint System Modules.

FIGURE 2 Wheelchair Restraint Bristle Plate Assembly.

FIGURE 3 Actuated Wheelchair Restraint Boxes With Bristles Engaging Wheelchair.

FIGURE 4 Wheelchair Restraint System Holding a Wheelchair.

FIGURE 5 Wheelchair Restraint System in Retracted Configuration.