THE POSIP SYSTEM - IMPROVING OCCUPANT PROTECTION IN CONVERTIBLES AND COUPES DURING SIDE IMPACTS

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Abstract

In recent years, passive safety has been continuously improved. Legal requirements and demands regarding occupant protection in side impacts exist. A lot of reinforcements for the BIW of the cars have been constantly optimized, based on the results of static and dynamic tests.

A new developed part of the occupant protection is a door-based side-airbag system combined with an energy-absorbing door, named POSIP, i.e. POrsche Side Impact Protection system.

The side-airbag module includes a totally new 30 l two-chamber airbag which covers a big part of the upper door area. This side airbag has been designed to reduce both the head and thorax loads also in side pole impacts.

For the first time in automotive history, a standard head protection system is offered which can be installed regardless of the roof design. The POSIP system also protects the occupants of convertibles or of cars with novel roof concepts when involved in side impact pole crashes.

1 Introduction

In many markets today, passive safety is one of the criteria which, along with an appealing styling and sporty performances, make an essential contribution to the success of a car concept. The occupant protection is a primary target in automotive engineering.

Over the last 10 years, occupant protection has been considerably improved, mainly with regard to frontal collisions. Accident research, mathematical analysis and lab tests yielded valuable experiences which have helped to further optimize the cars and their components in terms of passive safety.

In 1986 already, Porsche started setting new standards, being the first European car maker to launch a series car with standard driver and front-passenger airbags on the North American market.

According to the results of pertinent accident research, side collisions are the second most frequent type of accidents after frontal collisions. As accident analyses and injury statistics show, it should be possible to further improve the occupant protection during side impacts.

2 Demands on the side structure

Compliance with the legal requirements regarding occupant protection in side impacts must be demonstrated in static tests and in dynamic side impact tests with moving barriers or moving cars.

2.1 Static side impact test

In the USA, the quality of passenger protection in side collisions is checked by performing a static compression test according to the first part of FMVSS 214 /1/. A test rigid steel cylinder is pressed against the outer door panel in order to demonstrate that the BIW offers a deformation-dependent minimum intrusion resistance. At the same time, this test serves to verify the strength of doors, hinges and locks.

2.2 Dynamic testing using a moving barrier

There are two different side impact tests available, whose rules take into account the vehicle populations and accident conditions existing when the tests were first introduced. This explains the differences between the two tests and the results they are expected to yield.

In the USA, occupant protection in lateral collisions is checked in accordance with part 2 of FMVSS 214 /1/ using a dynamic side impact test. The driver or passenger side of the standing car is impacted by a deformable barrier moving at an angle. The test is performed with one dummy each on the front and rear seats. The barrier hits the side of the car at a speed of about 54 km/h (33.54 mph) and at an angle of 27° (Figure 1). This test configuration simulates a right-angle 50 km/h (30 mph) impact of the barrier with the car moving ahead at half that speed. The characteristic data of the barrier, that is the mass of 1,396 kg, the ground clearance of 0.2794 m, the height of the deformation element of 0.8382 m and the stiffness rather correspond to those of a light-duty truck.

To measure the occupant loads, the US Side Impact Dummy (US-SID) is used. This new dummy has been developed from the Hybrid II frontal impact dummy and provided with a newly designed thorax. For the thorax and lap, corresponding load limits have been stipulated and must be complied with.

The NHTSA (National Highway Traffic Safety Administration) also performs side impact tests at an impact speed of 38.0 mph or 61.2 km/h respectively. These are the so-called NCAP tests.

The countries of the European Union use 96/97/EG /2/ - a method which is comparable to the American FMVSS 214. However, the 950 kg barrier is considerably less heavy, the ground clearance is 0.3 m and the upper edge of the deformation element is 0.760 m above the ground. With this configuration, the barrier corresponds to the average European automobile. The deformable EEVC barrier hits the standing car at a right angle and an impact speed of 50 km/h (Figure 2). ECE-R 95 shows the same configuration with the difference that the ground clearance of the barrier is only 0.260 m /3/.

The test is performed using the EUROSID 1 (European Side Impact Dummy) with no hands and forearms, developed especially for this test and allowing the abdominal loads on the front passenger to be more efficiently measured.

2.3 Dynamic tests with the car moving

The revised version of FMVSS 201 which will be published soon includes a lateral pole impact /4/ under Option 3: the car moving at a 90° angle to its longitudinal axis collides with a rigid 10 inch (254 mm) diameter pole (fig. 3). The collision speed is 18 mph (29 km/h). The car is positioned in such a way that the point of impact is at the center-of-gravity level of the head of the dummy sitting on the front seat.

The dummy to be used for this test is to be a combination of the Hybrid III head/neck structure and the US-SID from FMVSS 214. Besides the dummy, the pole diameter, too, is worth mentioning: contrary to the 305 mm pole diameter prescribed for the static compression test under FMVSS 214, the dynamic test described above uses a pole diameter of 254 mm.

It should be noted that an ISO procedure currently under way, requires the pole diameter to be 350 mm /5/. Which reason exist, that the diameter of the pole have a range between 254 and 350 mm ?

For car-to-car side collisions, no standardized test conditions exist. Therefore, this type of test is carried out to the instructions of each individual automotive manufacturer.

2.4 Safety test results

When comparing the moving-barrier tests after the ECE-R 95 and the FMVSS 214 test conditions, we find that both the resulting deformations to the car and the loads on the dummies are quite different from each other.

The side impact according to FMVSS 214 produces a bellied indentation between the front and rear wheels of the impacted car which evenly increases in longitudinal direction from the A to the B post. The intrusion depth is greatest in the lower portion of the door where the bumper profile of the barrier causes a very clear indentation which is about 50 mm deeper than the damage caused to the vehicle's side structure by the main barrier element.

When tested according to 96/27/EG or ECE-R 95, the impacted car shows a strong deformation of the door ahead of the B-post and between the B-post and the rear wheel. The deepest side structure deformation is found in the center of the door. The bumper profile of the barrier does not leave any particularly pronounced marks.

ECE-R 95 and FMVSS 214 result in different intrusions when used on the same type of car and the dummies respond differently to the loads caused by the intruding side structures.

The US-SID, when tested to FMVSS 214, is particularly sensitive to the intrusion speed at the moment of impact with the side structure. The thorax and pelvis acceleration measurements are quite reliable whereas the rib deformation results are less informative. What is important about this dummy is that the thorax loads are averaged using the Thoracic Trauma Index (TTI) as an evaluation criterion. The US-SID receives particular protection through a resilient, padded inner door lining and a stiff body structure which lowers the intrusion velocity.

The EUROSID 1 dummy used for the european test measures rib deformations, abdominal and pelvic forces as well as head loads. Rib acceleration measurements, however, do not yield any conclusive results. If the side structure of the car is not hit perpendicularly, the EUROSID 1 dummy might yield too low load values. The side structure deformations caused by this test differ from those of the American regulations and place higher loads on the dummy's thorax. The loads depend on the intrusion depth of the side structure and the duration of the contact between the side structure and dummy. It is necessary to minimize the intrusion velocity by providing for a stiff side structure.

3 Possibilities for effective occupant protection in side impacts

In a side collision, the available deformation zone of the impacted car is far smaller than in a frontal collision. Therefore, one of the most vital demands for an efficient occupant protection in side impacts is to provide for a stiff lateral body structure. A stiff body structure lowers the intrusion velocity of the impacted car side and thus can reduce the loads on the vehicle occupants.

Occupant protection is particularly efficient if the body side structure complies with the static and dynamic regulations of both, FMVSS 214 and ECE-R 95. The protective effect can be further improved by using appropriate occupant restraint systems.

3.1 Improvements to the vehicle side structure

Vehicle side structures have to meet very stringent demands. To realize further improvements numerous detail solutions must be found.

The hinges and locks, for example, must be able to transmit the collision forces to the body structure. The minimum breaking force levels stipulated in FMVSS 206 /6/ are sufficient for that purpose.

The reinforcing elements required for compliance with FMVSS 214 have been installed in all Porsche series cars sold worldwide since model year 1985. The upper door area of the Porsche cars is additionally stiffened by a profile fixed to the window channel.

Under normal circumstances and due to its low position, the door sill is not hit by an impacting car or barrier. Nevertheless, the door sill must be designed for high stiffness since it plays an important role in pole collisions.

Another essential safety feature is the transverse reinforcement of the vehicle floor which allows the occupants' survival space to be maintained and the impact energy to be transmitted to the floor structure. This reinforcement is achieved through solidly dimensioned seat cross members at the front and rear which stiffen the area between the door sill and the center tunnel. The lower side of the center tunnel itself is closed by means of add-on members which minimize the tunnel deformations and allow forces to be transferred to the floor structure opposite of the impacted side.

The energy absorbing capacity in a side collision can be enhanced by providing for reinforcements of the doors, seats and body structure which, at the same time, lower the differential speed between the intruding door and the occupant thus reducing the dynamic and static deformations of the body. These measures are particularly beneficial as far as the thorax protection is concerned.

Thanks to these measures the impact forces are transmitted to the body structure via the A and B posts, the door sill and the floor. In that way, the entire side and floor structure is used for energy absorption with the rear seat structure serving as an additional reinforcement.

The seats, too, are vital elements when it comes to preserve the occupants' survival space. The transverse stiffness of the seat back and, above all, of the supporting structure should be high enough to reduce the risk of injuries to the pelvis.

Another essential aspect is the precise positioning of the inner door panel, door reinforcement and door lining elements relative to each other. If a car must also meet the provisions of FMVSS 214, it would make little sense to weaken the body at pelvis level and allow for higher loads on the pelvis and abdomen in order to reduce the thorax loads.

3.2 Restraint systems

In 1990, Porsche started an advanced engineering project to find out whether the protective potential of the existing side structures could be further enhanced through additional occupant protection systems like paddings or side airbags. In doing so, special attention was paid to the performance characteristics of airbag deployment components and mechanisms. The ultimate target was to develop a side airbag which would provide protection not only to the occupant's thorax but also to his head and be operational both in sedans and convertibles /7/.

3.3 New feature for occupant protection in side impacts

For its new car lines (Boxster, 911 Coupé /8,9/, 911 Convertible /10/) Porsche is offering an additional occupant protection device, the so-called 'POSIP' system with POSIP standing for POrsche Side Impact Protection. This novel side airbag system combined with an energy-absorbing door trim is available for the two front occupants.

The unique feature of the side airbag system is the integral protection of the thorax and head during side impacts including collisions with a pole or a tree. The Porsche convertible is the first one of its kind worldwide to also provide a head protection feature. It is complemented by an energy-absorbing door panel laid out to reduce the loads on the pelvis. The first POSIP was installed in a production car in April 1997 (Fig. 4).

4 The components of the side airbag system

The development of the side airbag complete with its cover and the integration of the system into the car required the redesign or modification of numerous parts from such areas as interior equipment, electrics, BIW and safety.

The POSIP side airbag module is fastened to the inner door panel at front-passenger level and covered by the door trim. What is visible to the occupant's eyes is just the cover of the side airbag module with an incorporated black clip carrying the 'AIRBAG' inscription.

The airbag module is screened by a cover harmoniously incorporated into the door trim. It is an apparent safety item which gives the occupants the reassurance they need. The airbag cover is available with a leather-finish only which is friendly to the touch and whose colour is matched with that of the interior trim. The visible tear seam is located in the center of the cover. The POSIP system is available for both the TPO and the leather-lined door trim panel (fig. 5).

The one-piece plastic cover is an injection-moulded element. Porsche's upholstering specialists provide it with a lining of low-shrinkage leather. The making of the tear seam is computer-controlled and documented in all details. Two additional ornamental seams run parallel to the tear seam. After having been sewn together, the leather lining is bonded onto the cover which is then incorporated into the door trim panel in compliance with the customer's order. POSIP is the first side airbag system to use a hinged cover - a solution which allows a precisely defined opening to be created for the unfolding airbag.

POSIP uses a novel hybrid gas generator located inside the airbag. With this particular gas generation technology the pyrotechnical elements account for as little as 4.7 grams of the overall mass. The gas comes from a pressure reservoir filled with argon and helium. This gas generation method which is currently used by few vehicle manufacturers only has been especially chosen for recycling and ecological reasons.

The airbag has a volume of 30 l. The inner face of the polyamide fabric is provided with a thin silicon lining. The airbag includes all the elements needed for a controlled deployment, i.e. the retaining strap, tear seam, darts and interpanels which include the pressure valve and exhaust opening. The airbag is both folded and rolled. It is mounted in a painted steel housing and protected by an additional covering which features all the required warning inscriptions. The housing is provided with one integrated bolting point used to fasten the lower retaining plate of the airbag cover to the door panel. An ejection channel integrated into the steel housing secures the correct positioning of the airbag. Further deployment of the airbag is controlled by the multifunctional retaining strap which has an integrated tear seam. This strap is located at thorax level and serves to limit the expansion of the airbag towards the cockpit center (fig. 6).

Even with the side windows down or shattered, the airbag continues to deploy vertically upwards and rearwards. When hit by the passenger, the upper part of the airbag is supported by the window channel or the intruding object respectively.

The triggering system of the side airbag is composed of the triggering unit on the center tunnel and two outside sensors at the RH and LH sills. In a lateral collision, the sensor on the impacted side activates the central unit which, in turn, triggers the airbag, provided that the signals recorded by the central unit and the safing sensor exceed a given threshold. In general, the airbag on the impacted side only is activated. This configuration allows the side airbag system to be triggered also by an impact outside of the passenger compartment.

To activate the side airbag, an impact higher then a certain threshold is required. Depending on the signals recorded during the collision, the chosen triggering/sensing concept ensures triggering times of about 5 ms and more.

No more than 8 to 9 ms after having been triggered the deploying airbag passes the shoulder point of the occupant whose seat is assumed to be adjusted to center position. Now follows the deployment of the part which protects the occupant's head. About 15 to 18 ms after having been fired the side airbag has reached its fully deployed volume (Fig. 7).

The POSIP airbag forms a flat cushion between the occupant and the inner door panel. The airbag exhaust gas load on the vehicle occupants is very low, since the hybrid gas generator is a low-emission one and the airbag does not have any additional exhaust opening. The airbag has been laid out to provide protection over the entire seat adjustment range and is shaped in a way so as to additionally shield the occupant's head regardless of the roof design.

If a Porsche child seat system is used, the front-passenger side and front airbags are simultaneously deactivated via an additional belt latch.

5 Development strategy

Almost from the beginning, POSIP development had mainly relied on testing. The amount of numerical simulations was gradually reduced as worked progressed.

Therefore, side airbag development was done mainly on the acceleration sled for which two different side impact configurations are available.

Since 1990, a configuration exists which allows the dummy and seat to be mounted freely on the sled whereas the side structure complete with the door, door trim and side airbag module are firmly fixed to the sled (fig. 8). This set-up is used to investigate the deployment conditions of the airbag and its protection potential at various intrusion velocities. The main advantage is that tests can be performed in rapid succession since only the seat, door trim and airbag module must be replaced. One of the drawbacks of this set-up is that the velocity-time response is limited. In the sled test, the occupant is farther away from the door panel than during a real car crash. This configuration is suitable for the simulation of impact speeds up to 7.5 ms and large-surface side-structure intrusions which are typical for FMVSS 214.

The second set-up uses a sled-on-sled structure /11/, which allows side impacts to be simulated even better: The impacting structure is located on a secondary sled which is accelerated by colliding with the primary sled (fig. 9). The intrusion velocity can be more easily adapted to real test conditions. However, with this set-up the representation of the collision process is more expensive. One of its advantages is that it is well suited for tests to ECE-R 95.

The POSIP system was submitted to additional crash tests using various test configurations (Fig. 10).

6 Conclusion

The POSIP system represents an mayor progress in occupant protection during side collisions. It protects the front passenger's thorax and head over the entire seat adjustment range and regardless of the roof design. For the first time in convertible history, an airbag system has been conceived which covers the side window area at occupant level and efficiently protects the occupant's head also in an open car.

7 Acknowledgments

The development of the POSIP system has been a team approach. We owe thanks to our module suppliers Breed Rückhaltesysteme für Fahrzeugsicherheit GmbH, Raunheim, D, Peguform GmbH, Bötzingen, D and Temic Telefunken microelectronic GmbH, Ingolstadt, D as well as the staff from all the departments of Porsche AG involved in the project.

8 References

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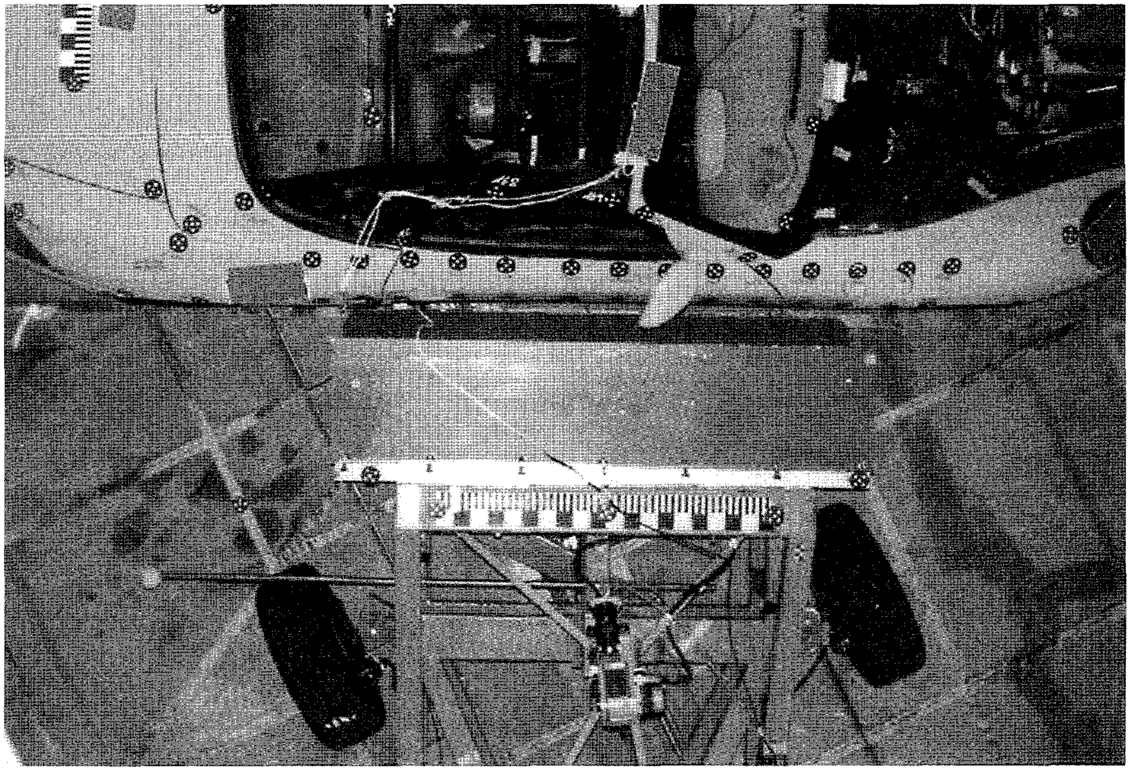


Fig. 1: Test configuration FMVSS 214

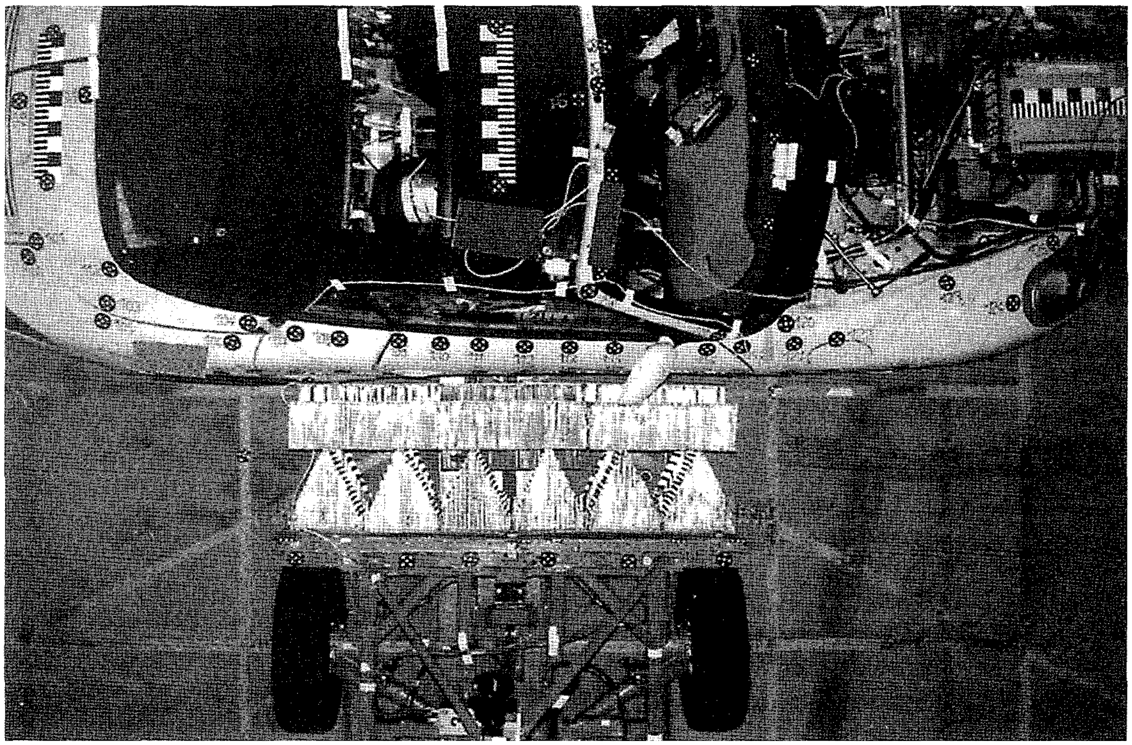


Fig. 2: Test configuration 96/97/EG

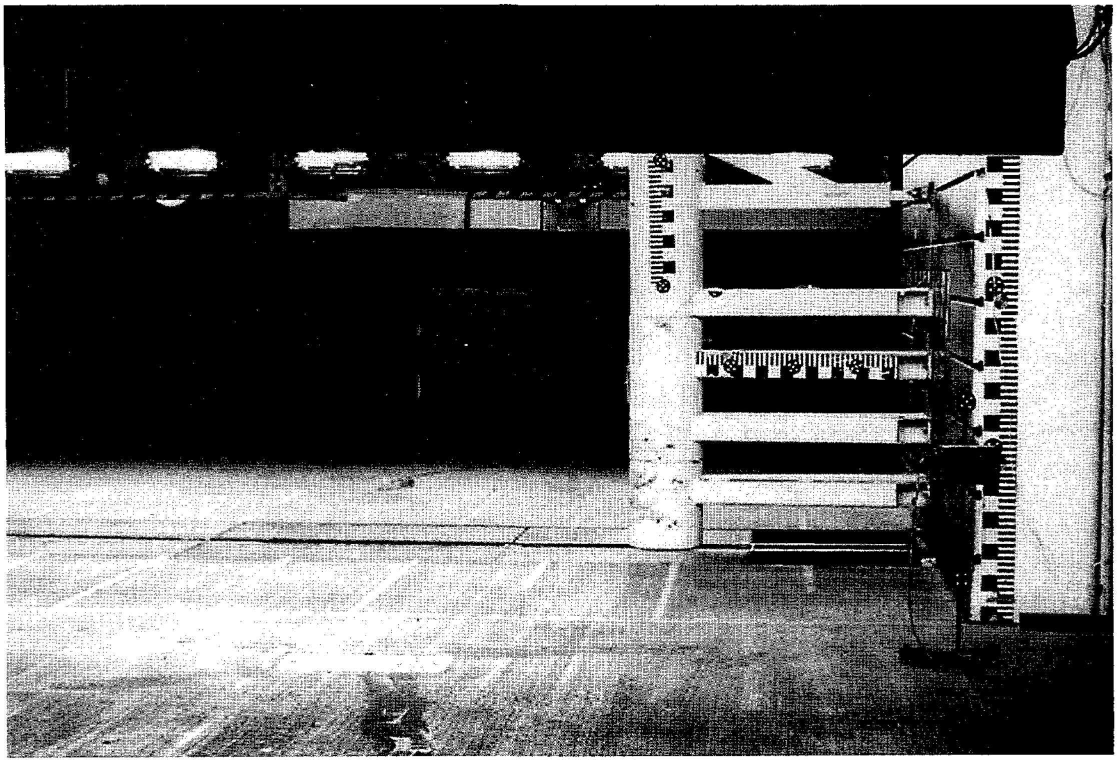


Fig. 3: Test configuration FMVSS 201 (Diameter ∅ 300 mm)

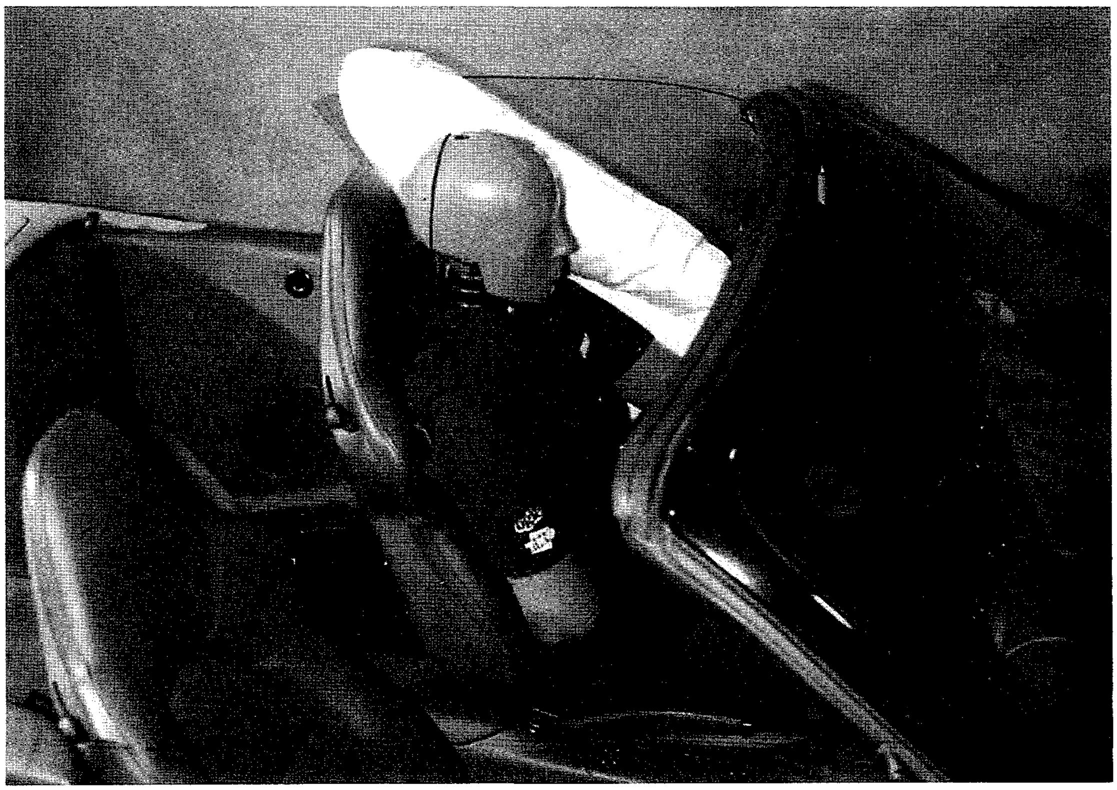
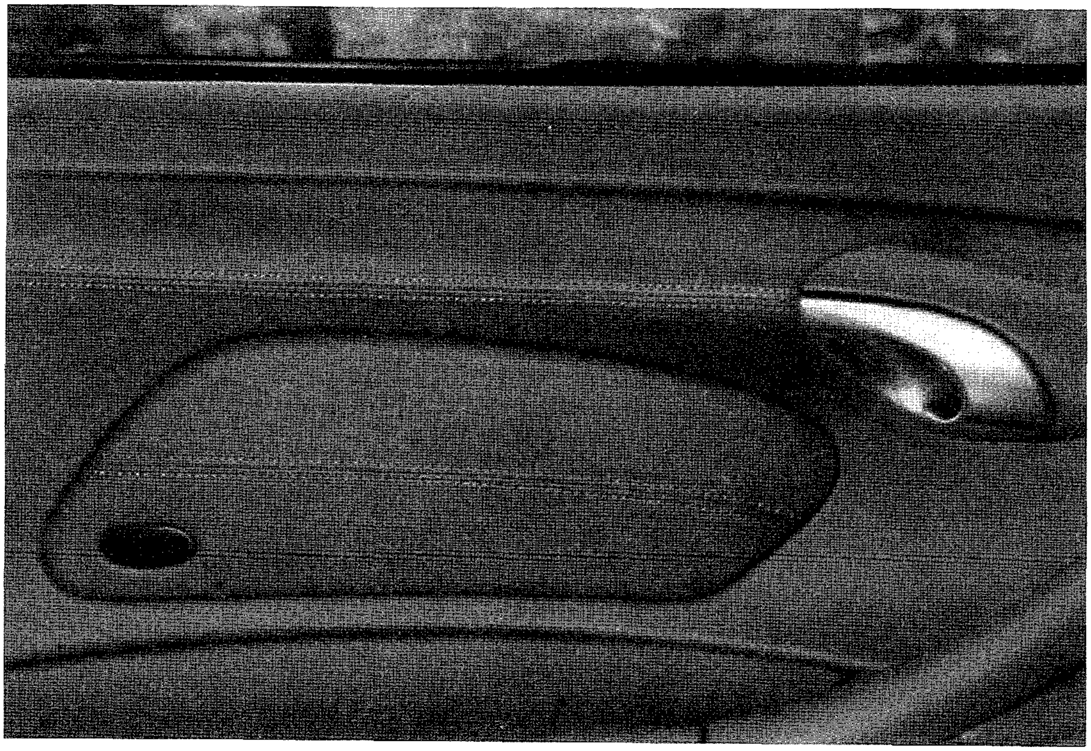


Fig. 4: The inflated cushion of the POSIP airbag in a convertible



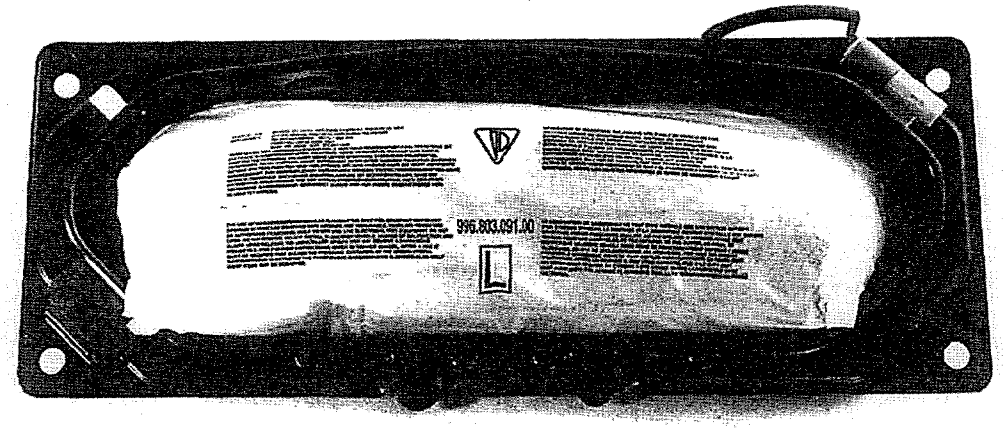


Fig. 6: The side airbag module

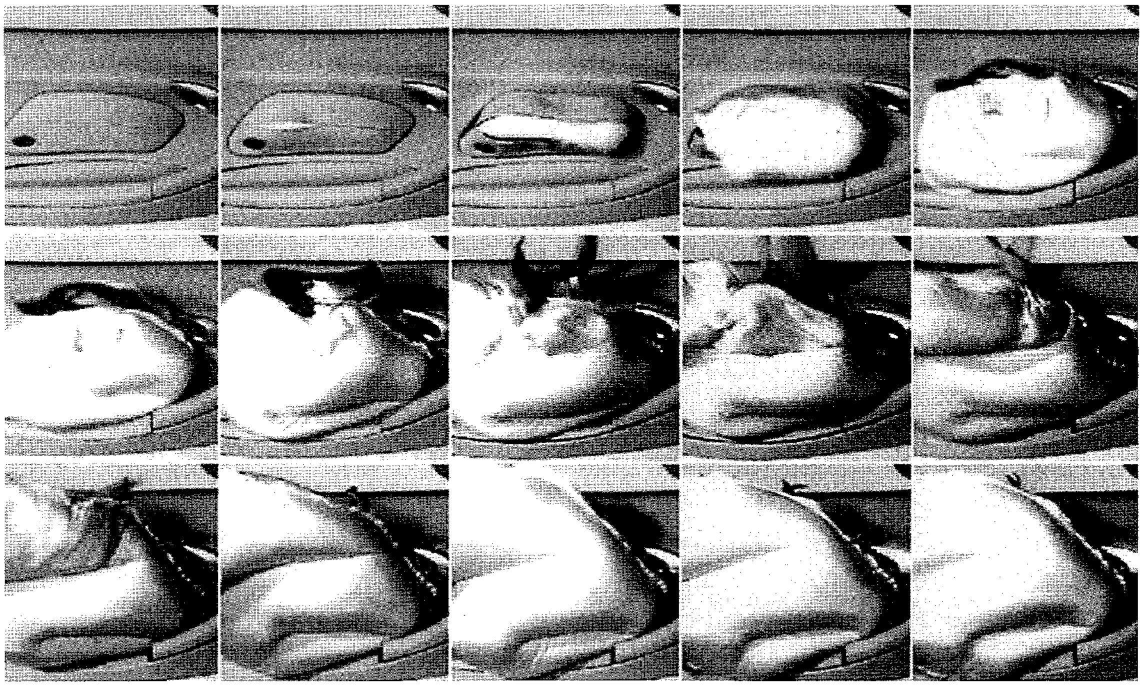


Fig. 7: Airbag deployment with no side windows

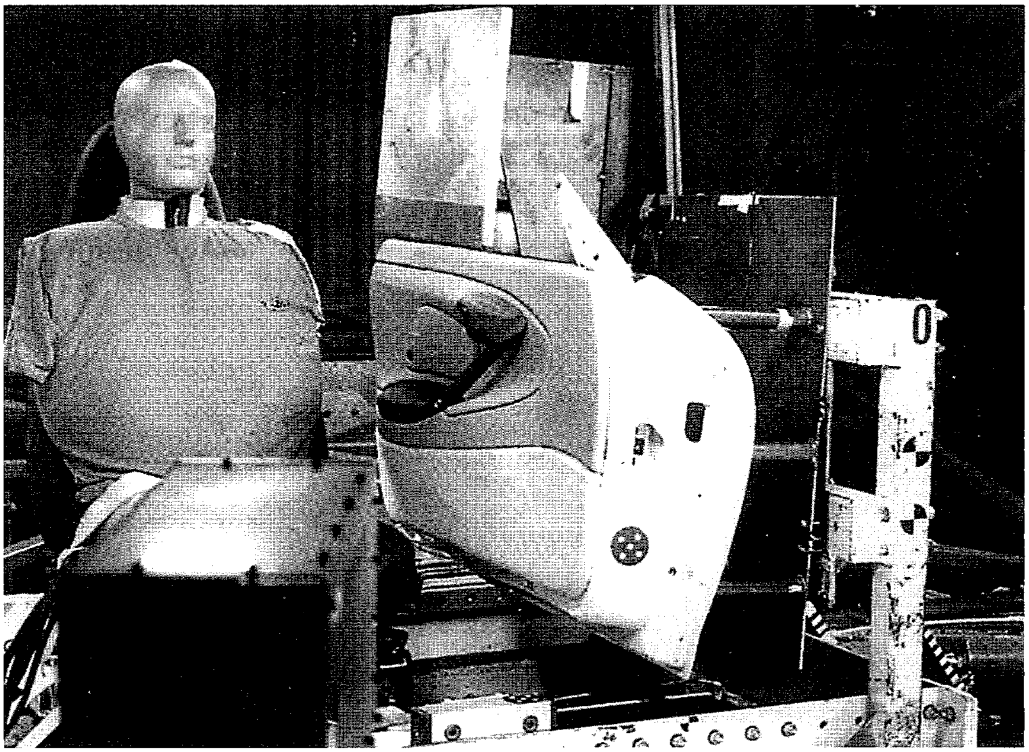


Fig. 8: Sled test configuration 1

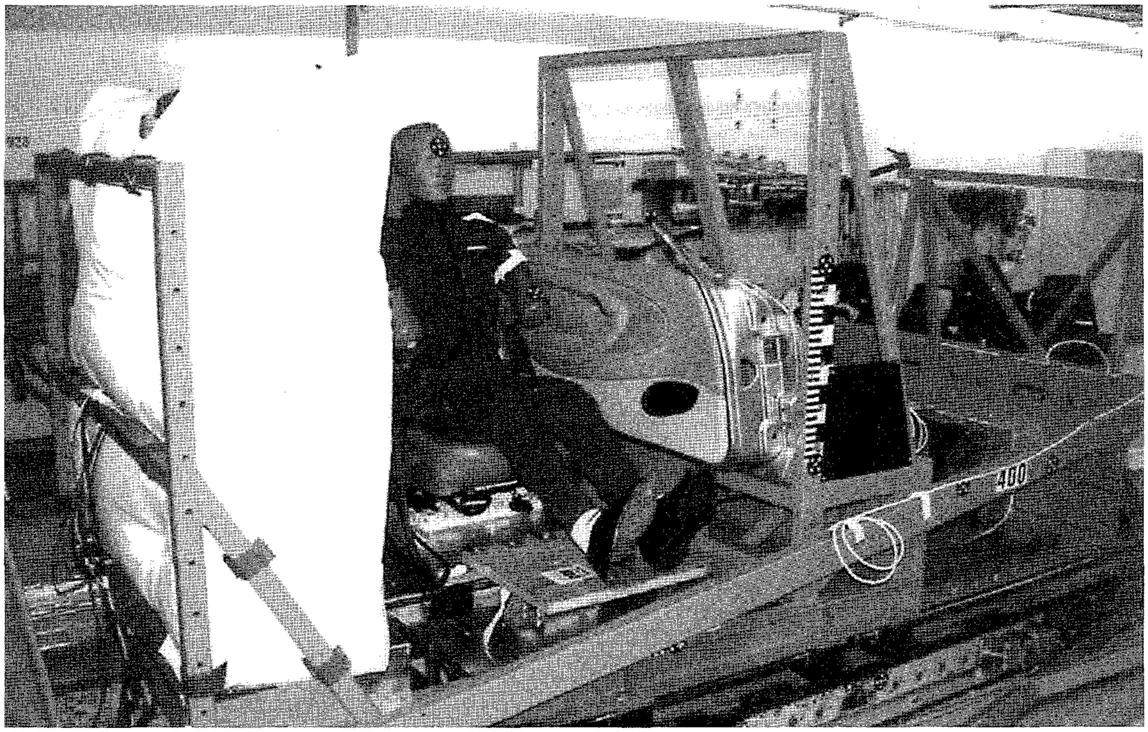


Fig. 9: Sled test configuration 2

Fig. 10: Example for a airbag deployment in a FMVSS 214 crash test