PERFORMANCE OF THE VW AUTOMATIC RESTRAINT SYSTEM BY

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1.0 Introduction

This technical paper describes the passive seat belt/knee bolster restraint system (VWRA), as installed in the Golf. This system, which was developed during the research development with the air bag in conjunction with the VW experimental vehicles, is being sold today on the market and has been, in fact, already installed in approximately 65,000 vehicles. The general concept and function of this system is to absorb the collision energy of the pelvis by way of the knees and femurs as opposed to the conventional method employing the lap belt. The upper torso is still restrained by a single torso belt similar to the one used with the standard 3-point belt system. The paper illustrates the general performance of this system in accident simulation tests and in real-world highway accidents. One accident was taken as an example and was simulated with the use of test surrogates (dummy test devices) and compared with the real injuries which resulted in the actual collision. The VWRA has shown that it is a viable alternative to the conventional 3-point belt in its present form.

2.0 Description of the System

The VWRA (see Figure No. 1) is comprised of the following four main components:

a) The seat belt with emergency locking retractor.
b) The seat with its associated mounting hardware.
c) The knee bolster.
d) The anchorage points at the door.

Figure No. 1
Passive restraint system in the Golf

2.1 Seat Belt and Emergency Locking Retractor

The seat belt used in this system has a conventional elastic characteristic of 12 percent elongation at a loading of 10 KN. The width of the belt is 48 millimeters and the belt material is polyester. One end of the belt is attached to the emergency release latch at the door, as shown in Figure No. 2. This latch allows the torso belt to be disconnected whenever it becomes necessary for emergency egress. The emergency release latch is connected and becomes integral with the side door frame when the door is closed by interlatching with the anchorage plate on the B-pillar. The other end of the torso belt is connected to the inertial locking retractor with its associated belt guide. The retractor is rigidly fixed at the anchor plate on the seat. The belt itself is guided by way of a chrome metal guide ring, which is attached to the seatback. Details of this arrangement are shown in Figure 3.

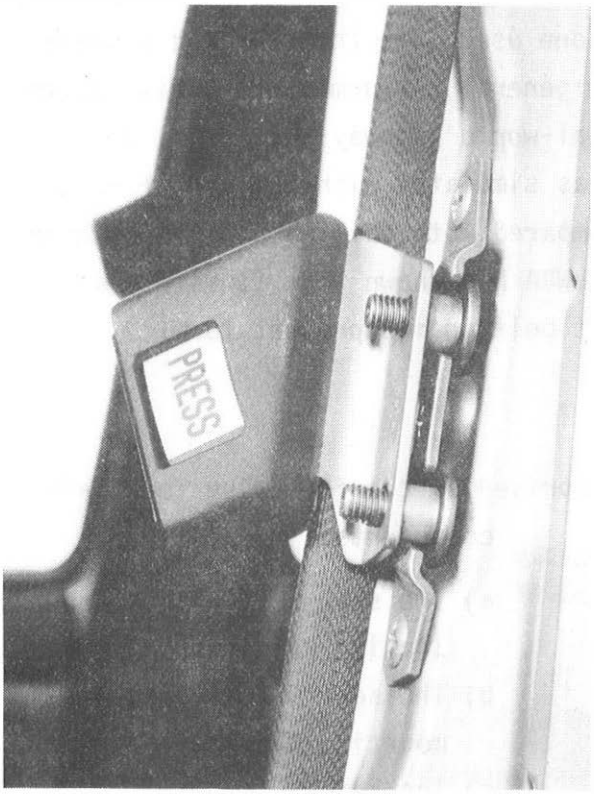


Figure No. 2
Emergency release latch
at the door

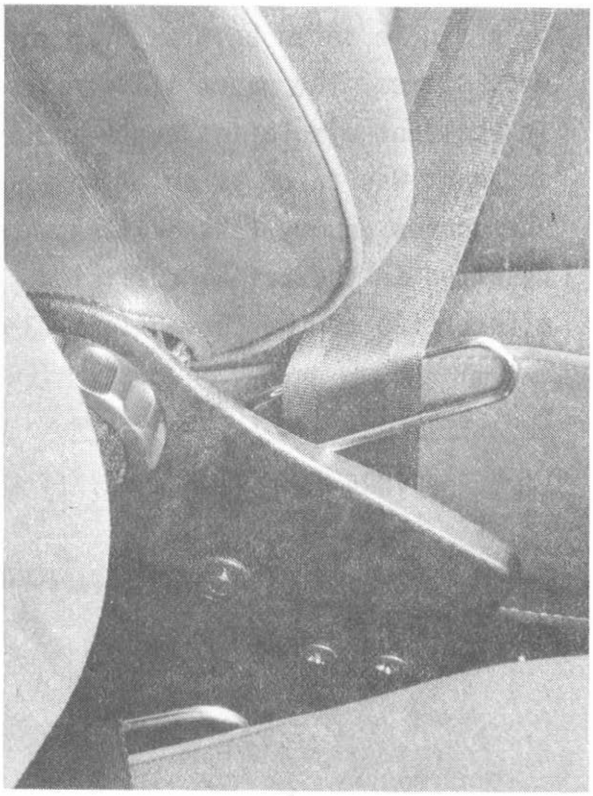


Figure No. 3
Belt guide

Optimization of retractor performance was given special design considerations. In contrast to the conventional retractor (which is normally attached to the vehicle B-pillar structure), the VWRA retractor is mounted on the seat directly. Whenever the door is opened, the belt webbing reels out from the retractor and is retracted through spring-force when the door is closed. With the door in the closed position, the torso automatically assumes the proper position across the chest of the occupant. One problem found to occur in early field testing was the inadvertant locking of the inertial retractor if the door was opened at a high value of acceleration. To preclude this, the webbing-sensitive inertial locking threshold was redesigned to be above 1.5 g's. The vehicle-sensitive locking threshold of the retractor was maintained at 0.4 g's. It is our opinion that the webbing-sensitive feature could be entirely eliminated from a technical standpoint because it is always the vehicle-sensitive locking which is operative during emergency maneuvers or collisions, but it has been retained, as some consumers feel more confident in the system if they can test the locking feature by pulling on the webbing.

2.2 Seats

The front seats in the Golf make up an important eliment of the overall VWRA performance in two primary aspects:

1) The seats function as an attachment point for the belt retractors.
2) The seat cushion structure prevents, due to its deformation characteristic, submarining of the occupant.

The force applied to the retractor is transmitted via a metal plate to the seat leg which is fastened and rides in the seat track. In general, the standard production seat was already of sufficient strength to meet this loading requirement. The basic seat design has for strength a triangular mounting of its three seat legs. In addition, it features a metal perforated seat shell which is covered with highly resilient foam rubber. The force-deformation characteristic of this seat system is such to prevent all but a minimal downward excursion of the seated occupant and, thus, eliminates the submarining effect. Figure No. 4 shows the force deflection curve at different locations on the seat.

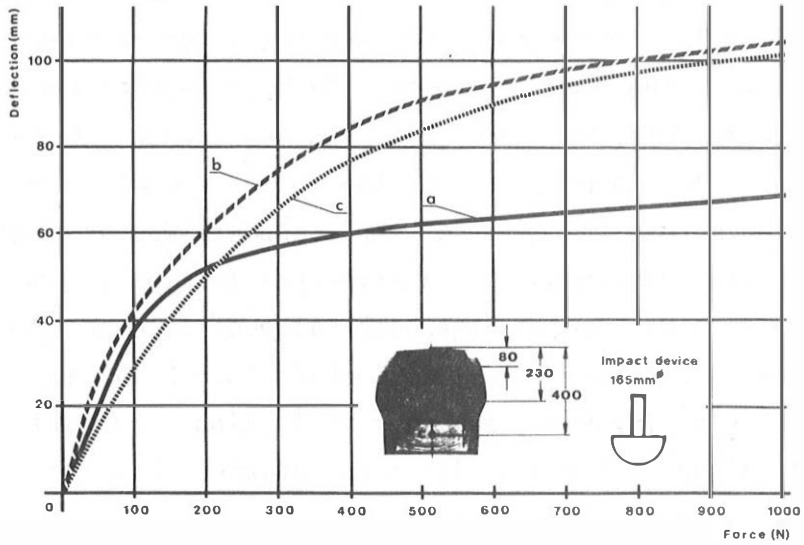
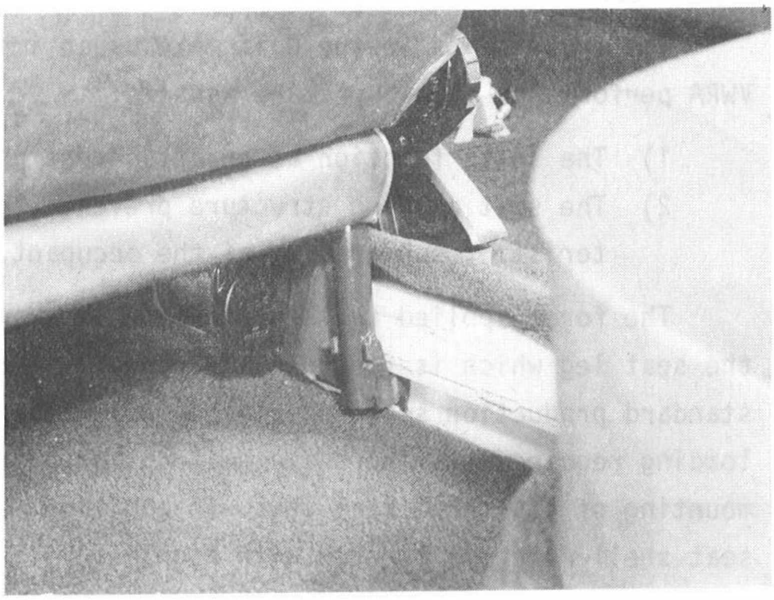


Figure No. 4
Force deflection characteristic at the seat cushion

It can be seen from this figure that at 40 mm deflection, the force increases very significantly. The attachment of the retractor to the seat track is shown in Figure No. 5.

Figure No. 5
Seat belt retractor attachment



The seat track had to be reinforced as a precaution, so that a belt loop load of 27,000 N could be applied. This was accomplished by a reinforcement plate on top of the seat track parallel to the vehicle tunnel.

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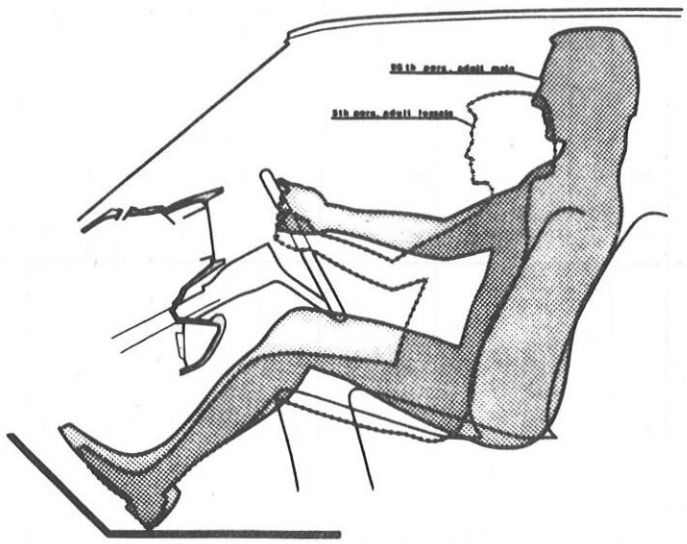
2.3 Knee Bolster

The knee bolster was designed to be compatible with the dimensional range of the standard 5 percent female up through the 95 percent male, as shown in Figure No. 6.

Figure No. 6
Knee bolster
installation



The interior structure and contour of the knee bolster is so designed that a force of approximately 4,000 N can be maintained over a range of 50 mm's of deflection. The knee bolster has a foam rubber outer thickness of 10 mm, which acts to distribute the loading over a wide area of the striking knee. In addition, the knee bolster has been designed to be used as a parcel shelf for the convenience of the vehicle user.

2.4 Connection to the B-Pillar

As referred to earlier, one end of the torso belt is attached to the emergency release latch. This latch is attached to the door-frame with two protruding flat head bolts. These bolts engage the anchorage plate on the B-pillar when the door is moved into the closed position. At this point, the latch and any loads imposed on it will be carried integrally with the B-pillar structure. Through this design, it was possible to use the same anchorage reinforcements that are used on the conventional 3-point belt. (See Figure No. 2).

3.0 Performance of the VWRA in Accident Simulated Tests

The following Table No. 1 provides some comparisons between the VWRA and the 3-point belt in a frontal crash at 30 mph.

	Driver						Passenger					
Restraint System	head		chest		Femur		head		chest		Femur	
	HIC	a_{res} 3ms	SI	a_{res} 3ms	left	right	HIC	a_{res} 3ms	SI	a_{res} 3ms	left	right
 0° VW-RA	769	79 g	392	50 g	4889 N	4830 N	573	52 g	296	42 g	4630 N	4120 N
Threepoint-belt	1402	152 g	350	46 g	2500 N	4500 N	1022	60 g	300	41 g	4150 N	3500 N
 30° VW-RA	475	47 g	248	39 g	4267 N	4500 N	347	41 g	223	36 g	4000 N	3250 N

Table No. 1
Comparison of frontal crash test at 30 mph

The table also shows that the head acceleration in the 30 degree barrier collisions. This is principally due to the lower amount of head rotation relative to the vehicle interior.
Figure No. 7 compares the head movement in two frontal impacts.

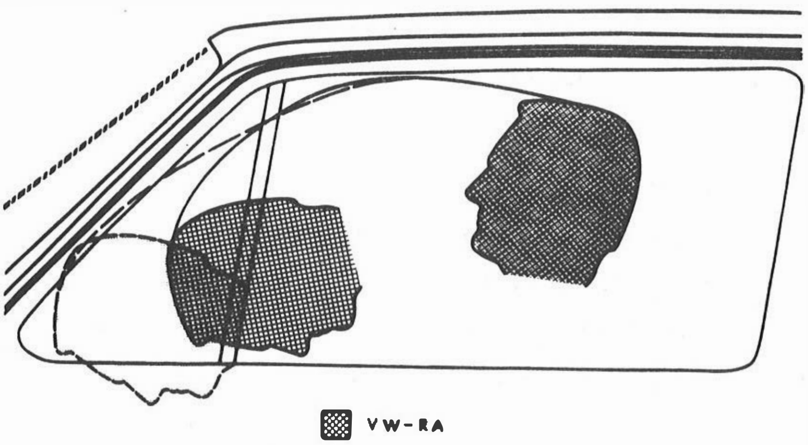


Figure No. 7 Foreward movement of the dummy head in a 30 mph frontal impact

The VWRA also showed good protective capability in other accident configurations. In lateral crashes, for example, the position of the torso belt across the lower inner pelvis provides some restraint similar to that of a lap belt. In vehicle upsets and in rear end collisions, movement of the occupants is adequately restricted by the VWRA.

4.0 Consumer Reaction

The reaction of customers who have bought the Golf has been extremely positive. A study conducted by Opinion Research and sponsored by the U.S. Government (NHTSA) indicated that approximately 80 percent wanted to buy the system in their next vehicle. After a short familiarization period by the consumer, they appreciated the convenience of being automatically restrained and not having to manually engage their seat belt.

5.0 Accident Investigations

With the introduction of the system in the United States, a systematic investigation of highway accidents was established. Up to now, we have recorded 60 documented accidents involving the VWRA restraint. The distribution of these accidents is shown in Figure No. 8.

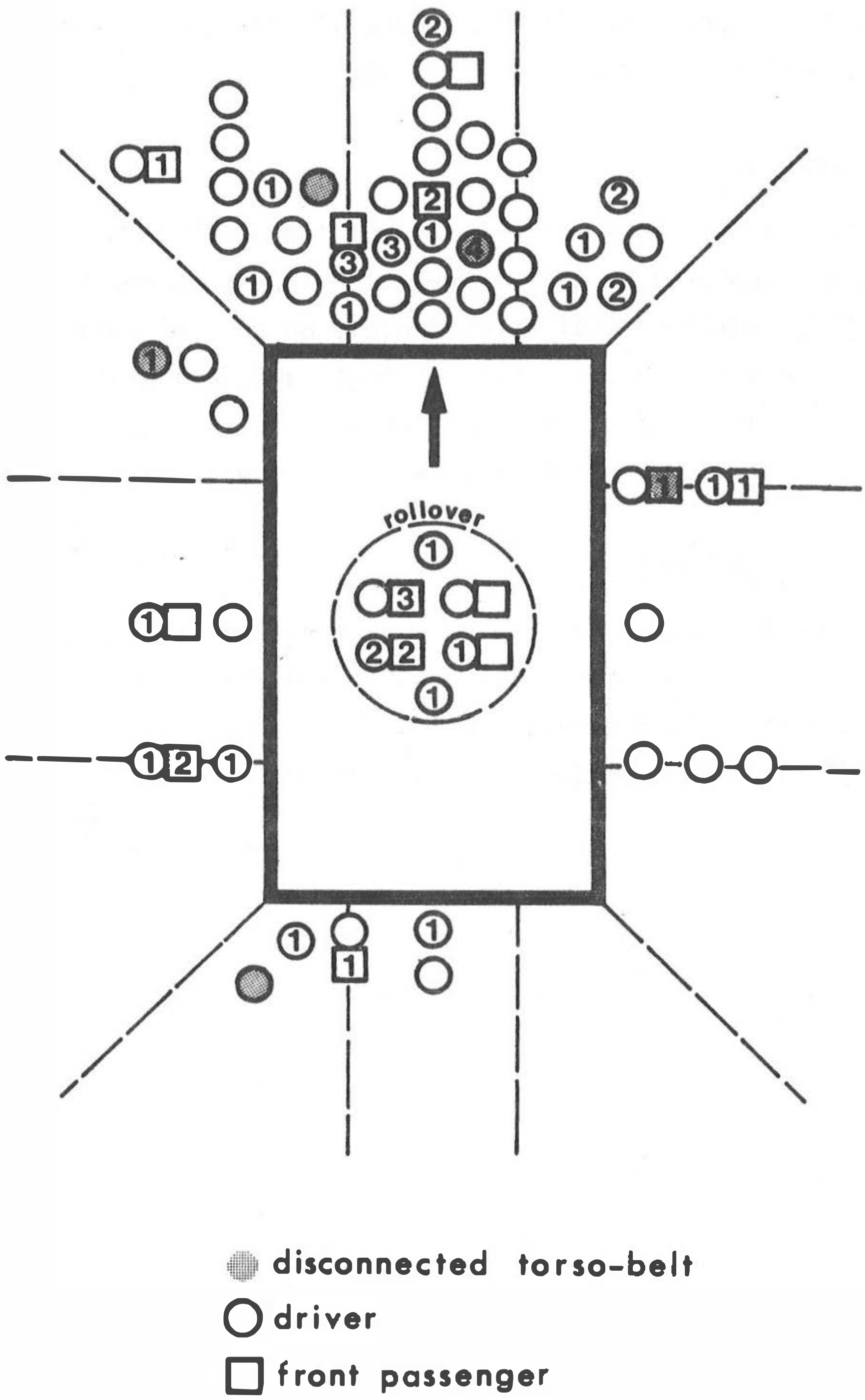


Figure No. 8 Distribution of accident type

Repair costs used as a measure of impact severity are correlated with occupant injury (using the AIS injury scale), as shown in Figure No. 9.

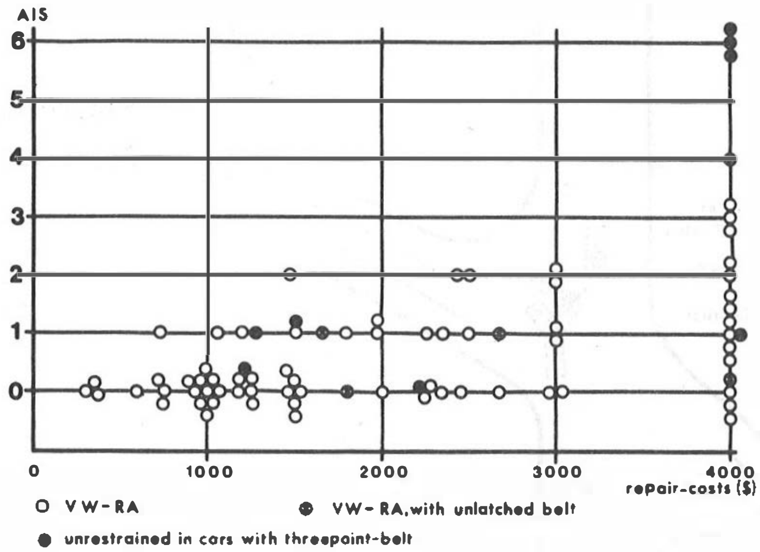


Figure No. 9   Injury Scale as a function of repair costs

In some collisions, crash data was recorded automatically by on-board U.S. Government supplied disc recorders. These devices measure the velocity change and acceleration levels versus time around 3 axes (longitudinal, transverse and vertical). It is anticipated in the future that an even more precise velocity change estimate will be calculated. One of the accidents involving a Golf with the VWRA has been simulated on our proving ground in an attempt to compare the actual injury with dummy data. This particular accident was also investigated by the Calspan Corporation multidisciplinary accident investigation team. The description of this accident is portrayed in Figure No. 10.

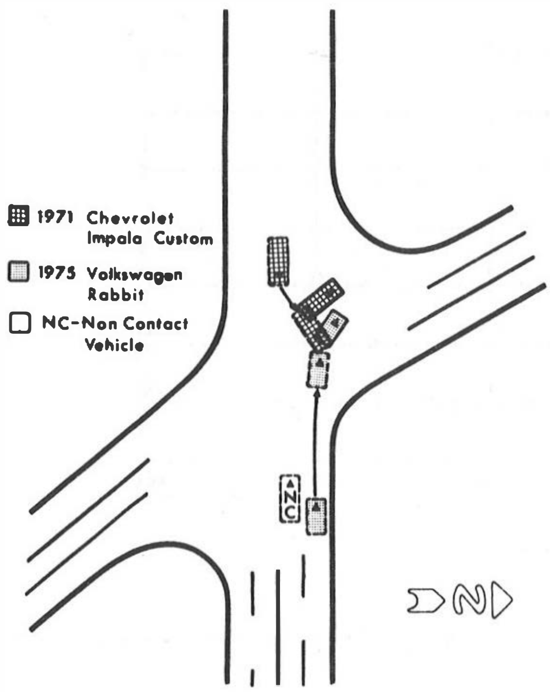


Figure No. 10
Accident schematic

The comparison of the field investigation and our accident simulation tests are shown in Table 2. There has been a total of two simulated tests performed. In the first car, two 5 percent female dummies were used and in the second car two 50 percent male, Part 572 dummies were used so that we could compare the dummy data and protection criteria of FMVSS 208 with actual injuries. We concluded that in this case the VWRA definitely prevented more severe injuries.

Table 2

ACCIDENT DATA AND ACCIDENT SIMULATION TEST

	Investigated by Calspan Accident	Simulation test No. 1	Simulation test No. 2
Vehicle No. 1 Vehicle No. 2	71 Chevrolet Impala 4514 lbs 75 Rabbit 2780 lbs	71 Galaxi 4572 lbs 75 Rabbit 2267 lbs	69 Thunderbird 4633 lbs 75 Rabbit 2284 lbs
V_{impact} Vehicle No. 1 Vehicle No. 2	 5 - 8 mph 32 - 38 mph	 0 33,8 mph	 0 45 mph
Change of Velocity	21,9 mph	15,8 mph	20,8 mph
Maximum Deformation: of Front after Impact: of Vehicle No. 2	266 mm	120 mm	390 mm
Occupants Vehicle No. 2 Driver	female 21 years 63" 115 lbs	5th perc.adult female 68" 102 lbs	50th perc.adult male 77,3" 164 lbs
Injuries + Cause probable: Steering wheel left Door Armrest or Door Pane Foot Controls	 pain, lower anterior thorax Gross hematuria, treated by foley catheter pain right ankle	 HIC 107 Head 35 g Chest 21 g SI 50 Femur left 1800 N right 2000 N	 HIC 270 Head 28 g Chest 30 g SI 230 Femur left 4500 N right 4600 N
Occupants Vehicle No. 2 Passenger	female 18 years 62,5" 105 lbs	5th perc.adult female 68" 102 lbs	50th perc.adult male 77,3" 164 lbs
Injuries + Cause probable Windshild probable floor pan	 abrasion right forearm contusion left ankle	 HIC 133 Head 38 g Chest 20 g SI 50 Femur left 3000 N right 1500 N	 HIC 154 Head 30 g Chest 30 g SI 200 Femur left 3400 N right 4000 N

6.0 Conclusion

In summary, we feel confident that the VWRA is a reasonable viable alternative to the standard 3-point belt. The system reveals benefits in frontal collision performance, as well as in the area of very high usage rates. It should be obvious that a restraint system which is not in use offers zero protective capability. The VW system, however, can still be further improved, as can any conventional belt 3-point system. In the future further development of the VWRA and the 3-point system will more than likely be implemented to meet even more severe impact protection criteria.