Department of Transport and Regional Development
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Development of an Australian Design Rule for Offset Frontal Crash Protection

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Federal Office of Road Safety

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Abstract
Frontal crashes are the cause of the majority of deaths and injuries on the roads. In 1995, the Federal Office of Road Safety (FORS) introduced Australian Design Rule (ADR) 69 for full frontal crash protection which sets head, chest and leg injury criteria which has seen the majority of passenger cars fitted with at least driver's side airbags. Since there are currently no regulations anywhere in the world for offset frontal crashes FORS has participated in the work of the European Experimental Vehicle Committee (EEVC) to develop a globally harmonised test procedure for offset frontal crash testing. Other participants included the USA, Canada and Japan. This report summarises the outcomes of Australia's offset frontal crash test program which was considered by EEVC Working Group 11 in drafting the European offset crash test requirements. These test requirements formed the basis of an Australian Design Rule (ADR 73/00) for offset frontal crash protection. Australia's aim is to have a set of frontal crash standards which will result in vehicle designs that protect occupants both in high deceleration head-on crashes as well as "softer" offset crashes which usually result in intrusion based injuries. While serious lower limb injuries are rarely life threatening, they usually result in extremely high societal costs associated with life-long debilitation.

Keywords
Occupant protection, crash test, ADR, road safety, passenger vehicles, offset frontal

Notes
(1) FORS research reports are disseminated in the interests of information exchange.
(2) The views expressed are those of the author and do not necessarily represent those of the Commonwealth Government

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Keith Seyer

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EXECUTIVE SUMMARY

Introduction

The Australian Design Rules (ADRs) set down a comprehensive range of performance and design requirements for motor vehicle safety and are among the most stringent in the world. The ADRs are administered under a type approval system by the Federal Office of Road Safety (FORS).

Since the first set of ADRs were implemented in 1969, there have been significant reductions in fatalities through the ADRs and other Australian Government initiatives such as compulsory seat belt wearing and drink driving campaigns. This saw the 1992 fatality figure half that of 1970.

Accident statistics show that frontal crashes are the cause of the majority of deaths and injuries on the roads.

A $1 million standards development program begun in 1989 by FORS led to the introduction of ADR 69 for full frontal crash protection which sets head, chest and leg injury criteria. All new passenger cars were required to comply with it by 1996 and by 1997 about 70% of passenger cars were fitted with at least driver's side airbags to demonstrate compliance.

Offset Crash Test Program

After head-on crashes, the next most prevalent type of frontal accident is offset crashes where only part of the vehicle's front structure absorbs the impact. When this research program started in 1993, there were no regulations anywhere in the world for this type of crash situation.

This was the reason the Federal Office of Road Safety decided to participate in the work of the European Experimental Vehicle Committee (EEVC) to develop a globally harmonised test procedure for offset frontal crash testing. Australia, Japan, Canada and the USA participated together with most European countries.

This report details the offset frontal crash test program which formed Australia's input into the considerations of EEVC Working Group 11.

The FORS test program aimed at addressing the following issues:

- Base research to assist WG 11 in determining the best offset, test speed and barrier design to incorporate into the test procedure.
- Examine the effects of drivetrain asymmetry on test outcome.
- Further research on barrier face design as a result of initial test series.

Australia's aim is to have a set of frontal crash standards which will result in vehicle designs that protect occupants both in high deceleration head-on crashes as well as "softer" offset crashes which usually result in intrusion based injuries.

Why an Offset Deformable Barrier Face

When vehicles have a head-on crash, engagement of the front structures of the impacting cars causes high initial decelerations which start the car's crumple zones collapsing. This is replicated in a regulatory test of the car into a rigid barrier.

In an offset test, these high initial decelerations do not always occur (until a stiff structure such as the engine/drivetrain is engaged). Without these high initial decelerations the car's stiff crumple zones may not start collapsing but rather transfer the crash energy into the passenger compartment. A deformable barrier face was chosen as the means of replicating this by eliminating the high initial decelerations.

EEVC Base Research

Many popular passenger cars are now designed with a transverse front engined, front wheel drive configuration. The initial WG 11 work was predominantly on left hand drive (LHD) vehicles in Europe with the small and medium test cars having this configuration with the gearbox on the left hand side. The large car used had a longitudinal front engine, rear wheel drive configuration similar to the two best selling passenger cars in Australia.

The initial research conducted by the EEVC used a 50 psi compression aluminium honeycomb barrier. Following analysis of the data, it was found that the load paths generated by the barrier were different to those seen in the car to car crash of the same vehicle into itself. This resulted in the introduction of a small 200 psi compression bumper element in the front of the barrier face to produce the correct load path.

A test speed of between 56 km/h to 60 km/h appeared to reproduce the deformations seen in the car to car test of the same vehicle each travelling at 50 km/h. This is because the deformable barrier face absorbs some energy.

Australian Base Research (Phase 1 Tests)

In parallel with the initial EEVC work, FORS began a test series using a small (Toyota Corolla) right hand drive (RHD) transverse front engined, front wheel drive vehicle in the same drivetrain configuration as the EEVC small and medium test vehicles. Because the Australian vehicle was RHD, the engine was offset to the driver's side.

This initial program consisted of the following four tests:

- 40% overlap test into a deformable barrier at 60 km/h (no bumper).
- 50% overlap test into a deformable barrier at 60 km/h (no bumper).
- 50% overlap car to car test with each vehicle travelling at 50 km/h.
- 40% overlap test into a deformable barrier at 60 km/h (with bumper).

The FORS Phase 1 tests confirmed that the bumper element was required to achieve the correct load path into the vehicle and that 40% appeared to be the correct amount of overlap for the test. However, a test speed of 60 km/h was required to reproduce deformations approaching those seen in the car to car test of the same vehicle each travelling at 50 km/h.

The following summarises the outcome of the Phase 1 tests:

- In general, the time histories of the dummy responses were different between the car to car test and the deformable barrier tests.
- The time histories of both the engine and B-pillar transducers were different between the car to car test and the deformable barrier tests. The car to car test showed an earlier onset and higher peak decelerations.
- The firewall decelerations in both the car to car test vehicles were much higher than in the deformable barrier tests.
- The lower leg injury levels in the car to car tests were higher than those in the 40% overlap deformable barrier test.

These results indicated that the EEVC deformable barrier did not reproduce the vehicle and dummy kinematics for the drivetrain configuration found in the RHD test vehicle. FORS was particularly concerned with airbag equipped cars where the differences in the crash pulse could produce incorrect triggering of the airbag. This issue is being examined by the EEVC as the second stage development of the European offset regulation.

Effect of Drivetrain Symmetry (Phase 2 Tests)

This part of the FORS research aimed at complementing the EEVC work by examining the effects of drivetrain asymmetry on test outcome. Three LHD Corollas were tested as follows:

- 50% overlap car to car test with each vehicle travelling at 50 km/h.
- 40% overlap test into a deformable barrier at 60 km/h (with bumper).

On examination of the vehicles after the LHD car to car test, the following major points were noted when compared to the RHD car to car test:

- Without the engine bridging effect on the RHD vehicle, the LHD pulse has a slightly more gradual onset.
- The LHD cars had a lower peak vehicle deceleration compared to the RHD cars. However, firewall decelerations were higher.
- Sill at the bottom of the A pillar had failed in compression. On the RHD cars, the sill failed in buckling and further back (about 1/3 the distance towards the B pillar).
- Significantly more passenger compartment intrusion than on the RHD cars.
- The deformation of the two LHD cars was similar whereas the degree of deformation of the two RHD cars was quite different.
- The driver's HPCs for the LHD cars were both around 1100. This compares with 675 and 1174 for the RHD cars with the higher figure corresponding to the vehicle with greater deformation.

Both the LHD deformable barrier test and the LHD car to car test gave higher injury readings than the corresponding RHD tests.

The deformation characteristics of the LHD cars indicates that without the bridging effect of the engine onto the firewall seen in the RHD cars, the front longitudinal, A-pillar and sill are required to dissipate more energy in an offset frontal test.

The results confirm that for offset frontal impacts, drivetrain and structural symmetry are important parameters to be considered when selection of representative test vehicles are made.

Does Using a Different Model Car Affect the Outcome (Phase 3 Tests)

There was concern with some members of the EEVC WG11 that the test series based on the Toyota Corolla might lead researchers to an outcome that was vehicle specific.

For this reason, it was decided to conduct a car to car crash using a RHD Toyota Corolla running into a RHD 1995 model Ford Laser Liata. The engine on both models is offset to the driver's side. This would allow comparison of the Corolla's vehicle and dummy response in car to car tests where it runs into itself and also into another vehicle model in the same weight class.

The Ford Laser Liata was also subject to an offset deformable barrier test using the barrier described in Figure 2 by the Australian New Car Assessment Program. This test was performed at 40% overlap and a speed of 60 km/h. As FORS has no direct affiliation with the NCAP testing, their technical committee was approached to purchase the crash test data for the Laser offset deformable barrier test. This provided another vehicle model to compare the vehicle and dummy responses of a car to car test against an offset deformable barrier test.

Comparison of the car to car tests indicated that the vehicle and dummy kinematics of the Corolla were similar irrespective of whether the other test car was also a Corolla or a different vehicle, in this case a Ford Laser.

The outcome of Phase 3 supported the proposition that the vehicle and dummy responses seen in the Phase 1 tests were not vehicle specific to the Toyota Corolla but were also true for the Ford Laser.

Tests with a Modified Deformable Barrier (Phase 4 Tests)

The outcomes of the first 3 phases suggested that drivetrain configuration on the transverse front engined vehicles had a bearing on the dummy and vehicle responses in both a car to car crash and a test into a deformable barrier.

The Phase 1 tests indicated that the deformation characteristics, deceleration and dummy readings were different between the car to car test and the test into EEVC offset deformable barrier. The LHD test series showed that the EEVC offset deformable barrier appeared to correlate reasonably well with the LHD Corolla car to car test.

This indicated that when the engine is offset to the driver's side in a car to car crash the engagement of the engines result in a different response than that obtained when the engine is not engaged.

This posed the question of whether the deformable barrier could be modified to replicate this engine engagement and the subsequent bridging effect of the engine to the firewall.

To examine this, two tests were performed using a modified offset deformable barrier design. Both barriers had 3 bumper elements of 250 psi honeycomb at the front and were mounted 200 mm above the ground.

The first test used a deformable barrier face consisting of a 50 psi compression aluminium honeycomb main core with an inserted core of 250 psi honeycomb at the rear. This first test was conducted at 60 km/h at 40% overlap. This first test resulted in severe collapse of the passenger compartment with the injury data much higher than for the car to car test. However, the vehicle and dummy kinematics were now better aligned with that seen in the car to car crash. The inserted core showed very little crush. However, the initial crush phase through the 50 psi honeycomb was still more gradual than the car to car pulse.

The second test used a deformable barrier face consisting of a 65 psi compression aluminium honeycomb main core with an inserted core of 155 psi honeycomb at the rear). The second test was conducted at 55 km/h at 40% overlap. The 65 psi honeycomb was chosen to try and address the gradual onset in the initial crush phase.

The second test provided vehicle deformations similar to the car to car test and dummy data about half way between the outcomes of the two cars in the car to car test. The 65 psi honeycomb did not appear to address the "soft" initial crush although there was more crush of the inserted core. However, the front of the vehicle appeared more like the car to car test without the centre "notch" seen with the 50 psi homogeneous barrier face.

Future Developments

The last WG 11 meeting in 1995 finalised the draft offset frontal test procedure for consideration by the European Parliament in early 1996. At the meeting, there was considerable debate on the efficacy of the current instrumented lower legs. It was finally agreed to proceed with the regulation using newly developed legs which would improve test to test repeatability.

In early 1996, the European Parliament endorsed a move towards a draft directive which specified the offset frontal deformable barrier test developed by the EEVC.

While Australia saw merit in further work in relation to the barrier face specification, it was believed that the finalised WG 11 draft test procedure was a significant first step forward in improving offset frontal crash protection particularly for the lower legs.

Therefore FORS prepared a draft Australian Design Rule (ADR 73/00) which incorporated the requirements of the finalised WG 11 draft test procedure. This draft ADR together with a cost benefit analysis was issued for public comment during 1996.

The cost benefit analysis indicated that the annual Harm reduction that would accrue from the offset standard ***in addition*** to that achieved from ADR 69 was estimated to be at least A$297 million (a 15% reduction in frontal Harm) and at best, A$460 million (a 23% reduction in frontal Harm). The two estimates depended on the level of airbag usage. The full benefits would apply when all vehicles in the fleet complied with both standards.

As a second stage, the EEVC is doing further work on the impact speed and the design of the deformable barrier element to ensure that there are no detrimental effects on airbag deployment.

SUMMARY

- ADR 69 for full frontal impact protection is already in place in Australia and will test the vehicle's restraint system in a high deceleration crash situation. This ADR will continue in parallel with an ADR on offset frontal crash protection.

- The offset test will test the vehicle's structural integrity and, with lower leg injury criteria applied, the vehicle's ability to prevent debilitating leg injuries. It will also mitigate upper torso injuries resulting from reductions in occupant survival space.

- The offset test should result in vehicle designs with improved crash energy management.

- A draft ADR 73/00 was prepared incorporating the requirements of the finalised WG 11 draft test procedure for offset frontal crash protection. This ADR and a cost benefit analysis was issued for public comment during 1996. The draft ADR is included at Appendix 7.

- The Harm reduction analysis indicated that the annual benefit that would accrue from the offset standard, in addition to that achieved from ADR 69, to be at least A$297 million (a 15% reduction in frontal Harm) and at best, A$460 million (a 23% reduction in frontal Harm). The two estimates depended on the level of airbag usage.

- ADR 73/00 is being finalised with an introduction date of 1 January 2000 for passenger cars.

1 Introduction

Accident statistics show that frontal crashes are the cause of the majority of deaths and injuries on the roads.

Based on these statistics, the Federal Office of Road Safety commissioned a major study in 1989 to determine how the ADRs were performing in relation to frontal crashes and to determine what improvements could be made.

This study was part of a $1 million standards development program by the Federal Office of Road Safety which led to a new ADR for full frontal crash protection. This new Design Rule, ADR 69, sets head, chest and leg injury criteria and was introduced in December 1992. All new passenger cars were required to comply with it by 1996 and by 1997 about 70% of passenger cars were fitted with at least driver's side airbags to demonstrate compliance.

When vehicles have a head-on crash, engagement of the front structures of the impacting cars causes high initial decelerations which start the car's crumple zones collapsing. This is replicated in a regulatory test of the car into a rigid barrier (ADR 69).

However, not all frontal crashes are completely head-on. Some are offset crashes where only part of the vehicle's front structure absorbs the impact. When FORS commenced this project in 1993, there were no regulations anywhere in the world for this type of crash situation.

In an offset crash, the high initial decelerations seen in a rigid barrier test do not always occur (until a stiff structure such as the engine/drivetrain is engaged). Without these high initial decelerations the car's crumple zones may not start collapsing but rather transfer the crash energy into the passenger compartment. This is particularly true if the crumple zones have been optimised only for a rigid barrier test and are very stiff. A deformable barrier face was chosen as the means of eliminating the high initial decelerations to replicate real world crashes.

The aim of a requirement for an offset crash standard was to make available to the Australian public vehicle designs which would protect the occupants both in a high deceleration head-on crash as well as a softer offset crash which usually results in intrusion based injuries.

For this reason, the Federal Office of Road Safety participated in the work of the European Experimental Vehicle Committee (EEVC) to develop a globally harmonised test procedure for offset frontal crash testing. Australia, Japan, Canada and the USA participated together with most European countries.

This report details the offset crash test program which follows on from the work on full frontal crash protection, and formed part of the input into the considerations of the EEVC.

The FORS test program aimed at addressing the following issues:

- Base research to assist the EEVC in determining the best offset, test speed and barrier design to incorporate into the test protocol.
- Examine the effects of drivetrain symmetry on test outcome.
- Tests to ensure the outcome of the program were not model specific.
- Further research on deformable barrier face design as a result of initial test series.

The finalised EEVC test procedure was used as the basis of a new Australian Design Rule for offset frontal crash protection to be implemented from the year 2000.

In parallel, Monash University Accident Research Centre was commissioned to conduct a Harm Reduction analysis to determine the benefits of an offset frontal crash standard in addition to ADR 69. A summary of this benefit analysis is included in this report.

2 PHASE 1 - Developing the Offset Frontal Crash Test Procedure

2.1 Introduction

At the time the Federal Office of Road Safety commissioned these offset tests, the EEVC had completed a series of offset tests in Europe. The outcome of these tests indicated the most likely test requirement would set the vehicle test speed at 60 km/h into a deformable barrier face with an overlap of between 40% to 50%.

The EEVC's initial deliberations concentrated on defining a barrier test which would replicate the vehicle deformation and collapse mode of the front structure which is seen in real life car to car offset crashes.

It is the intent of the final EEVC test procedure to include injury parameters for the head, chest, abdomen, and upper and lower limbs.

The aim of the FORS offset test program was to provide feedback on the differences in dummy and vehicle kinematics of the three tests performed and also differences in injury criteria recorded.

Initially Phase 1 of the crash test program consisted of the following tests:

- 40% overlap test into a deformable barrier at 60 km/h (B3014).
- 50% overlap test into a deformable barrier at 60 km/h (B3015).
- 50% overlap car to car test with each vehicle travelling at 50 km/h (B4009).

The test speed of 60 km/h for the deformable barrier tests was chosen because earlier work in Europe indicated that this gave vehicle deformations commensurate with a car to car test with both vehicles travelling at 50 km/h. This is because the deformable barrier absorbs some of the crash energy.

2.2 Test Procedure

The crash tests were conducted at New South Wales Road and Traffic Authority Crashlab facilities under contract to the Federal Office of Road Safety. A description of the facility and the data acquisition equipment is provided at **Appendix 1**.

The tests were set up as closely as possible to the EEVC contractors test protocol to assist comparison. This included the type and positioning of dummy and vehicle transducers.

Because the crash facility was limited to 60 channels of data acquisition, it was necessary to compromise with the car to car test in not having both dummies and vehicles fully instrumented. These differences in instrumentation are described in the sections covering the test vehicles and test dummies.

2.3 Test Vehicles

All test vehicles used were 1993 Toyota Corolla Liftbacks fitted with power steering, air conditioning, and automatic transmission. The vehicles were right hand drive cars, front wheel drive with the engine offset to the right (driver's) side.

The vehicles complied with ADR 29 - Side Door Strength which meant that all the side doors were fitted with intrusion beams.

Underbody components on the front of the vehicle were painted contrasting colours to facilitate analysis of vehicle deformation.

Each vehicle was weighed on delivery to the test facility and ballasted to the mass specified in Clause 6.1 of ADR 69/00 which includes dummies and test equipment. The test vehicle data sheets are provided in **Appendix 2**.

2.3.1 Tests into Deformable Barrier

Single axis accelerometers were placed at the following points on the test vehicles

- left and right side of top and bottom of engine
- left and right on top of the suspension towers
- left and right on the interior side of the firewall where the front longitudinals join

In addition, triaxial accelerometers were installed on the rocker panel just behind the B-pillar on each side.

2.3.2 Car to Car Test

Only the right hand side of each car was instrumented for these tests, viz:

- Single axis accelerometers top and bottom of engine
- Single axis accelerometer on top of the suspension towers
- Single axis accelerometer on the interior side of the firewall where the front longitudinals join

The above locations were chosen to give an indication of the load path in the vehicle structure during the crash sequence.

A triaxial accelerometer was installed on the rocker panel just behind the B-pillar. This position provides the overall vehicle deceleration pulse.

2.4 Test Dummies

Hybrid III dummies were installed in each front seating position and restrained by the vehicle's lap sash seat belts. The dummies were positioned in accordance with ADR 69 (same as FMVSS 208). **Appendix 3** provides the positioning measurements.

The vehicles and dummies were soaked in a climatically controlled preparation shed and a record of temperature and humidity kept.

Chalk solutions of contrasting colours were painted onto the dummies' face to mark contact points with the vehicle interior.

2.4.1 Dummy Instrumentation

For this series of tests the following set of instrumentation was available:

- Head centre of gravity acceleration (triaxial accelerometer) – A_X, A_Y, A_Z
- Upper neck load cell (6 axis) – F_X, F_Y, F_Z, M_X, M_Y, M_Z
- Chest acceleration (triaxial accelerometer) - A_X, A_Y, A_Z
- Sternum deflection – D_X
- Pelvis acceleration (triaxial accelerometer) - A_X, A_Y, A_Z
- Femur load cells– F_Z
- Upper tibia load cell – M_X, M_Y
- Lower tibia load cell – F_X, F_Y, F_Z, M_X, M_Y

Because of the data acquisition limitations, the dummy instrumentation differed for the deformable barrier tests and car to car test.

2.4.2 Deformable Barrier Tests

Driver dummies were fitted with all available instrumentation except tibia F_X and M_Y (see §2.4.1). Passenger dummies were not fitted with tibia, pelvic or neck instrumentation except in test B4054 where neck measurements were recorded but femur forces were omitted.

The dummies were fully calibrated before each test. The instrumented lower limbs were calibrated by the manufacturer in the USA prior to the test series.

2.4.3 Car to Car Test

Neither passenger dummy was instrumented.

The driver dummy in vehicle 1 was fully instrumented. The driver dummy in vehicle 2 was not fitted with tibia, pelvic or neck instrumentation.

2.5 Injury Assessment

Through the series of tests, injury calculations for the dummies were made as set out in the EEVC protocol and subsequent EC directive and draft ECE regulation. The injury measurements are tabulated in **Appendix 5.** In some cases data acquisition or dummy limitations did not allow all of the necessary channels to be recorded. In these cases no measurements are listed in the appendix. The injury tolerances specified in the final Australian Design Rule (ECE R94) are as follows:

Head Performance Criterion (HPC)

HPC is calculated using the same procedure as HIC, used in ADR 69, with the exception that HPC is only evaluated when there is head contact and over a maximum of 36ms. HPC is calculated from the tri-axial accelerometer in the Hybrid III head.

$$\mathrm{HPC} = (t_2 - t_1)\left[\frac{1}{t_2 - t_1}\int_{t_1}^{t_2} a\,dt\right]^{2.5}$$

The rule allows for the start of the HPC time interval to be established manually, however when this cannot be determined the time interval determined by the HPC algorithm is considered acceptable. The start of the head contact was not calculated manually for these tests as it was established that this would make little or no difference to the injury comparisons.

The tolerance limit for HPC is 1000.

Head Acceleration (3ms clip)

The rule specifies that head acceleration must not exceed 80g for more than 3ms. This is calculated cumulatively and excludes head rebound. All vehicles which failed this injury criteria also failed on the HPC measurement.

Neck Injury Criterion (NIC)

The neck injury tolerances for tension and shear force are specified by time dependent tolerance curves. These are included in the copy of ADR 73 at **Appendix 7**. These are calculated from the neck tension (F_Z) and fore aft shear (F_X) measurements in the upper neck load cell. The NIC curves were generated for all tests where the necessary channels were recorded. No tests in this series exceeded either the time based or peak force limits, therefore only peak values are tabulated in **Appendix 5**. The peak tolerance values are 3.3kN in tension and 3.1 kN in shear.

Neck Bending Moment

The neck bending moment (M_y) is measured at the upper neck load cell. The injury tolerance is specified for extension only and is 57Nm.

Thorax Compression (ThCC)

The thorax (chest) compression is measured at the Hybrid III sternum and may not exceed 50mm.

*Viscous Criterion (V*C)*

The viscous (or soft tissue) criterion was introduced late in the development of the offset rule. V*C is calculated from the thorax compression measurement and is the product of chest compression and chest velocity (calculated from compression through differentiation). The full procedure for calculating V*C is included in ADR 73 at **Appendix 7**. The tolerance limit for viscous criterion is 1.0 ms^{-1}.

Femur Force Criterion (FFC)

Femur force is limited by a time based criterion similar to the Neck Injury Criterion. Force is measured along the femur shaft by the femur load cell (F_Z). The curves are included in **Appendix 7**. The curves specify a peak force limit (ie 0ms) and there were no cases where the time based injury criteria were exceeded where the peak force criteria was not. Therefore only the peak force values are tabulated in **Appendix 5**. The peak force limit is 9.07kN.

Tibia Compression (TCFC)

Tibia compression force was measured at the lower tibia (ankle) load cell and is limited to 8kN.

Tibia Index (TI)

The method for evaluating tibia injury was changed by the EEVC during the course of this study, consequently the necessary measurements to evaluate the Tibia Index were not recorded for all tests. The final tibia index calculation uses moments about the *x* and *y* axes of the tibia load cell (M_X and M_Y), as well as the compressive force (F_Z) and should be calculated at both upper and lower tibia load cells. In these tests the necessary channels were only recorded to calculate the upper Tibia Index and these results are presented in **Appendix 5**. The compressive force is allowed to be measured at either the upper or lower end of the tibia shaft and can be used for either upper or lower TI calculation. The formula for Tibia Index is as follows:

$TI = |M_R / (M_C)_R| + |F_Z / (F_C)_Z|$ where:

M_R = resultant bending moment = $\sqrt{(M_x)^2 + (M_y)^2}$
$(M_C)_R$ = critical bending moment and shall be taken to be 225 Nm
F_Z = compressive axial force in the z direction
$(F_C)_Z$ = critical compressive force in the z direction and shall be taken to be 35.9 kN

The injury tolerance for Tibia Index is 1.3, which may not be exceeded at either upper or lower load cell.

Knee Displacement

The rule states that the movement of the sliding knee joints must not exceed 15mm. These were not measured in this series due to data restrictions.

Resultant chest acceleration and neck flexion are not required injury criteria in ADR 73 however these measurements have been included in **Appendix 5** for reference.

2.6 Deformable Barrier Face

A deformable barrier face using 50 psi compression aluminium honeycomb was used. The barriers were purchased certified from Cellbond in the UK and conformed to the specification being used by EEVC contractors. The specifications of the barrier face are described in figure 2.1. The barrier was mounted 200 mm above the ground. The barrier did not have a bumper.

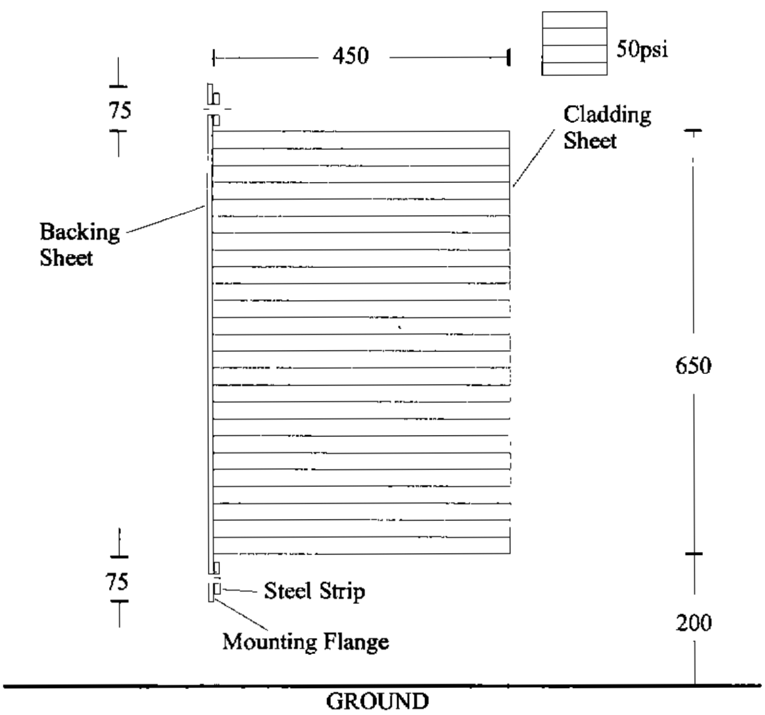

Figure 2.1 - Deformable barrier element

The deformable face was mounted on the test facility's rigid offset barrier. This rigid barrier had a round edge of 150 mm radius. The edge of the deformable barrier was mounted with its end at the start of round edge.

2.7 Photography

For the deformable barrier tests, there were off-board high speed cameras placed on the left and right hand side, overhead, underneath in the camera pit, and oblique on the left hand side.

For the deformable barrier test, one on-board camera was fitted to each of the front doors to track lower limb kinematics. In addition, another camera was placed on the inside towards the rear of the car to record the overall dummy kinematics from the rear.

For the car to car test, there was only one on-board camera in each vehicle and this was fitted to the driver's door.

Pre-test still photographs were taken of both vehicle and dummy positioning. The same sequence of photographs were taken post-test to show vehicle deformation and dummy contact points with the vehicle's interior. The pre and post test photographs are provided in **Appendix 8**.

The same high speed and still photographic requirements were used throughout the whole test series. The only exception being that vehicles used in subsequent deformable barrier tests did not have a rear camera inside the vehicle.

2.8 Phase 1 Test Results

The 40% overlap test was run number B3014. The 50% overlap was number B3015. The car-to-car test was run number B4009.

Vehicle deformation measurements are provided in **Appendix 4**. The dummy results of the tests are summarised in **Appendix 5**. The vehicle crash pulses are provided in **Appendix 6.**

2.8.1 Summary of Deformable Barrier Tests

The results of the tests at 40% and 50% overlap have indicated the following:

- The 50% overlap gives a slightly higher vehicle deceleration pulse with earlier onset.
- The 50% overlap gives slightly higher head and chest injury criteria for both dummies, and higher femur loads for the driver.
- The 40% overlap gives more intrusion.
- The 40% overlap gives higher lower leg injury criteria for the driver.

- The barrier faces bottomed out in both tests but this occurred late in the crash sequence. This may be due to the fitment of side intrusion beams in Australian cars to comply with ADR 29 Side Door Strength (same requirements as old FMVSS 214) increasing the longitudinal stiffness of the body structure.

- In both tests, there was significant upward rotation of the brake pedal. It is unclear if this is vehicle specific. If the driver were braking at the time of a real crash, this would have serious consequences on lower limb injuries. There is a need to examine whether the dummy setup for an offset test should place the driver dummy's right foot on the brake. Alternatively, consideration could be given to limiting the movement of the brake pedal.

2.8.2 Comparison of Results of Deformable Barrier and Car to Car Tests

Car 2 suffered more deformation during the crash than Car 1. The roof rail had failed in combined bending and tension which resulted in more facia, footwell and A-pillar intrusion. The deformation suffered by Car 1 was of a similar level to that which occurred in the 60 km/h test into a deformable barrier at 40% offset.

The HPC figures for Car 2 were nearly double those of Car 1. The HIC_{15} figure for Car 2 that the driver suffered a severe head strike. The HPC figure for Car 1 was similar to that for the 40% offset test. The HPC figure for Car 2 was similar to that for the 50% offset test.

The chest data in the car to car test peaked at lower levels and about 10 msec earlier than the deformable barrier tests. The chest data was similar for the 40% and 50% overlap tests.

Both the upper tibia and ankle moments and forces were generally higher in the 40% test than the 50%. However, there was some trend reversal suggesting that the differences were due to test variability. It should also be remembered that these tests were performed using the original foot/ankle design with limited articulation and no soft stops. This design was prone to bottoming out and causing problems with repeatability. In turn, the car to car figures were higher than in the offset deformable barrier tests.

The engine decelerations were higher in the car to car tests than for the deformable barrier tests. The was little or no rotation of the engine in the car to car tests. The time histories for the car to car test were similar to the deformable barrier tests with a peak at 30 msec. However, in the deformable barrier tests, there is a second peak at 60 msec which could be the engine bottoming out on the rigid backing plate of the barrier.

The time histories for the B-pillar decelerations are quite different for the car to car test and the offset deformable barrier tests. The car to car shows a peak at 40 msec with a second peak at about 65 msec. In the deformable barrier tests, there is a gradual rise to a peak at about 85 to 90 msec. Right B-pillar deceleration at 40% overlap is higher than 50%. However, the 50% overlap showed a less gradual onset as would be expected from more engine engagement. The resultant B-pillar deceleration in the car to car test is higher than either barrier tests although the x-axis figure is lower which may indicate more rotation in the other two axes.

The firewall decelerations in both the car to car test vehicles were much higher than in the deformable barrier tests.

There was interaction between the engine and the firewall in both the car to car test and the tests into the deformable barriers.

2.8.3 Summary of Phase 1 Tests

The following summarises the outcomes of the initial set of deformable barrier tests (without bumper element) and the car to car test:

- The deformable barrier tests showed that the 40% overlap test produced the higher intrusion.
- The car to car lower leg injury levels were higher than those in the offset deformable barrier tests.
- In the car to car test, one car suffered more deformation than the other.
- Of the deformable barrier tests, the one at 40% overlap looked more like the least damaged of the car to car test vehicles.
- There was visible rotation of the engine in the deformable barrier tests. There was negligible rotation of the engine in the car to car test.
- The time histories of both the engine and B-pillar transducers are quite different between the car to car test and the deformable barrier tests. The 50% overlap test better matched the onset rate seen in the car to car test.
- The firewall decelerations in both the car to car test vehicles were much higher than in the deformable barrier tests.
- There was interaction between the engine and the firewall in all tests.
- The time histories of the dummy responses were also different between the car to car test and the deformable barrier tests.

The EEVC test series also found a difference in the engine rotation in the car to car tests when compared to the tests of the same car into the offset deformable barrier. This difference was due to different load paths at sill and waist level between the two tests.

To address this issue, the EEVC conducted further tests and modified the barrier design by incorporating a three stage bumper element in front of the barrier.

2.9 Supplementary Phase 1 Test

To examine the effectiveness of the modified deformable barrier with a bumper element, a further test was performed at 40% overlap and 60 km/h using this new design. This test was run number B4054.

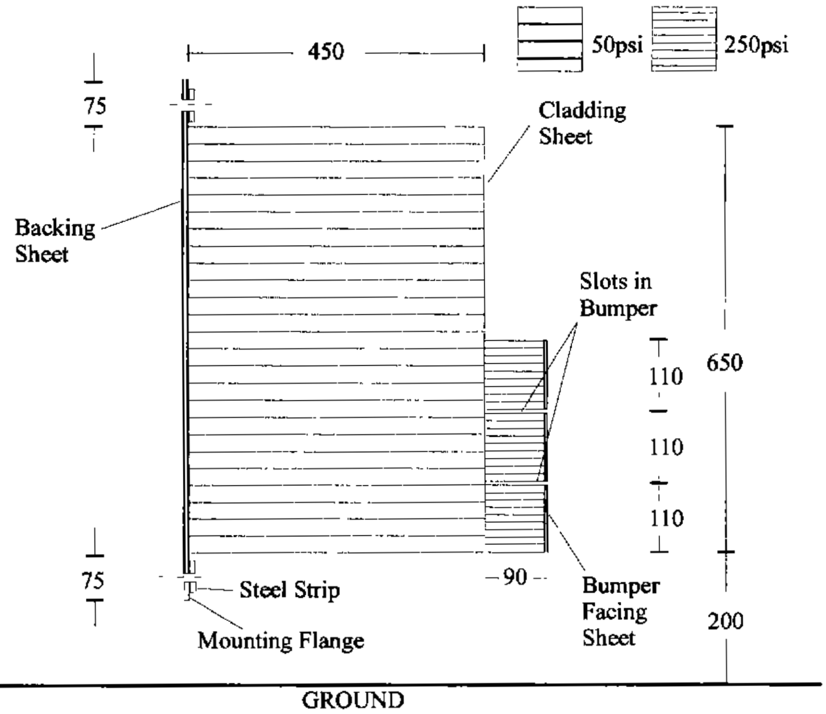

Figure 2.2 - Deformable barrier with bumper element

The barrier design is as described in Section 2.6 except for the addition of a bumper element to the front face consisting of three strips of 250 psi aluminium honeycomb running the full width of the barrier face, 90 mm deep and 110 mm high. Figure 2.2 shows a drawing of the barrier face with bumper elements.

2.9.1 Phase 1 Supplementary Test Results

Examination of the vehicle post test indicated that the bumper element had changed the sill level load path sufficiently to reduce the engine rotation so that it was now similar to that seen in the car to car test. The data from this additional test is given in the appendices.

2.10 Discussion of Phase 1 Tests

One major outcome of the Phase 1 tests was the recognition that the time histories for both vehicle dummy responses were quite different between the car to car test and the car into deformable barrier tests. Figures 2.3 and 2.4 show the time histories for the resultant B-pillar decelerations and resultant head accelerations respectively for the vehicles tested in Phase 1.

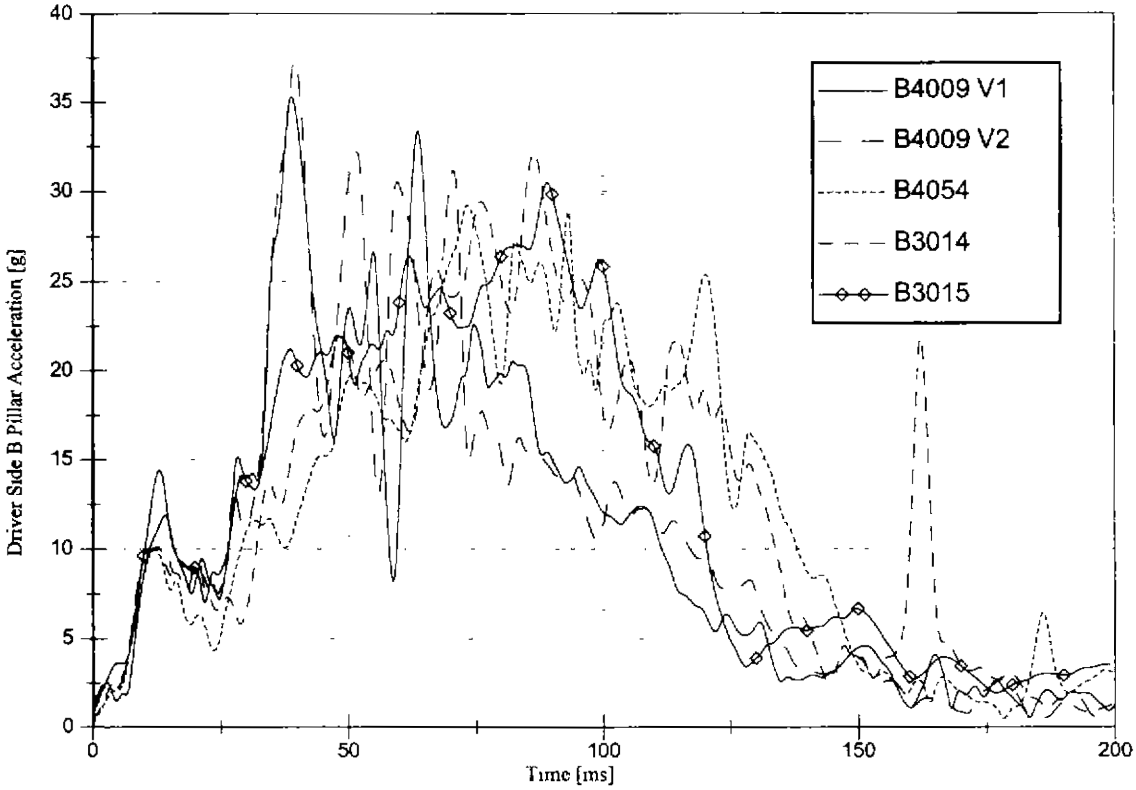

Figure 2.3 – B Pillar Accelerations, Phase 1

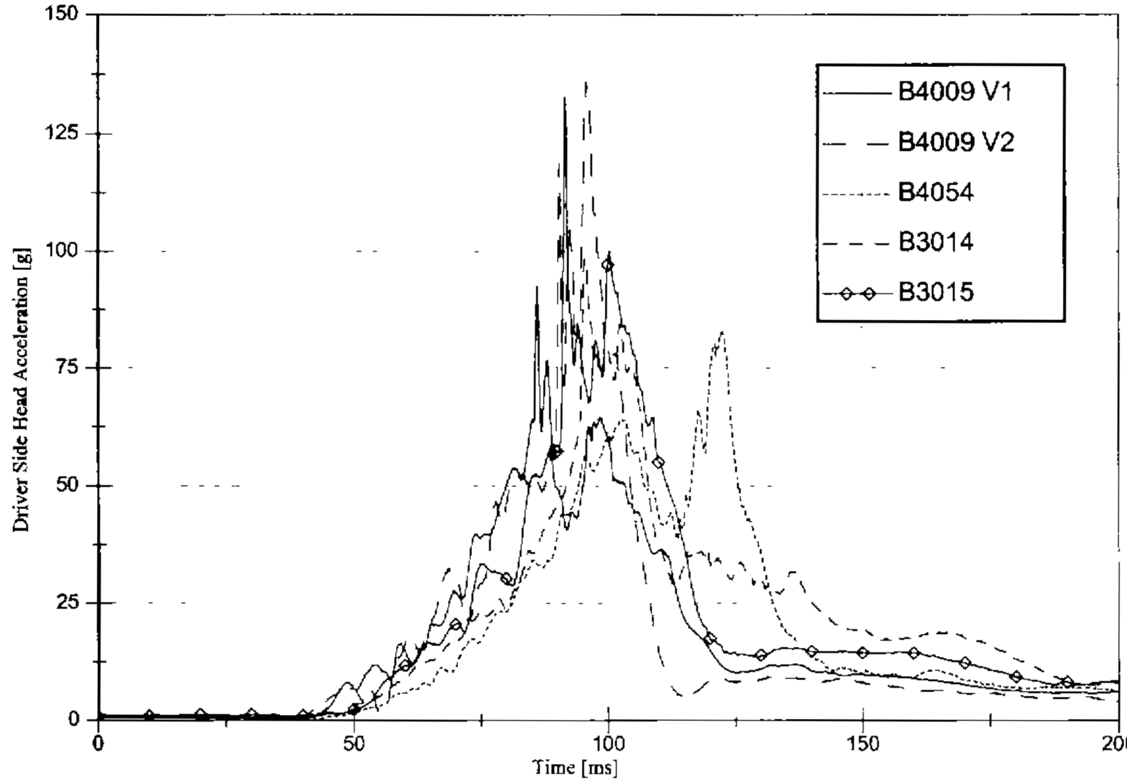

Figure 2.4 – Driver Head Accelerations, Phase 1

2.10.1 Vehicle Crash Response

During the initial 10 - 15 msec of contact, the B-pillar time histories show that the deformable barrier generally reproduces the crush sequence seen in the car to car test.

As the front structure crushes in the car to car test and engages the engine, there is a second peak of about 35g at around 40 msec.

However, in the deformable barrier test, the engagement of the engine produces a gradual rise in the B-pillar deceleration as the homogeneous honeycomb continues to crush to a peak of under 30g at around 80 msec.

Examination of the top engine transducers shows an initial peak of about 40-50 g at around 25 to 30 msec for the deformable barrier test. However, the corresponding decelerations for the car to car test occur at a similar time (30 msec) but at a significantly higher level of 95 to 100g due to the engine blocks engaging. It is interesting to note that in the car to car test there is a positive acceleration peak of about 20g at about 45 msec which is probably the engines engaging the firewall. This positive peak is not seen in the deformable barrier tests.

Chapter 3 contains a comparison with the results of the car to car test using LHD Corollas.

2.10.2 Dummy Response

The differences in vehicle response between the car to car test and the deformable barrier test are also reflected in the dummy responses.

The head resultant accelerations of the dummies in the car to car test show an earlier onset and higher peak level than those of the deformable barrier test.

The chest decelerations again exhibit the earlier onset in the car to car test, although the ultimate peak decelerations are similar to the deformable barrier tests.

Examination of the lower limb dummy responses showed that the ankle transducers again indicated earlier onset and higher peaks with the car to car test than the deformable barrier test.

In the car to car test, the driver dummy's knee transducers showed more potential for injury for the left leg than the corresponding results for the deformable barrier test. The results for the right knee were similar for both car to car and deformable barrier tests.

2.11 Outcome of Phase 1 Tests

The results of the Phase 1 tests on RHD vehicles indicated that the EEVC deformable barrier did not reproduce the vehicle and dummy kinematics for the drivetrain configuration found in the test vehicle. Further tests were conducted in Phase 2 to evaluate the effects of drivetrain configuration.

3 PHASE 2 - EXAMINING THE EFFECT OF DRIVETRAIN SYMMETRY

3.1 Introduction

The EEVC test program used one small and one medium sized left hand drive transverse engined car model with the gearbox on the driver's side. The FORS test program used one small right hand drive model with the same drivetrain configuration which meant that the engine was on the driver's side.

Based on their test program, the EEVC appeared reasonably assured that the deformable barrier design provided vehicle crush characteristics and dummy kinematics similar to those recorded in car to car tests of the same vehicle model.

However, the FORS Corolla tests indicated that the deformation characteristics, deceleration and dummy readings were significantly different between the car to car test and the car to deformable barrier test. This posed the question of whether the bridging effect of the engine to the firewall significantly affected the test outcome using the proposed test procedure.

To examine this, Toyota was requested to assist in determining how best to obtain three left hand drive Corollas for a second series of tests. Firstly, a parts list was prepared to determine what changes were required to convert a RHD Corolla to LHD. This indicated that the cutting and rewelding of structural members would be required. Therefore, it was decided that it would be more appropriate to obtain European specification LHD Corollas than to try and convert RHD Australian specification vehicles to LHD.

Phase 2 of the program consisted of the following tests:

- 50% overlap car to car test with each car travelling at 50 km/h (B5020).
- 40% overlap deformable barrier test at 60 km/h (B6026).

The car to car test was conducted first and compared with the outcome of the RHD car to car test before proceeding with the deformable barrier test.

3.2 Test Procedure

The crash tests were conducted at New South Wales Road and Traffic Authority Crashlab facilities under contract to the Federal Office of Road Safety. A description of the facility and the data acquisition equipment is provided at **Appendix 1**.

The vehicle and dummy instrumentation set-up is given in the following sections.

3.3 Test Vehicles

All three LHD Corollas were purchased on behalf of the Federal Office of Road Safety by Toyota Germany to match the Australian specification vehicles as closely as possible. All the vehicles had traceable histories and none had any accident damage or corrosion. The test vehicle data sheets are provided in **Appendix 2**.

3.3.1 Vehicle Preparation

The main differences between the LHD and RHD vehicles were:

- One of the LHD cars was fitted with a front anti-sway bar. The bar attaches to the lower control arm and is mounted on the chassis using a bracket which also attaches the rear of the lower control arm to the chassis. This bracket appears to be of a similar design whether a bar is fitted or not. As this area is subject to considerable forces and can affect floorpan intrusion, it was decided to remove the anti-sway bar.

- The LHD cars were fitted with a larger capacity battery which is wider and taller and also necessitates a different mounting bracket. As the different sized batteries (mounted on the LHS) may have had some effect on the crush resistance in that area, it was decided to replace the battery with the smaller unit used in the RHD cars together with the associated brackets.

- The intake manifold in the LHD cars have a slightly lower plenum chamber and induction tubes which are slightly different in shape to those in the RHD cars. The intake manifold is offset to the right of the car and is unlikely to engage fully with the firewall in the LHD offset test. The throttle bodies, air filter and other plumbing on the left of the cars are identical. The slightly different intake manifolds are unlikely to affect crash performance in the LHD car to car test and were not changed.

- The bumper facias are slightly different but are sufficiently resilient to not affect crash performance. Neither front bumpers have any solid reinforcements behind the plastic fascia. The bumper brackets are also slightly different to accommodate the different fascias but are made from fairly thin gauge pressed metal and were considered unlikely to affect crash performance and were not changed.

- The LHD cars have a 3 speed auto while the RHD cars are a 4 speed. The transmission housings have the same approximate dimensions. The differential housings are slightly different castings but similar in size and were considered unlikely to affect crash performance and were not changed.

- The steering wheels appeared similar although the hubs have different logos on them - Toyota on the LHD and Corolla on the RHD. Since the steering wheels were probably made in different factories, its was decided to replace them with Australian specification units (made by Bridgestone).

- The LHD cars do not have intrusion beams in the doors. These were replaced with Australian specification doors.

- The LHD cars had adjustable upper torso anchorage points. The centre position corresponded to the fixed anchorage point on the RHD cars and this was used for the anchorage position for the tests.

- The front seat belt assemblies were replaced.

- The LHD cars had 13 inch wheels and tyres. These were replaced by 14 inch wheels and tyres as fitted to Australian specification cars.

- The LHD cars were not fitted with air conditioning. Since the condenser is aluminium, it was considered that this would not have any effect on crush resistance. In addition, the compressor is mounted on the right hand side and was considered unlikely to be engaged during the test (this was confirmed post test).

3.3.2 Vehicle Instrumentation

By the time this series of tests were conducted, the test facility had expanded its data acquisition capability. Therefore, it was possible to instrument the vehicles similarly for both the car to car and deformable barrier tests.

Single axis accelerometers were placed at the following points on the test vehicles:

- left and right side of top and bottom of engine
- left and right on top of the suspension towers
- left and right on the interior side of the firewall where the front longitudinals join

The above locations were chosen to give an indication of the load path in the vehicle structure during the crash sequence.

Triaxial accelerometers were installed on the rocker panel just behind the B-pillar. This position provides the overall vehicle deceleration pulse.

3.4 Test Dummies

Hybrid III dummies were installed in each front seating position and restrained by the vehicle's lap sash seat belts. The dummies were positioned in accordance with ADR 69 (same as FMVSS 208). **Appendix 3** provides the positioning measurements. Injury measures were calculated as described at §2.5 and are reported in **Appendix 5**.

The vehicles and dummies were soaked in a climatically controlled preparation shed and a record of temperature and humidity kept.

Chalk solutions of contrasting colours were painted onto the dummies' face to mark contact points with the vehicle interior.

3.4.1 Deformable Barrier Test

The driver dummy was fitted with all available instrumentation except neck F_Y, M_X and M_Z, upper tibia M_X and lower tibia F_Y and M_X (see §2.4.1). Passenger dummies were not fitted with neck F_Y, M_X, M_Z or tibia instrumentation.

The dummies were fully calibrated before each test. The instrumented lower limbs were calibrated by the manufacturer in the USA prior to the test series.

3.4.2 Car to Car Test

Neither passenger dummy was instrumented.

Driver dummies were fitted with all available instrumentation except neck F_Y, M_X and M_Z, upper tibia M_X and lower tibia F_X, F_Y and M_X.

3.5 Deformable Barrier Face

A deformable barrier face using 50 psi compression aluminium honeycomb with a bumper element on the front face consisting of three strips of 250 psi aluminium honeycomb running the full width of the barrier face, 90 mm deep and 110 mm high. The barrier was mounted 200 mm above the ground (see Chapter 2, Figure 2.2). The barrier was purchased certified from Cellbond in the UK and conformed to the specification being used by EEVC contractors.

3.6 Photography

For the deformable barrier tests, there were off-board high speed cameras placed on the left and right hand side, overhead, underneath in the camera pit, and oblique on the left hand side.

For the deformable barrier test, one on-board camera was fitted to each of the front doors to track lower limb kinematics. In addition, another camera was placed on the inside towards the rear of the car to record the overall dummy kinematics from the rear.

For the car to car test, there was only one on-board camera in each vehicle and this was fitted to the driver's door.

Pre-test still photographs were taken of both vehicle and dummy positioning. The same sequence of photographs were taken post-test to show vehicle deformation and dummy contact points with the vehicle's interior. The pre and post test photographs are provided in **Appendix 8**.

3.7 Phase 2 Results

Vehicle deformation measurements are provided in **Appendix 4**. The dummy results of the tests are summarised in **Appendix 5**. The vehicle crash pulses are provided in **Appendix 6**.

3.7.1 Car to Car Test

On examination of the vehicles after the LHD car to car test, the following points were noted:

- The engines rotated slightly forward (around the crankshaft axis). This compares with the RHD car to car test where the engines stayed fairly horizontal with a slight rotation rearwards.
- Both driver's lower legs were jammed between the intruded floorpan and dashboard.
- Cars appear to have rotated slightly more than the RHD cars.
- Dummy trajectory appears to be slightly more outward.
- Both dashboards moved up so that the steering wheels rotated to a more horizontal position. This was more prominent on Vehicle 1.
- Sill at the bottom of the A pillar has failed in compression. On the RHD cars, the sill failed in buckling and further back (about 1/3 the distance towards the B pillar).
- More passenger compartment intrusion than on the RHD cars.
- HPCs were 1111 for the red car coming from the prep shed and 1030 for the grey car coming from the barrier. This compares with 675 and 1174 for the RHD cars.
- The deformation of the two LHD cars were fairly similar whereas the degree of deformation of the RHD cars was quite different.
- The peak firewall decelerations for the two LHD cars were 91g and 130g.
- Vehicle 1 had the driver (left) door beam separate from the front of the door and the door outer skin also separated. The roof cant rail started to peel the welds apart. The consequence of all these factors was slightly more upper level intrusion than Vehicle 2.

3.7.2 Deformable Barrier Test

The offset deformable barrier test had to be repeated because of data acquisition problems in the initial test.

The results indicated the following:

- The engine rotated slightly forward around the crankshaft axis.
- Both driver dummy's legs were jammed between the intruded floorpan and the dashboard. However, the dummy was slightly easier to remove than those in the car to car test.
- The sill panel popped its spotwelds and began to fail in compression slightly more towards the B-pillar than in the car to car test.
- LHD car seems to have rotated less than the RHD car.
- HPC was 1524 for the driver and 817 for the passenger.
- Peak deceleration at the firewall was 81g at 61 msec.

3.8 Discussion of Phase 2 Results

3.8.1 Car to Car Test

Figure 3.1 shows the B-pillar time histories for the RHD and LHD car to car tests overlaid on each other. It can be seen that the crash pulse for each of the RHD cars are similar, as are the pulses for the LHD cars.

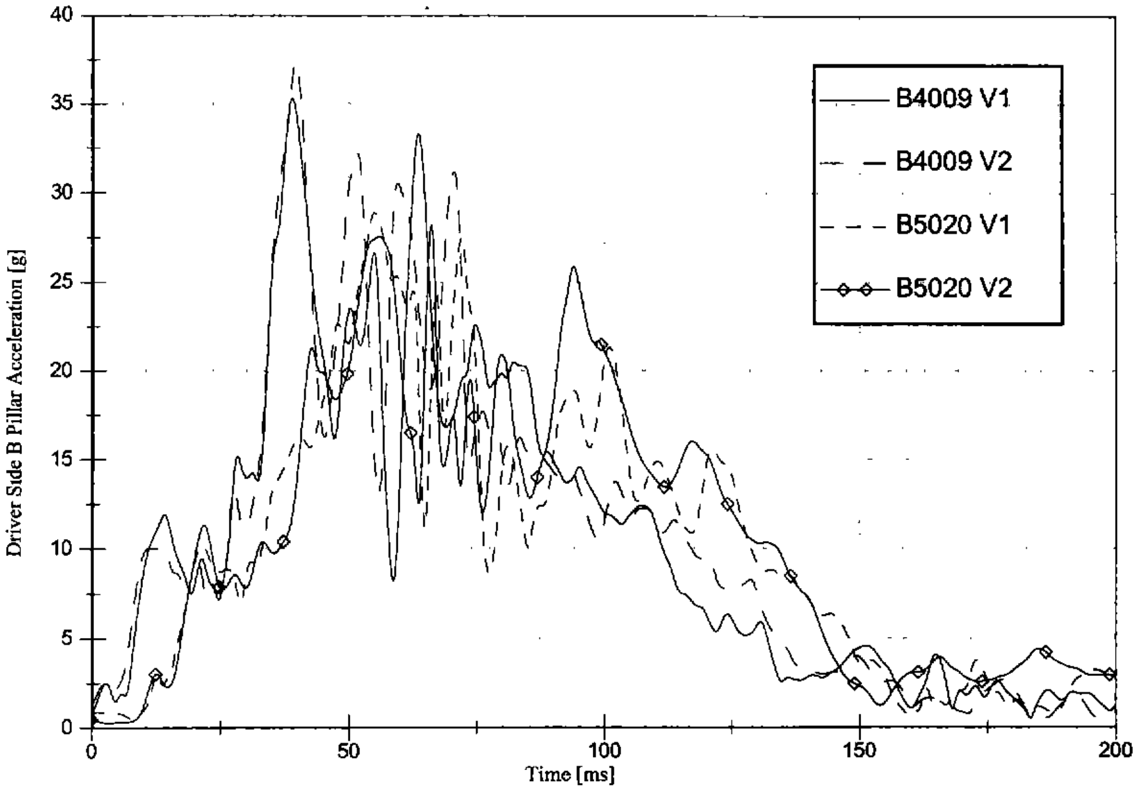

Figure 3.1 - B Pillar Accelerations, Car to Car

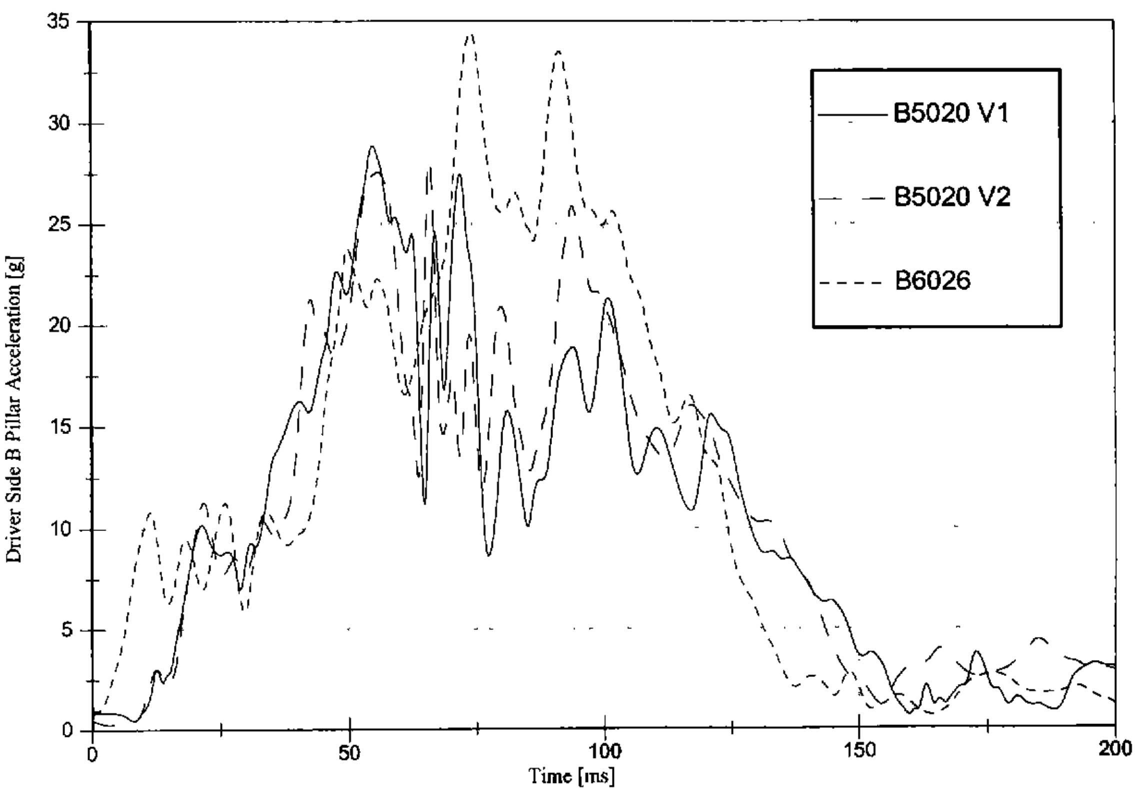

Figure 3.2 - B Pillar Accelerations, LHD Car to Car and Deformable Barrier

The following observations can be made when the RHD and LHD pulses are compared:

- Without the engine bridging effect on the RHD vehicle, the LHD pulse has a more gradual onset.
- The LHD cars have a lower vehicle peak deceleration of about 28g compared to 36g for the RHD cars.
- The LHD cars peak occurs at 56 msec whereas the RHD cars peak at 40 msec.
- The LHD cars exhibit a higher level of deceleration for longer than the RHD cars after this peak. This behaviour resembles that observed in the deformable barrier tests of the LHD cars using a homogeneous main honeycomb block. This can be seen in Figure 3.2.
- The results confirm that for offset frontal impacts, drivetrain and structural symmetry are important parameters to be considered when selection of representative test vehicles are made.

The deformation characteristics of the LHD cars indicates that without the bridging effect of the engine onto the firewall seen in the RHD cars, the front longitudinal, A-pillar and sill are required to dissipate more energy.

The result is noticeably more passenger compartment intrusion resulting from different load paths, and increased injury levels recorded by the dummies.

3.8.2 Deformable Barrier Test

Figure 3.3 shows the B-pillar time histories for the LHD and RHD offset deformable barrier tests overlaid. The following observations can be made when the RHD and LHD pulses are compared:

- The RHD pulse has a slightly more gradual onset than the LHD car.
- Peak vehicle decelerations were higher for the LHD car.
- Peak firewall decelerations were higher for the LHD car (81g versus 50g) indicating higher load transfer to the LHD car's structure.
- There was less rotation of the LHD car.
- Driver HPC was 1524 for the LHD car and 825 for the RHD car (B4054).

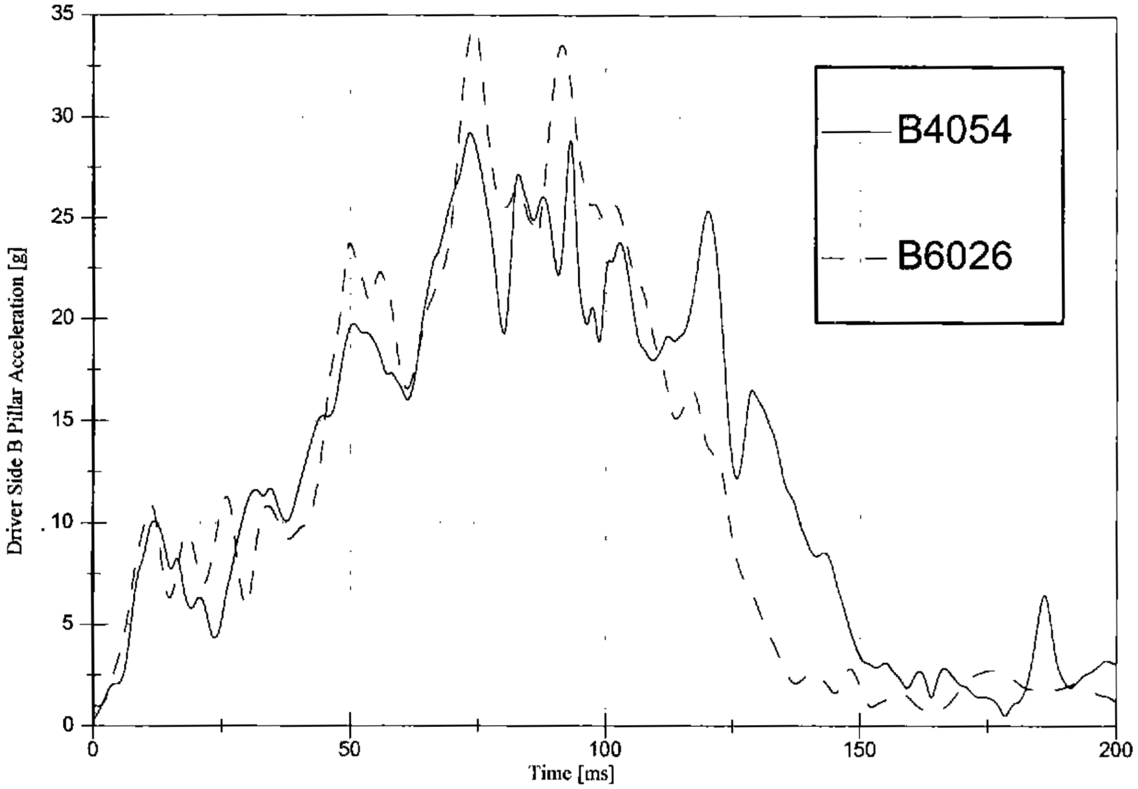

Figure 3.3 - B Pillar Accelerations, Offset Deformable Barrier

3.8.3 Summary

Both the LHD deformable barrier test and LHD car to car test gave higher injury readings than the corresponding RHD tests.

The load onset and dummy kinematics of the LHD deformable barrier test correlates well with the LHD car to car tests.

RHD and LHD results are not comparable in vehicles having an asymmetric drivetrain, eg front engined with engine offset to one side.

4 PHASE 3 - CAR TO CAR AND DEFORMABLE BARRIER TESTS USING FORD LASER LIATA

4.1 Introduction

There was some concern with some members of the EEVC WG11 that the test series based on the Toyota Corolla may result in an outcome that was vehicle specific.

For this reason, it was decided to conduct a car to car crash using the Toyota Corolla impacting a 1995 Ford Laser Liata (B5019). This would allow comparison of the Corolla's vehicle and dummy response in car to car tests where it runs into itself and also into another vehicle model in the same weight class.

The Ford Laser Liata was also subject to an offset deformable barrier test using the barrier described in Chapter 2 Figure 2.2 by the Australian New Car Assessment Program (B5008). As FORS has no direct affiliation with NCAP, their technical committee was approached in relation to purchasing the crash test data for the Laser offset deformable barrier test. This would then provide another vehicle model to compare the vehicle and dummy responses of a car to car test against an offset deformable barrier test.

This section deals with the outcome of this work.

4.2 Test Procedure

The crash tests were conducted at New South Wales Road and Traffic Authority Crashlab facilities under contract to the Federal Office of Road Safety. A description of the facility and the data acquisition equipment is provided at **Appendix 1**.

Because the crash facility had limited data acquisition capability, it was necessary to compromise with the car to car test in not having both dummies and vehicles fully instrumented.

The car to car test was done at 50% overlap with both cars travelling at 50 km/h.

The NCAP car to deformable barrier test was conducted at 40% overlap and a speed of 60 km/h using a test procedure closely matching the draft EEVC protocol.

4.3 Test Vehicles

One of the test vehicles used was a 1993 Toyota Corolla Liftback fitted with power steering, air conditioning, and automatic transmission. The test vehicle was purchased second-hand from government fleets since that model of Toyota Corolla had been superseded. The test vehicle had a completely traceable history and did not have any accident damage. The test vehicle data sheets are provided in **Appendix 2**.

The Ford Laser Liata LXi Hatchback was purchased new under normal procedures through the government fleet contract. The vehicle was fitted with power steering, and automatic transmission. To match the specification of the NCAP test vehicle, air conditioning was not fitted.

Both vehicles were right hand drive cars, front wheel drive with the engine offset to the right (driver's) side.

Underbody components on the front of the vehicle were painted contrasting colours to facilitate analysis of vehicle deformation.

Each vehicle was weighed on delivery to the test facility and ballasted to the mass specified in Clause 6.1 of ADR 69/00 which includes dummies and test equipment. The test mass of the vehicles used in the Phase 4 test series were:

- Toyota Corolla 1323 kg
- Ford Laser 1387 kg

4.4 Test Vehicle Instrumentation

Both the vehicles were instrumented similarly. Single axis accelerometers were placed at the following points on the test vehicles

- left and right side of top and bottom of engine
- left and right on top of the suspension towers
- left and right on the interior side of the firewall where the front longitudinals join

The above locations were chosen to give an indication of the load path in the vehicle structure during the crash sequence.

Triaxial accelerometers were installed on the rocker panel just behind the B-pillar. This position provides the overall vehicle deceleration pulse.

4.5 Test Dummies

Hybrid III dummies were installed in each front seating position and restrained by the vehicle's lap sash seat belts. The dummies were positioned in accordance with ADR 69 (same as FMVSS 208). **Appendix 3** provides the positioning measurements. Injury measures were calculated as described at §2.5 and are reported in **Appendix 5**.

The vehicles and dummies were soaked in a climatically controlled preparation shed and a record of temperature and humidity kept.

Chalk solutions of contrasting colours were painted onto the dummies' face to mark contact points with the vehicle interior.

4.5.1 Deformable Barrier Test

The driver dummy was fitted with all available instrumentation except neck F_Y, M_X and M_Z, pelvis, upper tibia M_X and lower tibia F_Y and M_X (see §2.4.1). Passenger dummies were not fitted with neck F_Y, M_X, M_Z, pelvis, femur or tibia instrumentation.

The dummies were fully calibrated before each test.

4.5.2 Car to Car Test

Neither passenger dummy was instrumented.

Driver dummies were fitted with all available instrumentation except neck F_Y, M_X and M_Z, upper tibia M_X and lower tibia F_X, F_Y and M_X.

4.6 Photography

Off-board high speed cameras placed on the left and right hand side, and overhead, underneath in the camera pit.

There was only one on-board camera in each vehicle and this was fitted to the driver's door.

Pre-test still photographs were taken of both vehicle and dummy positioning. The same sequence of photographs were taken post-test to show vehicle deformation and dummy contact points with the vehicle's interior. The pre and post test photographs are provided in **Appendix 8**.

4.7 Phase 3 Test Results

Vehicle deformation measurements are provided in **Appendix 4**. The dummy results of the tests are summarised in **Appendix 5**. The vehicle crash pulses are provided in **Appendix 6**.

The Laser has a very stiff crossmember tying the front longitudinals together. The bottom of it is 180 mm off the ground and it is 30 mm thick. This seems to have under-ridden the deformable barrier in the NCAP test(B5008). However, in the car to car test this crossmember and the longitudinal have engaged with the Corolla's longitudinal.

Both cars in the car to car test had crash pulses with a double peak with earlier onset than the deformable barrier test.

The following table summarises the differences for each car when the outcome of the Corolla/Laser car to car test is compared to that of each car into the current draft offset deformable barrier at 40% overlap at 60 km/h :

Corolla	**Laser**
Car to car test deformation significantly greater	Car to car test deformation slightly greater
Car to car test HPC greater (1460 vs 900)	Car to car test HPC LESS (750 vs 1350)
Front structure collapse similar for both car to car and car into deformable barrier	Front longitudinal punched hole in barrier and engine stayed relatively level while the longitudinal collapsed and engine rotated upwards in car to car test. The car into deformable barrier test appears to have caused more lower level crush and less upper level crush indicating different load paths.

4.8 Discussion of Phase 3 Results

In the RHD car to car tests, the vehicle and dummy kinematics of the Corolla are similar irrespective of whether the other test car is also a Corolla or a different vehicle, in this case a Ford Laser. The engine on both models is offset to the driver's side.

For both the Corolla and the Laser, the EEVC offset deformable barrier does not produce the same vehicle or dummy kinematics as the car to car crash of the Corolla into the Laser or the Corolla into itself.

The outcome of Phase 3 supports the proposition that the vehicle and dummy response characteristics are not vehicle specific.

However, the outcomes of the first 3 phases also suggests that drivetrain configuration on the transverse front engined vehicles has a significant bearing on the dummy and vehicle responses in a car to car crash.

The Phase 2 results indicated that the EEVC offset deformable barrier with the bumper element provided a vehicle and dummy response generally replicating the car to car test when the LHD Corollas were tested. However, the same tests with RHD Corollas did not exhibit this correlation.

The vehicles and dummies were soaked in a climatically controlled preparation shed and a record of temperature and humidity kept.

Chalk solutions of contrasting colours were painted onto the dummies' face to mark contact points with the vehicle interior.

The driver dummy was fitted with all available instrumentation except neck F_Y, M_X and M_Z, pelvis, upper tibia M_X and lower tibia F_Y and M_X (see §2.4.1). Passenger dummies were not fitted with neck F_Y, M_X, M_Z or tibia instrumentation.

The dummies were fully calibrated before each test.

5.5 Deformable Barrier Face

The first test (B5021) used a deformable barrier face consisting of a 50 psi compression aluminium honeycomb main core with an inserted core of 250 psi honeycomb at the rear. The barrier was mounted 200 mm above the ground. The barrier is described in figure 5.1.

The second test (B5028) used a deformable barrier face consisting of a 65 psi compression aluminium honeycomb main core with an inserted core of 155 psi honeycomb at the rear. The barrier was mounted 200 mm above the ground. The barrier is described in figure 5.2.

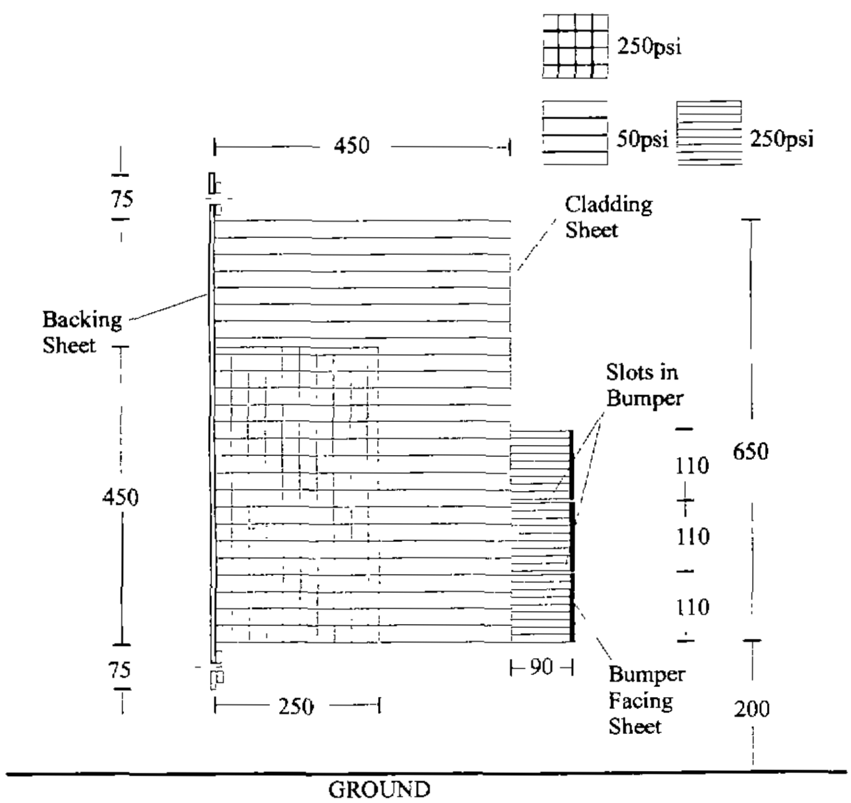

Figure 5.1 - Modified deformable barrier, B5021

Both barriers had the 3 element bumper at the front. The barriers were purchased certified from Cellbond in the UK. The deformable face was mounted on the test facility's rigid offset barrier. This rigid barrier had a round edge of 150 mm radius. The edge of the deformable barrier was mounted with its end at the start of round edge.

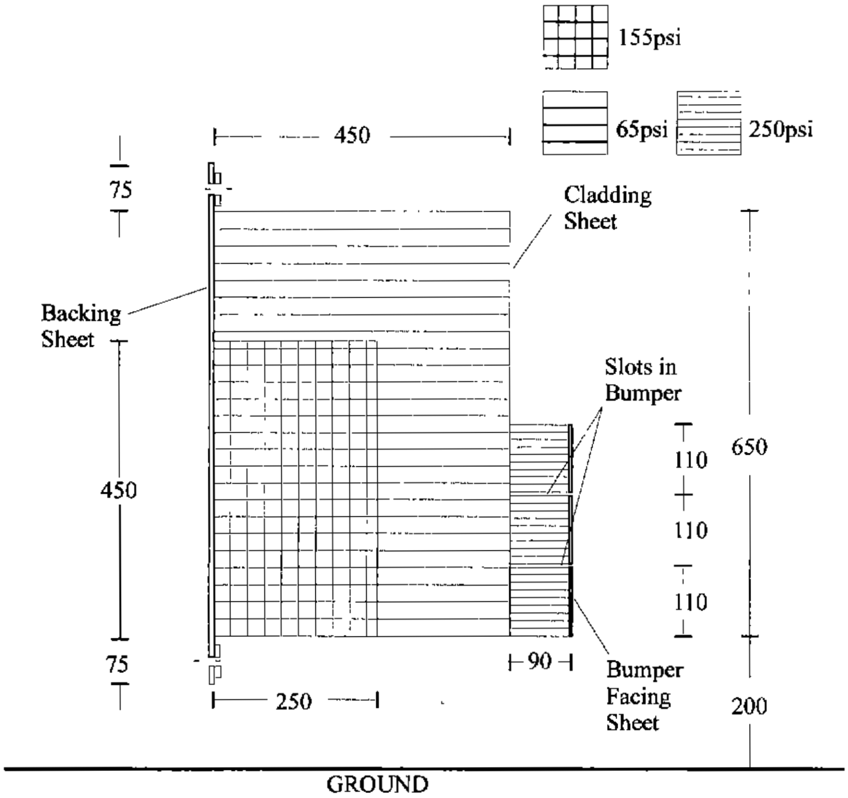

Figure 5.2 - Modified deformable barrier, B5028

5.6 Photography

Off-board high speed cameras were placed on the left and right hand side, overhead, and underneath in the camera pit.

There was only one on-board camera in each vehicle and this was fitted to the driver's door.

Pre-test still photographs were taken of both vehicle and dummy positioning. The same sequence of photographs were taken post-test to show vehicle deformation and dummy contact points with the vehicle's interior. The pre and post test photographs are provided in **Appendix 8**.

This difference could be explained by the EEVC barrier's homogeneous main core of 50 psi honeycomb. This should closely replicate the LHD vehicle's generally homogeneous structure because the engine was not on that side.

For this reason, the Phase 4 tests were conducted to examine whether an inserted core at the rear of the deformable barrier could reproduce the vehicle and dummy response characteristics seen in the RHD car to car tests.

5 PHASE 4 - TESTS USING MODIFIED DEFORMABLE BARRIERS

5.1 Introduction

The Phase 1 RHD Corolla tests indicated that the deformation characteristics, deceleration and dummy readings were significantly different between the car to car test and the car to EEVC offset deformable barrier test. The LHD test series reported in Chapter 3 indicated that the EEVC offset deformable barrier appeared to correlate reasonably well with the LHD Corolla car to car test.

This indicated that when the engine is offset to the driver's side in a car to car crash the engagement of the engines result in a significantly different response than that obtained when the engine is not engaged.

This posed the question of whether the deformable barrier could be modified to replicate this engine engagement and the subsequent bridging effect of the engine to the firewall.

To examine this, two offset deformable barrier tests were conducted using a modified barrier design.

5.2 Test Procedure

The crash tests were conducted at New South Wales Road and Traffic Authority Crashlab facilities under contract to the Federal Office of Road Safety. A description of the facility and the data acquisition equipment is provided at **Appendix 1**.

The vehicle and dummy instrumentation set-up is given in the following sections.

5.3 Test Vehicles

These test vehicles were purchased second-hand from government fleets since that model of Toyota Corolla had been superseded. All test vehicles had completely traceable histories and none had any accident damage. The test vehicle data sheets are provided in **Appendix 2**.

The vehicles were prepared according to the procedures outlined in section 2.3.

5.4 Test Dummies

Hybrid III dummies were installed in each front seating position and restrained by the vehicle's lap sash seat belts. The dummies were positioned in accordance with ADR 69 (same as FMVSS 208). **Appendix 3** provides the positioning measurements. Injury measures were calculated as described at §2.5 and are reported in **Appendix 5**.

5.7 Phase 4 Test Results

Vehicle deformation measurements are provided in **Appendix 4**. The dummy results of the tests are summarised in **Appendix 5**. The vehicle crash pulses are provided in **Appendix 6**.

5.7.1 First Test (B5021)

The first test used the deformable barrier face described in Figure 5.1. The test was conducted at 60 km/h at 40% overlap.

The first test resulted in severe collapse of the passenger compartment which required the driver dummy's legs to be unbolted before the dummy could be removed. The injury data were much higher than for the car to car test. However, the vehicle and dummy responses were now better aligned with that seen in the car to car crash. The inserted core showed very little crush. However, the initial crush phase through the 50 psi honeycomb was still more gradual than the car to car pulse. This indicated that the combination of speed and/or barrier stiffness was still not correct.

5.7.2 Second Test (B5028)

The second test used the deformable barrier face described in Figure 5.2. The second test was conducted at 55 km/h at 40% overlap. The 65 psi honeycomb was chosen to try and address the gradual onset in the initial crush phase.

The second test provided vehicle deformations similar to the car to car test and dummy data about half way between the outcomes of the two cars in the car to car test. The 65 psi honeycomb did not appear to address the "soft" initial crush. However, there was more crush of the inserted core. In addition, the front of the vehicle appeared more like the car to car test without the centre "notch" seen with the 50 psi homogeneous barrier face.

5.8 Discussion of Phase 4 Results

Researchers in Europe have conducted some tests using modified deformable barriers of varying designs. It was found that different barrier elements produced a better match to certain car to car tests and not to others. It was agreed at the EEVC WG 11 meeting at the end of 1995 that the delay in defining a modified barrier design was unacceptable.

As a result, a two stage approach was agreed to:

- Proceed with a regulation using the finalised EEVC test procedure using a homogeneous 50 psi compression barrier element with a 3 stage 250 psi compression bumper.
- Do further work to refine the vehicle test speed and barrier design as a second stage to the regulation for implementation in the next century.

6 BENEFITS OF AN OFFSET FRONTAL CRASH STANDARD

6.1 Introduction

Australian vehicles are currently required to meet Australian Design Rule ADR 69 which specifies head, chest and femur dummy criteria in a dynamic full frontal crash test at 48km/h. This is based on the US regulation FMVSS 208 with the added allowance for the test dummies to be restrained by seat belts.

The European road safety community has been working towards developing a dynamic frontal offset standard to be mandated for all passenger cars towards the end of 1998. The Federal Office of Road Safety has been participating in this work with a view to adopting this new regulation if there were sufficient benefits to Australian motorists in addition to ADR 69 and whether they would be cost-effective.

The Monash University Accident Research Centre (MUARC) was commissioned by FORS to determine the likely benefits. The tasks included an examination of the pattern of injuries sustained in offset compared with full frontals as well as a Harm analysis to calculate the likely benefits of the proposed EEVC offset requirement.

6.2 Proposed European Offset Standard

The proposed EEVC offset requirement specifies a range of head, neck, chest, femur and lower leg criteria for two Hybrid III test dummies situated in the front seat of a passenger car impacting a deformable face fixed barrier offset 40% on the driver's side at an impact speed of 56 km/h.

The injury criteria specified for the dummies are more comprehensive than those currently applying in ADR 69 or FMVSS 208 and importantly includes lower leg injury criteria. This is really a first and an important breakthrough for occupant protection. A number of studies have reported lower leg injuries are frequent in frontal crashes and while not necessarily life threatening, nevertheless, are often disabling and extremely painful requiring considerable rehabilitation and very costly to the community in general.

In addition to lower limb criteria, the proposed EEVC offset requirement also includes neck injury criteria and more comprehensive head and chest requirements. Moreover, the standard is likely to lead to structural improvements in cabin integrity which will benefit car occupants.

6.3 Injuries in Offset Crashes

The first task undertaken was an analysis of the Crashed Vehicle File at MUARC, a database containing details of over 500 crashes and 600 hospitalised passenger car occupants. Of these, 215 were frontal crashes where the driver sustained a lower leg injury, roughly equally divided between full frontal and offset configurations.

The analysis revealed that the outcome for drivers involved in near-side offset collisions was considerably worse than for equivalent full frontal drivers. They sustained more severe injuries, especially to the lower torso and the legs than their counterparts in full frontal crashes and, on average, at lower impact speeds. This was not a function of differences in seat belt wearing rates but did appear to be influenced slightly by the type of car they were travelling in.

Lower limb injuries and severe injuries to the upper limbs seem to be areas requiring particular attention in near-side offset collisions (that is, when the offset crash was on the same side of the vehicle as the driver). Reduced intrusion inside the passenger compartment by the steering column, instrument panel, A-pillar and floor and toepan need greater emphasis in near-side offset frontal crashes for drivers.

6.4 Estimating Injury Reductions

As there were no injury data available and very few test results, an expert panel was formed comprising international specialists from vehicle manufacturing, research organisations, and government agencies responsible for vehicle safety.

From a one-day workshop held in Washington DC in December 1995, a number of assumptions were developed on which to calculate the likely injury reductions of the offset standard by body region. The expert panel were unanimous in their view that the benefits would be derived from three sources, namely from a general improvement in structural integrity (the so-called universal benefit), from a greater use of driver side airbags, and from specific countermeasures to address particular injuries such as those to the lower legs.

It was especially noteworthy that there was a high degree of consensus among the expert panel of the need for such a standard and likely injury reductions that would accrue. There was also a strong call from many of these organisations for a single worldwide offset standard to ensure the best possible outcome for vehicle occupants.

6.5 The Harm Reduction Method

A Harm analysis was then performed using these assumptions as a basis for calculating the likely Harm saved by the EEVC proposed offset standard. The Harm Reduction method developed by the Monash University Accident Research Centre in conjunction with Dr. Kennerly Digges for previous benefit studies was again used here.

The national Harm database developed previously (eg; Monash University Accident Research Centre, 1992; Fildes, Digges, Carr, Dyte & Vulcan 1995) was the basis for calculating the benefits of the proposed EEVC offset standard. Allowances were made for subsequent vehicle safety improvements such as ADR 69 in arriving at these benefits.

Analysis by body region was undertaken using a 3-step cascading model. Harm saved from the universal benefit was first deducted, followed by increase in airbag usage (up to 100%) and finally specific countermeasure benefits. Given that the likely usage rate of driver airbags in 1998 was unknown, these benefits were calculated for a range of possible usage rates from 70% to 100%.

6.6 Benefits of an Offset Standard

The benefits of adopting the proposed EEVC offset standard were expressed as both the annual Harm saved assuming all vehicles in the fleet were compliant as well as the unit Harm benefits per car across its lifetime. In computing unit Harm benefits, 5% and 7% discount rates were employed for 15 year and 25 year life of the vehicle periods.

6.6.1 Annual Harm Benefits

The annual Harm reduction that would accrue from the offset standard in addition to that achieved from ADR 69 was estimated to be at least A$297 million (a 15% reduction in frontal Harm) and at best, A$460 million (a 23% reduction in frontal Harm). The full benefits would apply when all vehicles in the fleet complied with both standards.

6.6.2 Unit Harm Benefits

Unit Harm benefits (the average savings per car across its lifetime) were then calculated using 5% and 7% discount rates and life of the vehicle periods of 15 and 25 years. These calculations showed that unit Harm savings from adopting the EEVC offset requirement would be somewhere between A$296 and A$576 per car. Therefore, the break-even cost for having to meet such a requirement is likely to be somewhere in this range.

It should be noted that the most conservative estimate was for a 15% reduction in frontal Harm attributed directly to this standard assuming no benefit from increased airbag use. This would seem to be a worthwhile improvement in occupant protection alone. The minimum break-even cost to achieve this benefit would be A$296 per vehicle which seems feasible in light of industry estimates which suggest a A$100 additional cost for achieving the side impact standard improvements outlined in Fildes et al, (1995).

6.7 Conclusion

On the basis of the benefits study, it would seem desirable for Australia to consider introducing an offset frontal crash standard similar to that being proposed in Europe.

The benefits likely to accrue would be somewhere between A$297 million and A$460 million annually with 100% fleet compliance. The break-even cost per car across its lifetime would be on average from A$296 to A$576.

This finding is conditional on all aspects of the EEVC proposal outlined in this report and is likely to be severely compromised if any of the injury criteria were to be removed or downgraded over that currently proposed.

The full report containing the MUARC benefits analysis, *CR 165 – Benefits of a Frontal Offset Regulation*, is available from MUARC or FORS.

7 CONCLUSIONS

The following conclusions were drawn from this FORS research program:

- The offset frontal ADR will test the vehicle's structural integrity and, with lower leg injury criteria applied, the vehicle's ability to prevent debilitating leg injuries. It will also mitigate upper torso injuries resulting from reductions in occupant survival space.
- ADR 69 for full frontal impact protection will test the vehicle's restraint system in a high deceleration crash situation. This ADR will continue in parallel with an ADR on offset frontal crash protection.
- Current research indicates that a test at 40% overlap and at least 56 km/h with an offset deformable barrier face with head, chest and lower limb injury criteria is appropriate. The barrier design has not been validated for speeds higher than 60 km/h.
- The homogeneous deformable barrier face consisting of 50 psi honeycomb with a 3 element bumper of 250 psi honeycomb appears appropriate as a first stage design.
- The barrier design has been validated for passenger cars. The design has not gone through the same vigorous validation for light commercial and 4 wheel drive vehicles. Such vehicles with perimeter chassis tend to punch through deformable core and/or over-ride the bumper element.
- The design of the barrier has also not been validated for passenger cars of a large mass. Vehicles heavier than the design limit of the barrier would tend to 'bottom out' the barrier face, producing unrealistic results. ECE Regulation 94 exempts vehicles greater that 2500kg. This exemption has been carried through to the draft Australian Design Rule.
- The finalised WG 11 draft test procedure is a significant first step in improving offset frontal crash protection. Therefore, a draft ADR was prepared incorporating the requirements of the finalised WG 11 draft test procedure for offset frontal crash protection.
- The Harm reduction analysis indicated that the annual benefit that would accrue from the offset standard, in addition to that achieved from ADR 69, to be at least A$297 million (a 15% reduction in frontal Harm) and at best, A$460 million (a 23% reduction in frontal Harm). The two estimates depended on the level of airbag usage.
- The draft ADR 73/00 (Appendix 7) and benefit analysis were issued for public comment during 1996. The ADR will be introduced on 1 January 2000 for passenger cars.

- As a second stage, the EEVC is doing further work on the impact speed and to ensure that the deformable barrier element specification is appropriate for asymmetric drivetrain configurations where the engine is offset to one side. This work will be part of the research on vehicle compatibility to ensure that improvements in one crash mode does not degrade safety in other crash types with different categories of vehicles.

Appendix 1 – Crash Facility Description

All crash tests were conducted at the Roads Traffic Authority Crashlab facility located in the Sydney suburb of Rosebery. This laboratory is wholly owned and operated by the New South Wales state government.
Crashlab is accredited by the National Association of Testing Authorities and holds AS 3901 accreditation.
The test contract was awarded to Crashlab following an open tender process.

Barrier

The Crashlab barrier facility is designed to comply with the requirements of Society Automotive Engineers' standard J850 "Fixed Rigid Barrier Collision Tests".
The barrier collision site is under cover and constructed from reinforced concrete at a mass of approximately 55 tonnes. Mounted on a 1.5 m concrete slab which in turn is anchored by concrete piles to the rock foundation, the barrier and foundations constitute a total mass of approximately 400 tonnes.
Leading up to the impact test area is a 145 metre precision approach track. The smoothness and flatness of the track facilitates self steering of the test vehicle and ensures the accurate positioning of the test dummies is not disturbed during the vehicle's approach to the barrier.
Located at the far end of the approach track is a test vehicle preparation shed which provides an environment controlled for temperature and humidity complying with the requirements of ADR 69/00.

Propulsion System

The vehicle propulsion system consists of a continuous tow cable driven by a 375 kW direct current electric motor. This system can accelerate the test vehicle from standstill at a pre-determined acceleration up to a specified test velocity. Maintenance of the approach acceleration and test velocity is achieved through the use of computer control up until the point of release 0.5 m from the impact surface. The primary measurement of the impact velocity is attained by measuring the tow cable velocity just prior to release while a secondary measure is taken via the use of an amphometer placed at the barrier.
Tracking control of the test vehicle while under tow is achieved by the use of a monorail guidance system. Running on this monorail system, a specially designed tow skate is used which is designed to release the test vehicle 0.5 m form the crash barrier face and detach itself from the tow cable prior to impact. This feature is used to ensure that the vehicle is no longer subject to the towing device just prior to impact.

Data Acquisition

The acquisition of crash test data is performed using a hybrid system developed by Crashlab. The capacity of the system was 64 channels at 10 kHz sampling rate, plus a further 16 channels at 8 kHz sampling rate. The full data acquisition capability was not available until part way through the testing program.

Appendix 2 – Vehicle Data Sheets

Vehicle Details:

Test Description:	RHD Corolla Offset Barrier		
Test No:	B3014		
Vehicle:	Toyota Corolla Seca		
VIN:	6T164AE9409644933	**Colour:**	White
Odometer (km):	17		
Engine:	4 cyl 1.6l Petrol	**Transmission:**	4sp Auto, Front Drive
Air Conditioning: Y	**Power Steering:** Y	**Adjustable Steering Col.**	Y
Tyres:	Bridgestone 14		
Pressure front (kPa):	180	**Rear (kPa):**	180
Seating Capacity Front:	2	**Rear:**	3
Restraints Front:	2xELR Lap Sash	**Rear:**	2xELR Lap Sash + 1xStatic Lap

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Test Description:	RHD Corolla Offset Barrier		
Test No:	B3015		
Vehicle:	Toyota Corolla Seca		
VIN:	6T164AE9409644933	**Colour:**	White
Odometer (km):	14		
Engine:	4 cyl 1.6l Petrol	**Transmission:**	4sp Auto, Front Drive
Air Conditioning: Y	**Power Steering:** Y	**Adjustable Steering Col.**	Y
Tyres:	Bridgestone 14		
Pressure front (kPa):	180	**Rear (kPa):**	180
Seating Capacity Front:	2	**Rear:**	3
Restraints Front:	2xELR Lap Sash	**Rear:**	2xELR Lap Sash + 1xStatic Lap

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Test Description:	RHD Corolla Car to Car		
Test No:	B4009 Vehicle 1		
Vehicle:	Toyota Corolla Seca CSi Limited		
VIN:	6T164AE9409646164	**Colour:**	White
Odometer (km):	13		
Engine:	4 cyl 1.6l Petrol	**Transmission:**	4sp Auto, Front Drive
Air Conditioning: Y	**Power Steering:** Y	**Adjustable Steering Col.**	Y
Tyres:	Bridgestone 175/65R14		
Pressure front (kPa):	180	**Rear (kPa):**	180
Seating Capacity Front:	2	**Rear:**	3
Restraints Front:	2xELR Lap Sash	**Rear:**	2xELR Lap Sash + 1xStatic Lap

Test Description:	RHD Corolla Car to Car		
Test No:	B4009 Vehicle 2		
Vehicle:	Toyota Corolla Seca CSi Limited		
VIN:	6T164AE9409645832	**Colour:**	White
Odometer (km):	14		
Engine:	4 cyl 1.6l Petrol	**Transmission:**	4sp Auto, Front Drive
Air Conditioning: Y	**Power Steering:** Y	**Adjustable Steering Col.**	Y
Tyres:	Bridgestone 175/65R14		
Pressure front (kPa):	180	**Rear (kPa):**	180
Seating Capacity Front:	2	**Rear:**	3
Restraints Front:	2xELR Lap Sash	**Rear:**	2xELR Lap Sash + 1xStatic Lap

Test Description:	RHD Corolla Offset Barrier		
Test No:	B4054		
Vehicle:	Toyota Corolla Seca CSi Limited		
VIN:	6T164AE9409644163	**Colour:**	White
Odometer (km):	37557		
Engine:	4 cyl 1.6l Petrol	**Transmission:**	4sp Auto, Front Drive
Air Conditioning: Y	**Power Steering:** Y	**Adjustable Steering Col.**	Y
Tyres:	Bridgestone 175/65R14 81H		
Pressure front (kPa):	180	**Rear (kPa):**	180
Seating Capacity Front:	2	**Rear:**	3
Restraints Front:	2xELR Lap Sash	**Rear:**	2xELR Lap Sash + 1xStatic Lap

Test Description:	LHD Corolla Car to Car		
Test No:	B5020 Vehicle 1		
Vehicle:	Toyota Corolla Seca Csi LHD		
VIN:	JT1LOAE9207064825	**Colour:**	Red
Odometer (km):	52123		
Engine:	4 cyl 1.6l Petrol	**Transmission:**	3sp Auto, Front Drive
Air Conditioning: N	**Power Steering:** Y	**Adjustable Steering Col.**	Y
Tyres:	Bridgestone 175/65R14 81H		
Pressure front (kPa):	180	**Rear (kPa):**	180
Seating Capacity Front:	2	**Rear:**	3
Restraints Front:	2xELR Lap Sash	**Rear:**	2xELR Lap Sash + 1xStatic Lap

Test Description:	LHD Corolla Car to Car		
Test No:	B5020 Vehicle 2		
Vehicle:	Toyota Corolla Seca Csi LHD		
VIN:	JTILOAE9207114226	**Colour:**	Green
Odometer (km):	56303		
Engine:	4 cyl 1.6l Petrol	**Transmission:**	3sp Auto, Front Drive
Air Conditioning: N	**Power Steering:** Y	**Adjustable Steering Col.**	Y
Tyres:	Bridgestone 175/65R14 81H		
Pressure front (kPa):	180	**Rear (kPa):**	180
Seating Capacity Front:	2	**Rear:**	3
Restraints Front:	2xELR Lap Sash	**Rear:**	2xELR Lap Sash + 1xStatic Lap

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Test Description:	LHD Corolla Offset Barrier		
Test No:	B6026		
Vehicle:	Toyota Corolla Seca Csi LHD		
VIN:	JT1LOAE9207074582	**Colour:**	Red
Odometer (km):	81139		
Engine:	4 cyl 1.6l Petrol	**Transmission:**	3sp Auto, Front Drive
Air Conditioning: N	**Power Steering:** Y	**Adjustable Steering Col.**	Y
Tyres:	Dunlop 175/65R14 81H		
Pressure front (kPa):	180	**Rear (kPa):**	180
Seating Capacity Front:	2	**Rear:**	3
Restraints Front:	2xELR Lap Sash	**Rear:**	2xELR Lap Sash + 1xStatic Lap

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Test Description:	Corolla / Laser Car to Car		
Test No:	B5019 Vehicle 1		
Vehicle:	Toyota Corolla Seca CSi Limited		
VIN:	6T164AE9409643636	**Colour:**	Red
Odometer (km):	42629		
Engine:	4 cyl 1.6l Petrol	**Transmission:**	4sp Auto, Front Drive
Air Conditioning: Y	**Power Steering:** Y	**Adjustable Steering Col.**	Y
Tyres:	Bridgestone 175/65R14 81H		
Pressure front (kPa):	180	**Rear (kPa):**	180
Seating Capacity Front:	2	**Rear:**	3
Restraints Front:	2xELR Lap Sash	**Rear:**	2xELR Lap Sash + 1xStatic Lap

Test Description:	Corolla / Laser Car to Car		
Test No:	B5019 Vehicle 2		
Vehicle:	Ford Laser Liata LXi		
VIN:	JCOAAASGPLRG18207	**Colour:**	Red
Odometer (km):	16		
Engine:	4 cyl 1.6l Petrol	**Transmission:**	4sp Auto, Front Drive
Air Conditioning: N	**Power Steering:** Y	**Adjustable Steering Col.**	Y
Tyres:	Dunlop 185/65R14		
Pressure front (kPa):	210	**Rear (kPa):**	210
Seating Capacity Front:	2	**Rear:**	3
Restraints Front:	2xELR Lap Sash	**Rear:**	2xELR Lap Sash + 1xStatic Lap

Test Description:	Laser Offset Barrier		
Test No:	B5008		
Vehicle:	Ford Laser Liata LXi		
VIN:	JCOAAASGPLRB12500	**Colour:**	Red
Odometer (km):	17		
Engine:	4 cyl 1.6l Petrol	**Transmission:**	4sp Auto, Front Drive
Air Conditioning: N	**Power Steering:** Y	**Adjustable Steering Col.**	N
Tyres:	Dunlop 185/65R14		
Pressure front (kPa):	210	**Rear (kPa):**	210
Seating Capacity Front:	2	**Rear:**	3
Restraints Front:	2xELR Lap Sash	**Rear:**	2xELR Lap Sash + 1xStatic Lap

Test Description:	Modified Offset Barrier 1		
Test No:	B5021		
Vehicle:	Toyota Corolla Seca CSi Limited		
VIN:	6T164AE9409644192	**Colour:**	Red
Odometer (km):	33036		
Engine:	4 cyl 1.6l Petrol	**Transmission:**	4sp Auto, Front Drive
Air Conditioning: Y	**Power Steering:** Y	**Adjustable Steering Col.**	Y
Tyres:	Bridgestone 175/65R14 81H		
Pressure front (kPa):	180	**Rear (kPa):**	180
Seating Capacity Front:	2	**Rear:**	3
Restraints Front:	2xELR Lap Sash	**Rear:**	2xELR Lap Sash + 1xStatic Lap

Test Description:	Modified Offset Barrier 2		
Test No:	B5028		
Vehicle:	Toyota		
VIN:	6T164AE9409644215	**Colour:**	White
Odometer (km):	36279		
Engine:	4 cyl 1.6l Petrol	**Transmission:**	4sp Auto, Front Dnve
Air Conditioning: Y	**Power Steering:** Y	**Adjustable Steering Col.**	Y
Tyres:	Bridgestone 175/65R14 81H		
Pressure front (kPa):	180	**Rear (kPa):**	180
Seating Capacity Front:	2	**Rear:**	3
Restraints Front:	2xELR Lap Sash	**Rear:**	2xELR Lap Sash + 1xStatic Lap

Vehicle Masses:

B3014, RHD Corolla Offset Barrier

Delivered:	Left (kg)	Right (kg)	Total (kg)	Distribution %
Front:	344.5	337	681.5	60.2
Rear:	223	229	452	39.8

Unloaded Delivery Weight (UDW):	1133.5kg	
Vehicle Capacity Weight (VCW):	386.5kg	
Designated Seating Capacity (DSC):	5	
Rated Cargo Weight (RCW):	46.35kg	= VCW – (68.03 x DSC)
Target Test Weight (TTW):	1328.65kg	= UDW + RCW + (2 x 74.4kg/dummy)

Test Mass:	Left (kg)	Right (kg)	Total (kg)	Distribution %
Front:	385	375.5	760.5	57.3
Rear:	285	280.5	565.5	42.7

Total Test Weight: 1326kg
Ballast Fitted: kg

Vehicle Attitude

Delivered	Left (mm)	Right (mm)	Ballasted	Left (mm)	Right (mm)
Front:	670	670	Front:		
Rear:	680	680	Rear:		

Wheel Base: 2430mm C of G 1036mm rearward of front wheel C/L

B3015, RHD Corolla Offset Barrier

Delivered:	Left (kg)	Right (kg)	Total (kg)	Distribution %
Front:	343.5	340	683.5	60.2
Rear:	226	224	450	39.8

Unloaded Delivery Weight (UDW):	1133.5kg	
Vehicle Capacity Weight (VCW):	386.5kg	
Designated Seating Capacity (DSC):	5	
Rated Cargo Weight (RCW):	46.35kg	= VCW – (68.03 x DSC)
Target Test Weight (TTW):	1328.65kg	= UDW + RCW + (2 x 74.4kg/dummy)

Test Mass:	Left (kg)	Right (kg)	Total (kg)	Distribution %
Front:	377.5	373.5	751	56.8
Rear:	287	283	570	43.2

Total Test Weight: 1320kg
Ballast Fitted: 0kg

Vehicle Attitude

Delivered	Left (mm)	Right (mm)	Ballasted	Left (mm)	Right (mm)
Front:	670	670	Front:		
Rear:	680	680	Rear:		

Wheel Base: 2430mm C of G 1049mm rearward of front wheel C/L

B4009 Vehicle 1, RHD Corolla Car to Car

Delivered:	Left (kg)	Right (kg)	Total (kg)	Distribution %
Front:	336	346	682	60.4
Rear:	230	217	447	39.6

Unloaded Delivery Weight (UDW):	1129kg	
Vehicle Capacity Weight (VCW):	391kg	
Designated Seating Capacity (DSC):	5	
Rated Cargo Weight (RCW):	50.85kg	= VCW – (68.03 x DSC)
Target Test Weight (TTW):	1328.65kg	= UDW + RCW + (2 x 74.4kg/dummy)

Test Mass:	Left (kg)	Right (kg)	Total (kg)	Distribution %
Front:	372.5	382.5	755	56.8
Rear:	292.5	282.5	575	43.2

Total Test Weight: 1330kg
Ballast Fitted: 9kg

Vehicle Attitude

Delivered	Left (mm)	Right (mm)	Ballasted	Left (mm)	Right (mm)
Front:	660	660	Front:	649	647
Rear:	670	675	Rear:	639	643

Wheel Base: 2430mm C of G 1051mm rearward of front wheel C/L

B4009 Vehicle 2, RHD Corolla Car to Car

Delivered:	Left (kg)	Right (kg)	Total (kg)	Distribution %
Front:	344.5	338	682.5	60.4
Rear:	222	224.5	446.5	39.6

Unloaded Delivery Weight (UDW):	1129kg	
Vehicle Capacity Weight (VCW):	391kg	
Designated Seating Capacity (DSC):	5	
Rated Cargo Weight (RCW):	50.85kg	= VCW – (68.03 x DSC)
Target Test Weight (TTW):	1328.65kg	= UDW + RCW + (2 x 74.4kg/dummy)

Test Mass:	Left (kg)	Right (kg)	Total (kg)	Distribution %
Front:	371.5	374	745.5	56
Rear:	291.5	293.5	585	44

Total Test Weight: 1330.5kg
Ballast Fitted: 0kg

Vehicle Attitude

Delivered	Left (mm)	Right (mm)	Ballasted	Left (mm)	Right (mm)
Front:	660	660	Front:	654	650
Rear:	675	675	Rear:	634	640

Wheel Base: 2430mm C of G 1069mm rearward of front wheel C/L

B4054, RHD Corolla Offset Barrier

Delivered:	Left (kg)	Right (kg)	Total (kg)	Distribution %
Front:	342.5	338	680.5	60.4
Rear:	222	224	446	39.5

Unloaded Delivery Weight (UDW):	1126.5kg	
Vehicle Capacity Weight (VCW):	393.5kg	
Designated Seating Capacity (DSC):	5	
Rated Cargo Weight (RCW):	53.35kg	= VCW – (68.03 x DSC)
Target Test Weight (TTW):	1328.65kg	= UDW + RCW + (2 x 74.4kg/dummy)

Test Mass:	Left (kg)	Right (kg)	Total (kg)	Distribution %
Front:	368	370	738	56
Rear:	293	293	586	44

Total Test Weight: 1324kg
Ballast Fitted: 0kg

Vehicle Attitude

Delivered	Left (mm)	Right (mm)	Ballasted	Left (mm)	Right (mm)
Front:	644	655	Front:	648	657
Rear:	661	655	Rear:	643	644

Wheel Base: 2430mm C of G 1076mm rearward of front wheel C/L

B5020 Vehicle 1, LHD Corolla Car to Car

Delivered:	Left (kg)	Right (kg)	Total (kg)	Distribution %
Front:	335.5	313	648.5	59.2
Rear:	223.5	223.5	447	40.8

Unloaded Delivery Weight (UDW):	1095.5kg	
Vehicle Capacity Weight (VCW):	424.5kg	
Designated Seating Capacity (DSC):	5	
Rated Cargo Weight (RCW):	84.35kg	= VCW – (68.03 x DSC)
Target Test Weight (TTW):	1328.65kg	= UDW + RCW + (2 x 74.4kg/dummy)

Test Mass:	Left (kg)	Right (kg)	Total (kg)	Distribution %
Front:	380	352.5	732.5	55.3
Rear:	299.5	291.5	591	44.7

Total Test Weight: 1323.5kg
Ballast Fitted: 45kg

Vehicle Attitude

Delivered	Left (mm)	Right (mm)	Ballasted	Left (mm)	Right (mm)
Front:	650	660	Front:	641	653
Rear:	650	660	Rear:	617	626

Wheel Base: 2430mm C of G 1085 mm rearward of front wheel C/L

B5020 Vehicle 2, LHD Corolla Car to Car

Delivered:	Left (kg)	Right (kg)	Total (kg)	Distribution %
Front:	335.5	316.5	652	59.5
Rear:	221.5	222.5	444	40.5

Unloaded Delivery Weight (UDW):	1096kg	
Vehicle Capacity Weight (VCW):	424kg	
Designated Seating Capacity (DSC):	5	
Rated Cargo Weight (RCW):	83.85kg	= VCW – (68.03 x DSC)
Target Test Weight (TTW):	1328.65kg	= UDW + RCW + (2 x 74.4kg/dummy)

Test Mass:	Left (kg)	Right (kg)	Total (kg)	Distribution %
Front:	372.5	340.5	713	53.8
Rear:	309	303.5	612.5	46.2

Total Test Weight: 1325.5kg
Ballast Fitted: 31.5kg

Vehicle Attitude

Delivered	Left (mm)	Right (mm)	Ballasted	Left (mm)	Right (mm)
Front:	645	650	Front:	640	650
Rear:	640	640	Rear:	610	619

Wheel Base: 2430mm C of G 1123mm rearward of front wheel C/L

B6026, LHD Corolla Offset Barrier

Delivered:	Left (kg)	Right (kg)	Total (kg)	Distribution %
Front:	310.5	307	617.5	58.3
Rear:	231	211	442	41.7

Unloaded Delivery Weight (UDW):	1059.5kg	
Vehicle Capacity Weight (VCW):	460.5kg	
Designated Seating Capacity (DSC):	5	
Rated Cargo Weight (RCW):	120 35kg	= VCW – (68.03 x DSC)
Target Test Weight (TTW):	1328.65kg	= UDW + RCW + (2 x 74.4kg/dummy)

Test Mass:	Left (kg)	Right (kg)	Total (kg)	Distribution %
Front:	374	339	713	54
Rear:	313.5	294	607.5	46

Total Test Weight: 1320.5kg
Ballast Fitted: 32kg

Vehicle Attitude

Delivered	Left (mm)	Right (mm)	Ballasted	Left (mm)	Right (mm)
Front:	650	650	Front:	641	645
Rear:	640	640	Rear:	614	620

Wheel Base: 2430mm C of G 1118mm rearward of front wheel C/L

B5019 Vehicle 1, Corolla / Laser Car to Car

Delivered:	Left (kg)	Right (kg)	Total (kg)	Distribution %
Front:	338	340.5	678.5	60.2
Rear:	226.5	221.5	448	39.8

Unloaded Delivery Weight (UDW):	1126.5kg	
Vehicle Capacity Weight (VCW):	393.5kg	
Designated Seating Capacity (DSC):	5	
Rated Cargo Weight (RCW):	53.35kg	= VCW – (68.03 x DSC)
Target Test Weight (TTW):	1328.65kg	= UDW + RCW + (2 x 74.4kg/dummy)

Test Mass:	Left (kg)	Right (kg)	Total (kg)	Distribution %
Front:	379.5	379.5	759	57.4
Rear:	285	278.5	563.5	42.6

Total Test Weight: 1322.5kg
Ballast Fitted: 36.5kg

Vehicle Attitude

Delivered	Left (mm)	Right (mm)	Ballasted	Left (mm)	Right (mm)
Front:	650	650	Front:		
Rear:	650	650	Rear:		

Wheel Base: 2430mm C of G 1035mm rearward of front wheel C/L

B5019 Vehicle 2, Corolla / Laser Car to Car

Delivered:	Left (kg)	Right (kg)	Total (kg)	Distribution %
Front:	356	349	705	61.3
Rear:	219	226.5	445.5	38.7

Unloaded Delivery Weight (UDW):	1150.5kg	
Vehicle Capacity Weight (VCW):	431.5kg	
Designated Seating Capacity (DSC):	5	
Rated Cargo Weight (RCW):	91.35kg	= VCW – (68.03 x DSC)
Target Test Weight (TTW):	1390.65kg	= UDW + RCW + (2 x 74.4kg/dummy)

Test Mass:	Left (kg)	Right (kg)	Total (kg)	Distribution %
Front:	399	402.5	801.5	57.9
Rear:	290	295.5	585.5	42.1

Total Test Weight: 1387kg
Ballast Fitted: 16kg

Vehicle Attitude

Delivered	Left (mm)	Right (mm)	Ballasted	Left (mm)	Right (mm)
Front:	675	675	Front:	666	665
Rear:	680	680	Rear:	659	655

Wheel Base: 2605mm C of G 1100mm rearward of front wheel C/L

B5008, Laser Offset Barrier

Delivered:	Left (kg)	Right (kg)	Total (kg)	Distribution %
Front:	354.5	346.5	701	61.1
Rear:	217	230	447	38.9

Unloaded Delivery Weight (UDW):	1148kg	
Vehicle Capacity Weight (VCW):	434kg	
Designated Seating Capacity (DSC):	5	
Rated Cargo Weight (RCW):	93.85kg	= VCW – (68.03 x DSC)
Target Test Weight (TTW):	1390.65kg	= UDW + RCW + (2 x 74.4kg/dummy)

Test Mass:	Left (kg)	Right (kg)	Total (kg)	Distribution %
Front:	405	401	806	58.2
Rear:	283	295	578	41.8

Total Test Weight: 1384kg
Ballast Fitted: 54kg

Vehicle Attitude

Delivered	Left (mm)	Right (mm)	Ballasted	Left (mm)	Right (mm)
Front:	680	675	Front:	679	675
Rear:	685	675	Rear:	669	660

Wheel Base: 2605mm C of G 1088mm rearward of front wheel C/L

B5021, Modified Offset Barrier 1

Delivered:	Left (kg)	Right (kg)	Total (kg)	Distribution %
Front:	343.5	335.5	679	60.1
Rear:	224	225	449	39.9

Unloaded Delivery Weight (UDW):	1128kg	
Vehicle Capacity Weight (VCW):	392kg	
Designated Seating Capacity (DSC):	5	
Rated Cargo Weight (RCW):	51.85kg	= VCW – (68.03 x DSC)
Target Test Weight (TTW):	1328.65kg	= UDW + RCW + (2 x 74.4kg/dummy)

Test Mass:	Left (kg)	Right (kg)	Total (kg)	Distribution %
Front:	375	374	749	56.4
Rear:	289.5	290.5	580	43.6

Total Test Weight: 1329kg
Ballast Fitted: 0kg

Vehicle Attitude

Delivered	Left (mm)	Right (mm)	Ballasted	Left (mm)	Right (mm)
Front:	655	660	Front:	659	662
Rear:	670	670	Rear:	655	658

Wheel Base: 2430mm C of G 1060mm rearward of front wheel C/L

B5028, Modified Offset Barrier 2

Delivered:	Left (kg)	Right (kg)	Total (kg)	Distribution %
Front:	342.5	341.5	684	60.5
Rear:	223	223	446	39.5

Unloaded Delivery Weight (UDW):	1130kg	
Vehicle Capacity Weight (VCW):	390kg	
Designated Seating Capacity (DSC):	5	
Rated Cargo Weight (RCW):	49.85kg	= VCW – (68.03 x DSC)
Target Test Weight (TTW):	1328.65kg	= UDW + RCW + (2 x 74.4kg/dummy)

Test Mass:	Left (kg)	Right (kg)	Total (kg)	Distribution %
Front:	371	376.5	747.5	56.3
Rear:	287.5	293	580.5	43.7

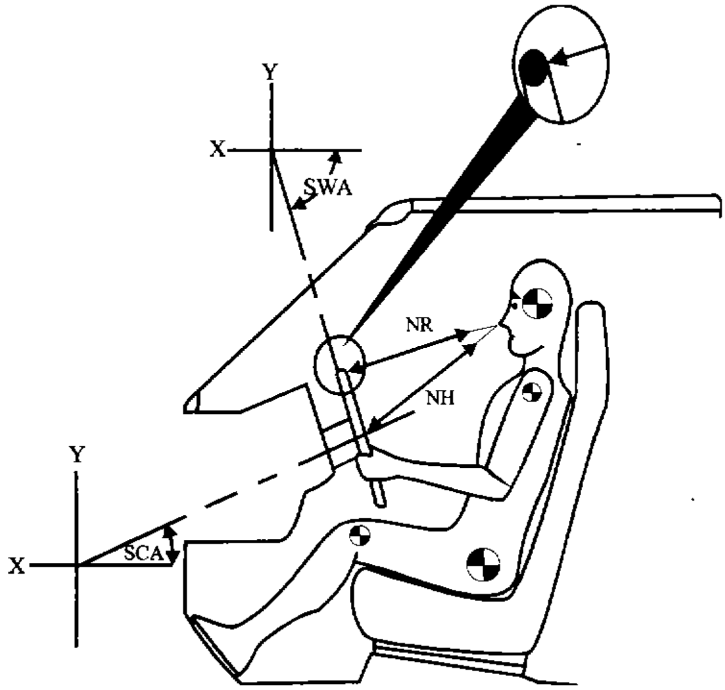
Total Test Weight: 1328kg
Ballast Fitted: 0kg

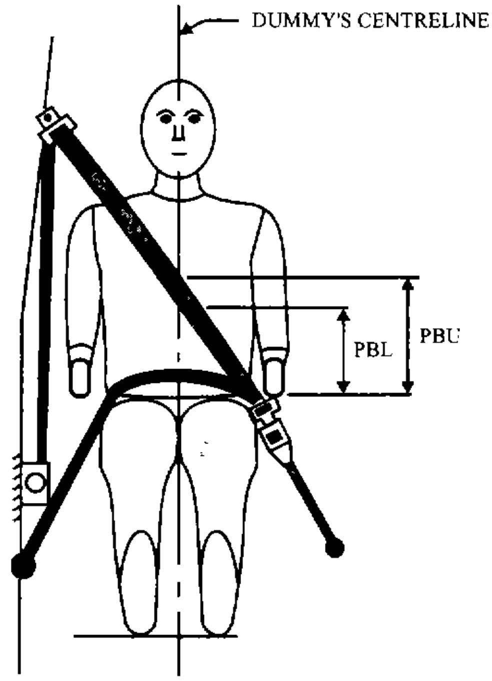
Vehicle Attitude

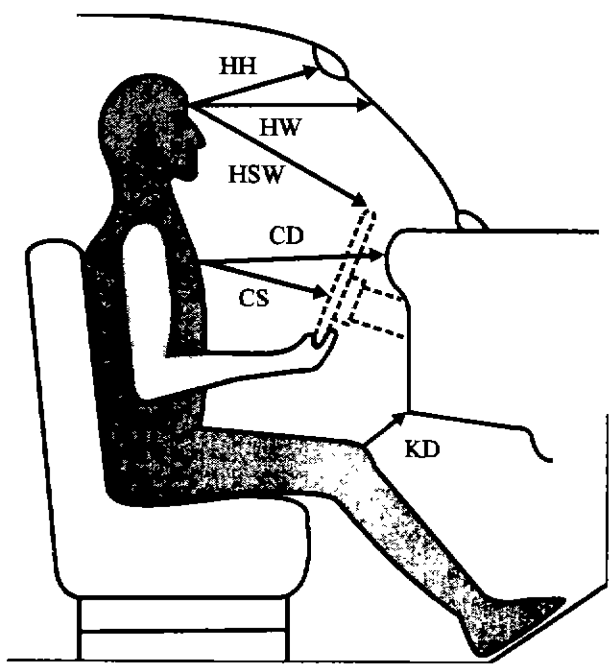
Delivered	Left (mm)	Right (mm)	Ballasted	Left (mm)	Right (mm)
Front:	647	650	Front:	663	660
Rear:	659	670	Rear:	650	656

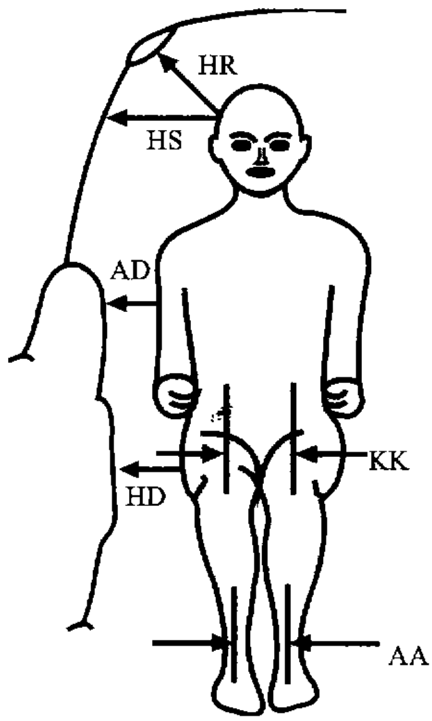
Wheel Base: 2430mm C of G 1062mm rearward of front wheel C/L

Appendix 3 – Dummy Positioning Data









Test		RHD Corolla 40% Offset		RHD Corolla 50% Offset	
		B3014		B3015	
		Driver	Passenger	Driver	Passenger
H-Point Location	X	2801	2873	2840	2919
	Y				
	Z	7487	7507	7496	7512
Chin to top of rim / facia	A				
Nose to top edge of glass	B				
Stomach to rim / facia	C				
Head to windshield header	HH	321	302	299	315
Head to windshield, horiz	HW	511	540	536	592
Head target to A pillar	HA				
Chest to dash	CD	501	501	506	520
Chest to steering wheel	CS	318		316	
Knee to dash, left	KDL	153	156	150	142
Knee to dash, right	KDR	153	154	150	142
Seat back angle (deg)	SA	24	25	25	25
Head target to side roof	HR	172	168	175	168
Head target to side window	HS	210	200	250	245
Upper arm to door	AD	133	114	109	104
Hip to door	HD	170	188	175	195
Ankle to ankle, centres	AA	192	104	215	121
Knee to knee, centres	KK	199	132	134	138
Nose tip to rim top rear	NR	400		439	
Nose tip to hub centre	NH	424		418	
Top of plate to sash, top edge	PBU	345	334	352	322
Top of plate to sash, lower edge	PBL	256	253	271	242
Head to roof	HT	101	100	104	103
Nose to dash		518	602	518	103
Steering wheel rim angle (deg)	SWA	64		63.2	

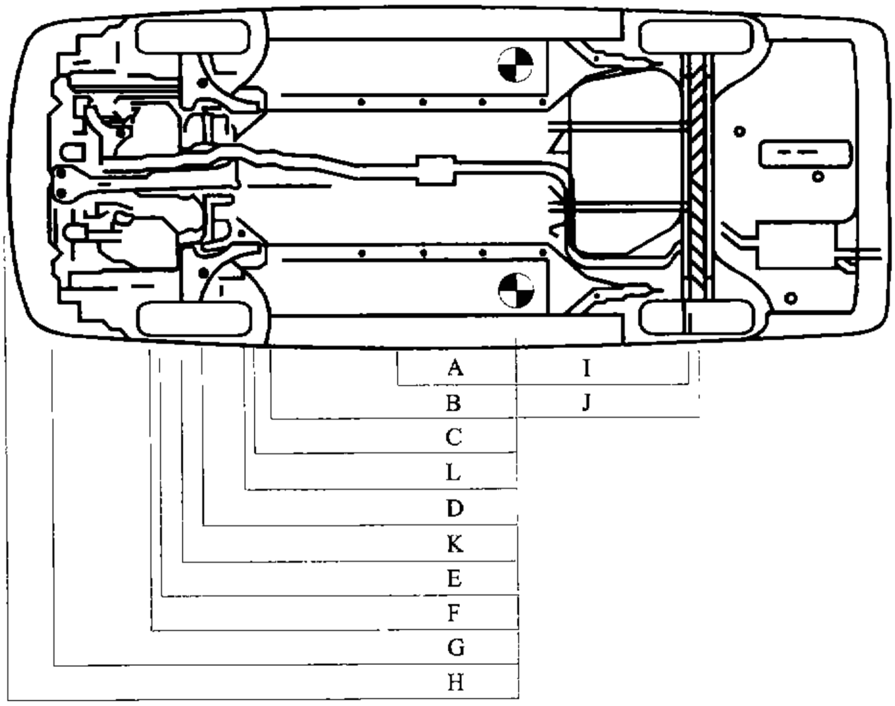
Test		RHD Corolla Car to Car				RHD Corolla 40% Offset	
		B4009v1		B4009v2		B4054	
		Driver	Passenger	Driver	Passenger	Driver	Passenger
H-Point Location	X	245	247	241	249	245	239
	Y	(from fiducial mark)		(from fiducial mark)		(from fiducial mark)	
	Z	78	82	74	83	71	67
Chin to top of rim / facia	A						
Nose to top edge of glass	B						
Stomach to rim / facia	C						
Head to windshield header	HH	293	283	320	287	315	299
Head to windshield, horiz	HW	480	415	441	443	530	511
Head target to A pillar	HA					470	455
Chest to dash	CD	485	532	498	550	514	511
Chest to steering wheel	CS	308		315		340	
Knee to dash, left	KDL	116	112	115	111	141	115
Knee to dash, right	KDR	114	128	111	106	135	115
Seat back angle (deg)	SA	25	24			24.5	25
Head target to side roof	HR	180	179	188	191	158	167
Head target to side window	HS	226	223	217	237	210	210
Upper arm to door	AD	137	111	126	109	128	129
Hip to door	HD	205	179	202	149	206	210
Ankle to ankle, centres	AA	204	126	154	139	305	200
Knee to knee, centres	KK	185	146	175	116	265	200
Nose tip to rim top rear	NR	410		438		417	
Nose tip to hub centre	NH	392		427		433	
Top of plate to sash, top edge	PBU	335	330	321	274	345	365
Top of plate to sash, lower edge	PBL	261	253	242	193	260	275
Head to roof	HT	105	97	101	92	93	96
Nose to dash		492	598	523	610		
Steering wheel rim angle (deg)	SWA	65					

		LHD Corolla Car to Car				LHD Corolla	
Test		B5020v1		B5020v2		B6026	
		Driver	Passenger	Driver	Passenger	Driver	Passenger
H-Point Location	X	246	244	-248	-240	244	240
	Y	(from fiducial mark)		(from fiducial mark)		(from fiducial mark)	
	Z	67	77	85	92	82	77
Chin to top of rim / facia	A	410	590	450	607	407	593
Nose to top edge of glass	B	303	299	315	301	305	315
Stomach to rim / facia	C	186	473	194	473	166	458
Head to windshield header	HH	241	250	280	253	296	302
Head to windshield, horiz	HW	487	483	519	452	565	555
Head target to A pillar	HA	427	434	452	450	466	494
Chest to dash	CD	498	494	501	481	500	519
Chest to steering wheel	CS	393		312		314	
Knee to dash, left	KDL	125	131	125	156	125	120
Knee to dash, right	KDR	98	123	139	148	140	122
Seat back angle (deg)	SA	24.5	23.5	25.5	23.5	25	24.5
Head target to side roof	HR	152	155	152	137	182	170
Head target to side window	HS	184	192	210	190	215	225
Upper arm to door	AD						
Hip to door	HD						
Ankle to ankle, centres	AA	280	215	328	205	260	220
Knee to knee, centres	KK	230	200	270	220	235	200
Nose tip to rim top rear	NR	398		414		396	
Nose tip to hub centre	NH	418		431		405	
Top of plate to sash, top edge	PBU	380	360	366	372	334	355
Top of plate to sash, lower edge	PBL	271	267	285	286	250	260
Head to roof	HT	94	98	96	81	114	105
Nose to dash							
Steering wheel rim angle (deg)	SWA	62.1				63	

		Corolla / Laser Car to Car				Laser 40% Offset	
Test		B5019v1		B5019v2		B5008	
		Driver	Passenger	Driver	Passenger	Driver	Passenger
H-Point Location	X	233	239	223	228	3061	3160
	Y	(from fiducial mark)		(from fiducial mark)			
	Z	64	67	214	151	7464	7438
Chin to top of rim / facia	A	435					
Nose to top edge of glass	B	335	322				
Stomach to rim / facia	C	195	477				
Head to windshield header	HH	296	295	309	304	301	323
Head to windshield, horiz	HW	525	506	540	549	640	619
Head target to A pillar	HA	565	540	499	514	537	525
Chest to dash	CD	512	523	516	484	538	525
Chest to steering wheel	CS	345		281		311	
Knee to dash, left	KDL			108	93	113	101
Knee to dash, right	KDR			100	94	113	109
Seat back angle (deg)	SA	25	24	21	21	20	21.5
Head target to side roof	HR	181	160	202	205	212	194
Head target to side window	HS	215	232	242	262	282	268
Upper arm to door	AD			162	119	132	123
Hip to door	HD			231	150	146	156
Ankle to ankle, centres	AA	300	195	284	205	286	205
Knee to knee, centres	KK	285	195	262	198	258	200
Nose tip to rim top rear	NR	414		380		394	
Nose tip to hub centre	NH	426		372		388	
Top of plate to sash, top edge	PBU	303	358	345	325	338	358
Top of plate to sash, lower edge	PBL	217	271	262	241	261	269
Head to roof	HT	103	100	132	132	141	129
Nose to dash							
Steering wheel rim angle (deg)	SWA	23					

Test		Corolla Mod. Barrier 1 B5021 Driver	Corolla Mod. Barrier 1 B5021 Passenger	Corolla Mod. Barrier 2 B5028 Driver	Corolla Mod. Barrier 2 B5028 Passenger
H-Point Location	X	241	242		
	Y	(from fiducial mark)			
	Z	62	60		
Chin to top of rim / facia	A	418	612	414	597
Nose to top edge of glass	B	325	338	324	315
Stomach to rim / facia	C	185	463	169	454
Head to windshield header	HH	274	299	316	308
Head to windshield, horiz	HW	485	521	561	520
Head target to A pillar	HA	520	510	453	475
Chest to dash	CD	504	520	517	535
Chest to steering wheel	CS	329		331	
Knee to dash, left	KDL	138	137	116	113
Knee to dash, right	KDR	135	127	120	115
Seat back angle (deg)	SA	25	25	24	25
Head target to side roof	HR	120	164	176	178
Head target to side window	HS	215	210	220	220
Upper arm to door	AD				
Hip to door	HD				
Ankle to ankle, centres	AA	310	190	385	195
Knee to knee, centres	KK	260	205	260	200
Nose tip to rim top rear	NR	406		434	
Nose tip to hub centre	NH	421		415	
Top of plate to sash, top edge	PBU	358	333	345	365
Top of plate to sash, lower edge	PBL	270	263	265	287
Head to roof	HT	93	97	100	99
Nose to dash					
Steering wheel rim angle (deg)	SWA	63.6		62.9	

Appendix 4 – Vehicle Deformation Measurements



Underside:

Measurement		B3014 Before	B3014 After	B3014 Crush	B3015 Before	B3015 After	B3015 Crush
A Door Sill Centre of A	L	1139	1143	-4	1137	1135	2
and B pillars	R	1138	1133	5	1140	1146	-6
B Door Sill Front Edge	L	1093	1092	1	1093	1090	3
	R	1093	1083	10	1095	1094	1
C Front Edge of Floor	L	1170	1168	2	1167	1160	7
Pan	R	1170	1148	22	1170	1154	16
D Centreline of Front	L	1160	1557	-397	1157	1553	-396
Face Cross Member	R	1159	1463	-304	1159	1485	-326
E Centreline of	L	1731	1766	-35	1729	1766	-37
Transmission	R						
F Engine Oil Drain Plug	L	1646	1487	159	1648	1511	137
	R						
G Front Edge of Frame	L	2182	2176	6	2183	2160	23
Longitudinal Member	R	2181	1810	371	2184	1855	329
H Front Bumper (inline	L	2345	1913	432	2350	1995	355
with Ref. Mark)	R						
I Rear Edge of Fuel	L	810	805	5	808	803	5
Tank	R	813	805	8	810	807	3
J Front Edge of Rear	L	873	872	1	873	877	-4
Axle	R	881	877	4	878	883	-5
K Rear Edge of Front	L	1153	1159	-6	1153	1152	1
Lower Wishbone Pivot	R	1149	1065	84	1155	1088	67
L Inner ball joint bolt -	L	1547	1579	-32	1547	1570	-23
front lower wishbone	R	1543	1425	118	1545	1446	99

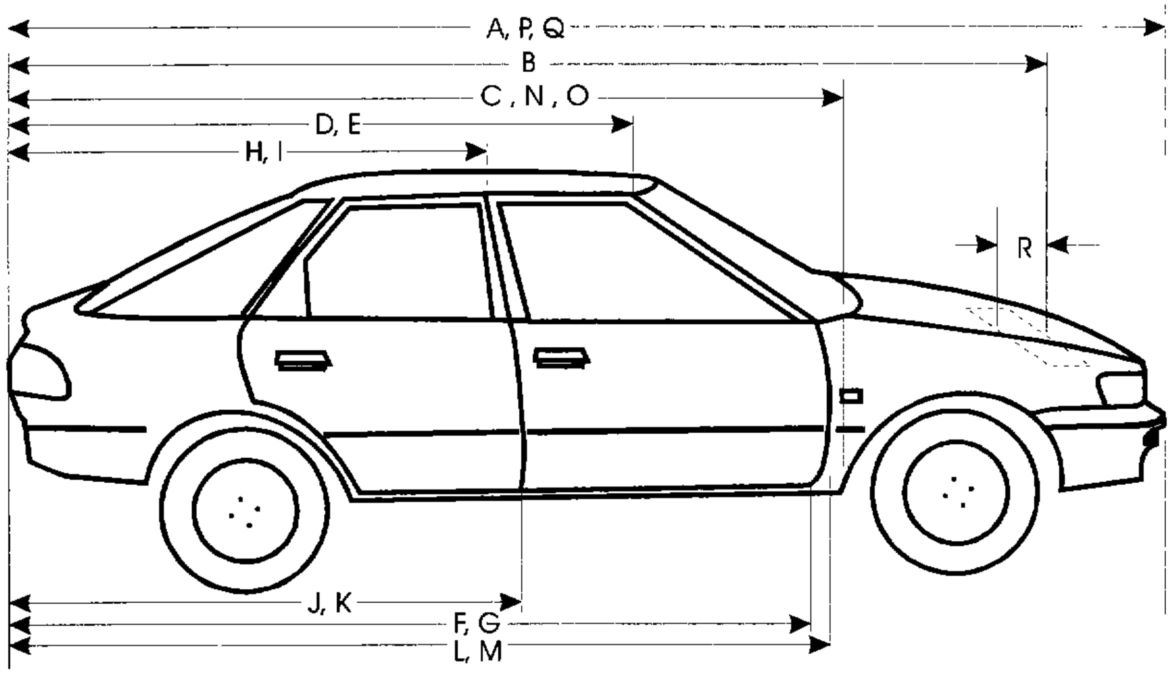
Measurement		B4009 Vehicle 1 Before	After	Crush	B4009 Vehicle 2 Before	After	Crush	B4054 Before	After	Crush
A Door Sill Centre of A	L	607	607	0	580	588	-8	612	610	2
and B pillars	R	595	587	8	590	596	-6	595	598	-3
B Door Sill Front Edge	L	1035	1000	35	1130	1138	-8	1035	1033	2
	R	1040	1027	13	1135	1111	24	1041	965	76
C Front Edge of Floor	L	1162	1162	0	1170	1166	4	1182	1177	5
Pan	R	1164	1139	25	1165	1118	47	1190	1110	80
D Centreline of Front	L	1471	1433	38	1500	1385	115	1529	1452	77
Face Cross Member	R									
E Centreline of	L	1725	1713	12	1725	1727	-2	1724	1733	-9
Transmission	R									
F Engine Oil Drain Plug	L	1641	1436	205	1645	1417	228			
	R							1656	1421	235
G Front Edge of Frame	L	2212	2015	197	2180	1998	182	2220	1898	322
Longitudinal Member	R	2234	1946	288	2195	1921	274	2237	1865	372
H Front Bumper (inline	L	2312	1983	329	2400	1980	420			0
with Ref. Mark)	R							2233	1780	453
I Rear Edge of Fuel	L	808	805	3	800	801	-1			
Tank	R	812	812	0	810	808	2			
J Front Edge of Rear	L	857	860	-3	860	858	2			
Axle	R	860	866	-6	860	863	-3			
K Rear Edge of Front	L							1500	1485	15
Lower Wishbone Pivot	R							1491	1342	149
L Inner ball joint bolt -	L							1543	1570	-27
front lower wishbone	R							1541	1343	198

Measurement		B5008 Before	After	Crush	B5019 Vehicle 1 Before	After	Crush	B5019 Vehicle 2 Before	After	Crush
A Door Sill Centre of A	L	Not Recorded			605	600	5	550	550	0
and B pillars	R				605	600	5	550	550	0
B Door Sill Front Edge	L				1115	1145	-30	1110	1125	-15
	R				1150	1100	50	1110	1000	110
C Front Edge of Floor	L				1260	1240	20	1278	1263	15
Pan	R				1255	1135	120	1280	1160	120
D Centreline of Front	L				2240	1975	265	2273	2040	233
Face Cross Member	R				2233	1905	328	2260	1925	335
E Centreline of	L				1735	1715	20	1660	1735	-75
Transmission	R				1845	1783	62	1788	1920	-132
F Engine Oil Drain Plug	L				1750	1550	200	1845	1685	160
	R				1653	1430	223	1645	1440	205
G Front Edge of Frame	L				2223	2055	168	2165	2028	137
Longitudinal Member	R				2243	2000	243	2220	1970	250
H Front Bumper (inline	L				2325	2075	250	2445	2113	332
with Ref. Mark)	R				2326	2065	261	2421	1985	436
I Rear Edge of Fuel	L				795	785	10	955	935	20
Tank	R				775	775	0	985	950	35
J Front Edge of Rear	L				895	883	12	1035	1035	0
Axle	R				895	890	5	1035	1025	10
K Rear Edge of Front	L									
Lower Wishbone Pivot	R									
L Inner ball joint bolt -	L									
front lower wishbone	R									

Measurement		B5020 Vehicle 1			B5020 Vehicle 2			B6026		
		Before	After	Crush	Before	After	Crush	Before	After	Crush
A Door Sill Centre of A and B pillars	L	670	670	0	620	630	-10	630	635	-5
	R	675	670	5	650	650	0	635	635	0
B Door Sill Front Edge	L	1145	760	385	1145	760	385	1140	1120	20
	R	1145	1140	5	1145	1145	0	1140	1140	0
C Front Edge of Floor Pan	L	1250	1025	225	1245	1000	245	1240	1155	85
	R	1245	1230	15	1255	1115	140	1230	1230	0
D Centreline of Front Face Cross Member	L	2230	1930	300	2225	1885	340	2215	1860	355
	R	2230	1975	255	2233	1945	288	2230	1935	295
E Centreline of Transmission	L	1735	1470	265	1737	1420	317	1740	1545	195
	R	1840	1640	200	1845	1603	242	1840	1700	140
F Engine Oil Drain Plug	L	1875	1755	120	1888	1725	163	1875	1835	40
	R	1780	1705	75	1781	1655	126	1775	1760	15
G Front Edge of Frame Longitudinal Member	L	2220	1900	320	2220	1850	370	2215	1860	355
	R	2240	1990	250	2240	1960	280	2230	1935	295
H Front Bumper (inline with Ref. Mark)	L	2315	1705	610	2340	1700	640	2330	1860	470
	R	2320	2170	150	2317	2100	217	2330	2220	110
I Rear Edge of Fuel Tank	L	785	785	0	790	790	0	790	790	0
	R	795	800	-5	795	790	5	800	800	0
J Front Edge of Rear Axle	L	890	890	0	893	893	0	905	905	0
	R	890	890	0	890	885	5	895	900	-5
K Rear Edge of Front Lower Wishbone Pivot	L									
	R									
L Inner ball joint bolt - front lower wishbone	L									
	R									

Measurement		B5021			B5028		
		Before	After	Crush	Before	After	Crush
A Door Sill Centre of A and B pillars	L	675	675	0	635	635	0
	R	650	650	0	350	645	-295
B Door Sill Front Edge	L	1145	1165	-20	1150	1145	5
	R	1150	1020	130	1155	1020	135
C Front Edge of Floor Pan	L	1253	1240	13	1250	1235	15
	R	1262	1090	172	1255	1165	90
D Centreline of Front Face Cross Member	L	2240	1985	255	2230	2035	195
	R	2230	1890	340	2230	1970	260
E Centreline of Transmission	L	1733	1705	28	1760	1750	10
	R	1848	1730	118	1880	1800	80
F Engine Oil Drain Plug	L	1748	1480	268	1745	1527	218
	R	1657	1355	302	1650	1415	235
G Front Edge of Frame Longitudinal Member	L	2225	2030	195	2215	2035	180
	R	2225	1920	305	2235	1970	265
H Front Bumper (inline with Ref. Mark)	L	2230	2165	65	2330	2155	175
	R	2233	1708	525	2335	1800	535
I Rear Edge of Fuel Tank	L	795	785	10	785	785	0
	R	800	795	5	790	790	0
J Front Edge of Rear Axle	L	890	885	5	885	885	0
	R	890	885	5	885	885	0
K Rear Edge of Front Lower Wishbone Pivot	L						
	R						
L Inner ball joint bolt - front lower wishbone	L						
	R						

Vehicle Deformation:



	Measurement (mm)	Side	B3014 (40% Offset)			B3015 (50% Offset)		
			Pre-Test	Post Test	Crush	Pre-Test	Post Test	Crush
A	Total Length	Centre	4019	3433	586	4022	3560	462
B	Rear to Front of Engine	Centre	3516	3140	376	3517	3156	361
C	Rear to Firewall	Centre	2485	2717	-232	2992	2727	265
D	Rear to Upper leading edge, front door	Right	2095	2088	7	2093	2002	91
E		Left	2090	2115	-25	2091	2033	58
F	Rear to Lower leading edge, front door	Right	2678	2584	94	2677	2638	39
G		Left	2673	2643	30	2874	2648	226
H	Rear to Upper trailing edge, front door	Right	1633	1641	-8	1627	1643	-16
I		Left	1628	1643	-15	1629	1644	-15
J	Rear to Lower trailing edge, front door	Right	1709	1629	80	1709	1666	43
K		Left	1705	1675	30	1709	1684	25
L	Rear to Bottom of A Pillar	Right	2705	2602	103	2703	2629	74
M		Left	2699	2669	30	2899	2676	223
N	Rear to Firewall	Right	2949	2623	326	2945	2680	265
O		Left	2962	2844	118	3368	2857	511
	Rear to Steering Column		3401	2159	1242	2313	2198	115
	Centre of Steering Column to A Pillar		369	353	16	385	367	18
	Centre of Steering Column to headlining		401	494	-93	403	473	-70
P	Total Length	Right	3949	3312	637	3955	3436	519
Q		Left	3945	3919	26	3950	3926	24
R	Length of Engine Block		180	180	0	180	180	0

			B4009 Vehicle 1			B4009 Vehicle 2		
	Measurement (mm)	Side	Pre-Test	Post Test	Crush	Pre-Test	Post Test	Crush
A	Total Length	Centre	4016	3574	442	4022	3505	517
B	Rear to Front of Engine	Centre	3517	3194	323	3520	3157	363
C	Rear to Firewall	Centre	3002	2848	154	3007	2808	199
D	Rear to Upper leading edge, front door	Right	2093	2069	24	2095	2035	60
E		Left	2091	2113	-22	2096	2120	-24
F	Rear to Lower leading edge, front door	Right	2672	2596	76	2674	2544	130
G		Left	2671	2659	12	2673	2643	30
H	Rear to Upper trailing edge, front door	Right	1627	1633	-6	1628	1653	-25
I		Left	1628	1649	-21	1634	1651	-17
J	Rear to Lower trailing edge, front door	Right	1706	1659	47	1708	1652	56
K		Left	1706	1697	9	1711	1682	29
L	Rear to Bottom of A Pillar	Right	2678	Damage		2677	2516	161
M		Left	2676	2664	12	2681	2650	31
N	Rear to Firewall	Right	2974	2719	255	2973	2640	333
O		Left	2982	2933	49	2975	2903	72
	Rear to Steering Column		2319	2204	115	2300	2176	124
	Centre of Steering Column to A Pillar		390	346	44	395	343	52
	Centre of Steering Column to headlining		435	490	-55	482	466	16
P	Total Length	Right	3950	3256	694	3952	3130	822
Q		Left	3951	3957	-6	3954	3945	9
R	Length of Engine Block		180	180	0	180	180	0

			B4054			B5008 (Laser - Barrier)		
	Measurement (mm)	Side	Pre-Test	Post Test	Crush	Pre-Test	Post Test	Crush
A	Total Length	Centre	4017	3483	534	3968	3464	504
B	Rear to Front of Engine	Centre	3519	3146	373	3512	3288	224
C	Rear to Firewall	Centre	2987	2725	262			
D	Rear to Upper leading edge, front door	Right	2095	2022	73			
E		Left	2092	2074	18			
F	Rear to Lower leading edge, front door	Right	2680	2511	169			
G		Left	2671	2677	-6			
H	Rear to Upper trailing edge, front door	Right	1634	1609	25			
I		Left	1628	1614	14			
J	Rear to Lower trailing edge, front door	Right	1723	1701	22			
K		Left	1710	1715	-5			
L	Rear to Bottom of A Pillar	Right	2693	2544	149	2683	2599	84
M		Left	2689	2694	-5	2680	2660	20
N	Rear to Firewall	Right	2946	2620	326			
O		Left	2946	3089	-143			
	Rear to Steering Column		2314	2170	144	2194	2137	57
	Centre of Steering Column to A Pillar		387	359	28			
	Centre of Steering Column to headlining		459	506	-47	437	522	-85
P	Total Length	Right	3957	3339	618			
Q		Left	3950	3968	-18			
R	Length of Engine Block		180	180	0			

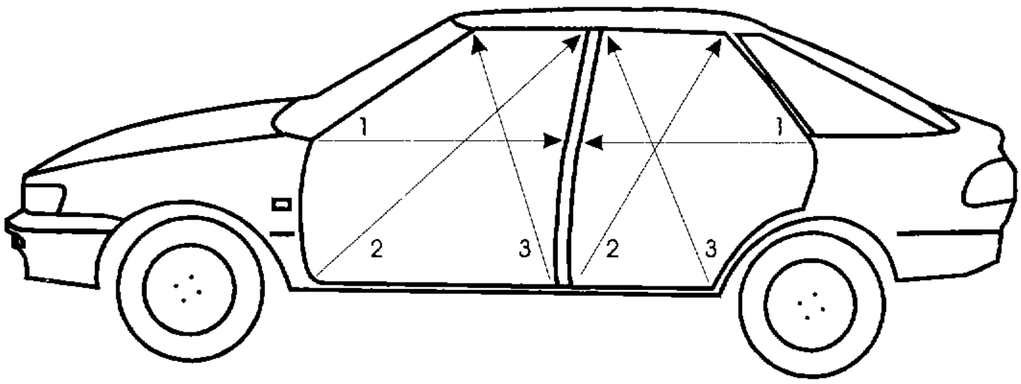
			B5019 Vehicle 1 (Corolla)			B5019 Vehicle 2 (Laser)		
	Measurement (mm)	Side	Pre-Test	Post Test	Crush	Pre-Test	Post Test	Crush
A	Total Length	Centre	4017	3801	216			
B	Rear to Front of Engine	Centre	3513	3199	314			
C	Rear to Firewall	Centre	2981	2841	140			
D	Rear to Upper leading edge, front door	Right	2092	1998	94			
E		Left	2088	2090	-2			
F	Rear to Lower leading edge, front door	Right	2681	2524	157			
G		Left	2672	2680	-8			
H	Rear to Upper trailing edge, front door	Right	1627	1633	-6			
I		Left	1627	1623	4			
J	Rear to Lower trailing edge, front door	Right	1713	1681	32			
K		Left	1707	1712	-5			
L	Rear to Bottom of A Pillar	Right	2681	2570	111	2632	2543	89
M		Left	2672	2672	0	2097	2625	-528
N	Rear to Firewall	Right	2950	2826	124			
O		Left	2944	2910	34			
	Rear to Steering Column		2310	2187	123	2206	2157	49
	Centre of Steering Column to A Pillar		408	373	35			
	Centre of Steering Column to headlining					418	434	-16
P	Total Length	Right						
Q		Left						
R	Length of Engine Block		180	180	0			

			B5020 Vehicle 1 (LHD Cor)			B5020 Vehicle 2 (LHD Cor)		
	Measurement (mm)	Side	Pre-Test	Post Test	Crush	Pre-Test	Post Test	Crush
A	Total Length	Centre	3999	3813	186	3953	3776	177
B	Rear to Front of Engine	Centre	3512	3334	178	3518	3331	187
C	Rear to Firewall	Centre	2981	2878	103	2988	2888	100
D	Rear to Upper leading edge, front door	Right	2087	2089	-2	2093	2097	-4
E		Left	2090	1989	101	2088	2014	74
F	Rear to Lower leading edge, front door	Right	2685	2695	-10	2690	2688	2
G		Left	2674	2433	241	2679	2420	259
H	Rear to Upper trailing edge, front door	Right	1626	1625	1	1628	1630	-2
I		Left	1631	1639	-8	1623	1625	-2
J	Rear to Lower trailing edge, front door	Right	1716	1723	-7	1721	1709	12
K		Left	1710	1693	17	1716	1697	19
L	Rear to Bottom of A Pillar	Right	2685	2691	-6	2690	2678	12
M		Left	2674	2453	221	2677	2402	275
N	Rear to Firewall	Right	2944	2893	51	2953	2901	52
O		Left	2948	2716	232	2950	2688	262
	Rear to Steering Column		2315	2188	127	2313	2176	137
	Centre of Steering Column to A Pillar		524	475	49	540	494	46
	Centre of Steering Column to headlining							
P	Total Length	Right						
Q		Left						
R	Length of Engine Block		180	180	0	180	180	0

			B6026 (LHD – Barrier)		
	Measurement (mm)	Side	Pre-Test	Post Test	Crush
A	Total Length	Centre	4002	3520	482
B	Rear to Front of Engine	Centre	3512	3308	204
C	Rear to Firewall	Centre	2984	2885	99
D	Rear to Upper leading edge, front door	Right	2091	2086	5
E		Left	2093	2011	82
F	Rear to Lower leading edge, front door	Right	2684	2692	-8
G		Left	2679	2645	34
H	Rear to Upper trailing edge, front door	Right	1624	1631	-7
I		Left	1622	1562	60
J	Rear to Lower trailing edge, front door	Right	1717	1718	-1
K		Left	1711	1710	1
L	Rear to Bottom of A Pillar	Right	2768	2777	-9
M		Left	2764	2713	51
N	Rear to Firewall	Right	2943	2880	63
O		Left	2943	2749	194
	Rear to Steering Column		2381	2283	98
	Centre of Steering Column to A Pillar		500	462	38
	Centre of Steering Column to headlining				
P	Total Length	Right			
Q		Left			
R	Length of Engine Block		180	180	0

			B5021 (Mod Barrier 1)			B5028 (Mod Barrier 2)		
	Measurement (mm)	Side	Pre-Test	Post Test	Crush	Pre-Test	Post Test	Crush
A	Total Length	Centre	4022	3884	138	4013	3877	136
B	Rear to Front of Engine	Centre	3518	3029	489	3518	3169	349
C	Rear to Firewall	Centre	2984	2552	432	2987	2751	236
D	Rear to Upper leading edge, front door	Right	2096	1998	98	2096	2057	39
E		Left	2089	2089	0	2090	2093	-3
F	Rear to Lower leading edge, front door	Right	2683	2461	222	2681	2578	103
G		Left	2672	2689	-17	2671	2677	-6
H	Rear to Upper trailing edge, front door	Right	1633	1640	-7	1631	1646	-15
I		Left	1627	1622	5	1625	1629	-4
J	Rear to Lower trailing edge, front door	Right	1716	1687	29	1711	1668	43
K		Left	1708	1716	-8	1702	1709	-7
L	Rear to Bottom of A Pillar	Right	2683	2498	185	2680	2578	102
M		Left	2672	2683	-11	2671	2673	-2
N	Rear to Firewall	Right	2947	2552	395	2950	1676	1274
O		Left	2947	2803	144	2943	2876	67
	Rear to Steering Column		2307	2061	246	2311	2196	115
	Centre of Steering Column to A Pillar		525	485	40	508	437	71
	Centre of Steering Column to headlining							
P	Total Length	Right	3203	2799	404	3198	2893	305
Q		Left	3188	3268	-80	3185	3264	-79
R	Length of Engine Block		400	400	0	400	400	0

Door Opening Width:



Measurement (mm)	B3014 (40% Offset) Pre-test	Post-test	Diff.	B3015 (50% Offset) Pre-test	Post-test	Diff.
Left Front 1	956	955	1	958	951	7
2	1390	1388	2	1390	1387	3
3	950	952	-2	945	948	-3
Right Front 1	960	859	101	958	903	55
2	1388	1322	66	1385	1356	29
3	944	1046	-102	953	1026	-73
Left Rear 1	824	823	1	824	823	1
2	1090	1087	3	1082	1085	-3
3	1010	1009	1	1009	1011	-2
Right Rear 1	824	820	4	822	822	0
2	1089	1078	11	1086	1082	4
3	1010	1006	4	1013	1009	4

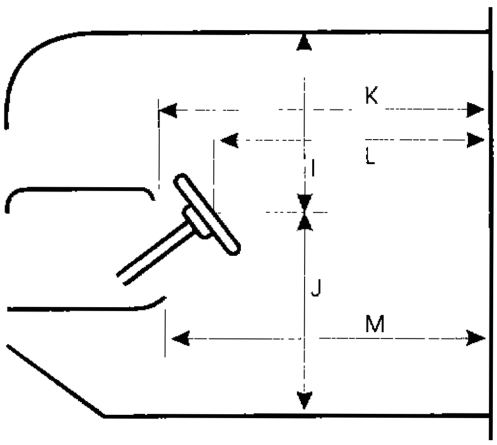
Measurement (mm)	B4009 Vehicle 1 Pre-test	Post-test	Diff.	B4009 Vehicle 2 Pre-test	Post-test	Diff.	B4054 Pre-test	Post-test	Diff.
Left Front 1	934	934	0	926	928	-2	922	916	6
2	1385	1385	0	1378	1379	-1	1380	1383	-3
3	947	945	2	935	942	-7	945	942	3
Right Front 1	938	831	107	930	760	170	921	761	160
2	1380	1292	88	1388	1203	185	1380	1233	147
3	944	1057	-113	940	1105	-165	933	1058	-125
Left Rear 1	816	816	0	807	812	-5	816	820	-4
2	1079	1079	0	1075	1073	2	1078	1082	-4
3	1001	1003	-2	997	1001	-4	993	994	-1
Right Rear 1	834	830	4	813	810	3	812	808	4
2	1082	1083	-1	1083	985	98	1067	1058	9
3	1002	993	9	991	1075	-84	1003	998	5

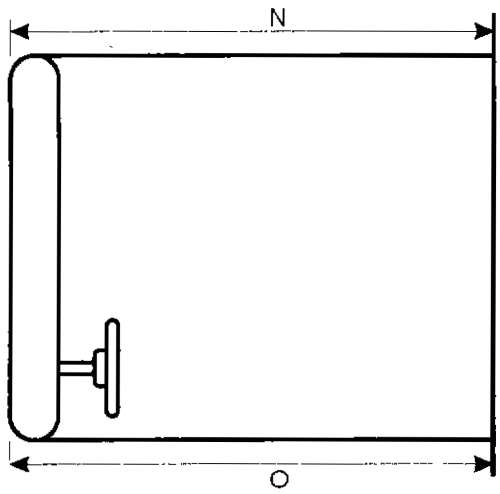
	B5008 (Laser – Barrier)			B5019 Vehicle 1 (Corolla)			B5019 Vehicle 2 (Laser)		
Measurement (mm)	Pre-test	Post-test	Diff.	Pre-test	Post-test	Diff.	Pre-test	Post-test	Diff.
Left Front 1	950	950	0	917	919	-2	943	943	0
2	1415	1410	5	1376	1380	-4	1415	1415	0
3	973	970	3	942	947	-5	965	965	0
Right Front 1	955	883	72	915	763	152	945	809	136
2	1412	1402	10	1387	1220	167	1425	1350	75
3	972	1013	-41	940	1073	-133	970	1049	-79
Left Rear 1	884	883	1	822	825	-3	900	890	10
2	1102	1101	1	1082	1081	1	1110	1107	3
3	1065	1057	8	1003	1009	-6	1058	1059	-1
Right Rear 1	884	879	5	827	821	6	900	890	10
2	1105	1102	3	1081	1082	-1	1110	1102	8
3	1061	1057	4	1002	995	7	1060	1062	-2

	B5020 Vehicle 1 (LHD)			B5020 Vehicle 2 (LHD)			B6026 (LHD Corolla)		
Measurement (mm)	Pre-test	Post-test	Diff.	Pre-test	Post-test	Diff.	Pre-test	Post-test	Diff.
Left Front 1	920	713	207	929	716	213	930	817	113
2	1386	1167	219	1385	1182	203	1395	1312	83
3	937	1066	-129	944	1085	-141	934	1032	-98
Right Front 1	915	921	-6	928	938	-10	924	924	0
2	1380	1382	-2	1383	1386	-3	1388	1389	-1
3	942	948	-6	940	945	-5	943	940	3
Left Rear 1	823	820	3	820	818	2	823	823	0
2	1084	1076	8	1081	1077	4	1080	1080	0
3	1005	1005	0	1002	1000	2	1009	1002	7
Right Rear 1	823	827	-4	825	827	-2	824	825	-1
2	1086	1082	4	1085	1087	-2	1079	1083	-4
3	1006	1006	0	1005	1007	-2	1009	1005	4

	B5021 (Mod Barrier 1)			B5028 (Mod Barrier 2)		
Measurement (mm)	Pre-test	Post-test	Diff.	Pre-test	Post-test	Diff.
Left Front 1	920	920	0	925	922	3
2	1382	1383	-1	1384	1387	-3
3	941	947	-6	935	937	-2
Right Front 1	915	691	224	918	773	145
2	1386	1203	183	1387	1279	108
3	946	1107	-161	946	1067	-121
Left Rear 1	821	821	0	817	819	-2
2	1082	1084	-2	1078	1083	-5
3	996	1003	-7	1005	1005	0
Right Rear 1	822	822	0	820	819	1
2	1081	1077	4	1085	1077	8
3	1009	1003	6	1008	1005	3

Driver Compartment Intrusion





Measurement (mm)	B3014			B3015		
	Pre-Test	Post Test	Diff.	Pre-Test	Post Test	Diff.
I	401	494	-93	403	473	-70
J	612	692	-80	615	658	-43
K	2390	2269	121	2388	2272	116
L	2231	2109	122	2226	2134	92
M	2558	2280	278	2551	2480	71
N	2657	2635	22	2656	2647	9
O	2654	2504	150	2657	2511	146

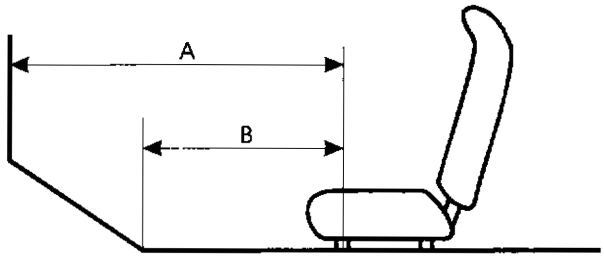
Measurement (mm)	B4009 Vehicle 1			B4009 Vehicle 2			B4054		
	Pre-Test	Post Test	Diff.	Pre-Test	Post Test	Diff.	Pre-Test	Post Test	Diff.
I	435	490	-55	482	466	16	Not Recorded		
J	650	709	-59	613	760	-147			
K	2382	2274	108	2382	2274	108			
L	2235	2134	101	2215	2129	86			
M	2396	2244	152	2394	2212	182			
N	2627	2705	-78	2637	2644	-7			
O	2642	2490	152	2643	2477	166			

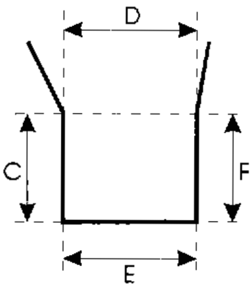
Measurement (mm)	B5008			B5019 Vehicle 1			B5019 Vehicle 2		
	Pre-Test	Post Test	Diff.	Pre-Test	Post Test	Diff.	Pre-Test	Post Test	Diff.
I	Not Recorded			439	455	-16	Not Recorded		
J				660	742	-82			
K				711	549	162			
L				550	437	113			
M				727	596	131			
N				957	950	7			
O				957	752	205			

Measurement (mm)	B5020 Vehicle 1			B5020 Vehicle 2			B6026		
	Pre-Test	Post Test	Diff.	Pre-Test	Post Test	Diff.	Pre-Test	Post Test	Diff.
I	339	430	-91	441	460	-19	382	503	-121
J	655	715	-60	640	690	-50	725	680	45
K	705	544	161	707	567	140	670	554	116
L	545	413	132	549	420	129	517	410	107
M	726	555	171	722	530	192	694	572	122
N	940	938	2	942	941	1	905	773	132
O	945	738	207	936	744	192	915	887	28

Measurement (mm)	B5021			B5028		
	Pre-Test	Post Test	Diff.	Pre-Test	Post Test	Diff.
I	442	463	-21	440	445	-5
J	655	720	-65	650	730	-80
K	708	469	239	669	492	177
L	549	293	256	509	385	124
M	724	358	366	662	510	152
N	938	921	17	897	880	17
O	945	631	314	900	699	201

Footwell Deformation:





Measurement (mm)	B3014			B3015		
	Pre-Test	Post Test	Diff.	Pre-Test	Post Test	Diff.
A	644	588	56	658	599	59
B	605	552	53	557	538	19
C						
D						
E						
F						

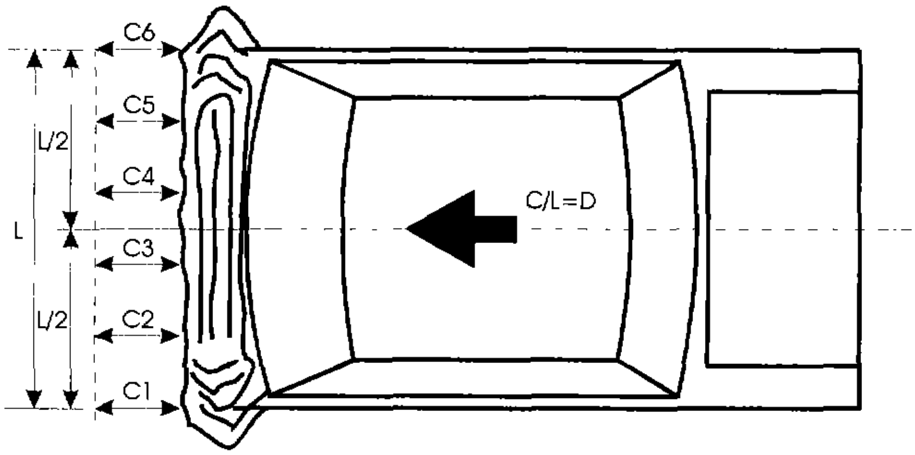
Measurement (mm)	B4009 Vehicle 1			B4009 Vehicle 2			B4054		
	Pre-Test	Post Test	Diff.	Pre-Test	Post Test	Diff.	Pre-Test	Post Test	Diff.
A	755	634	121	755	588	167	737	546	191
B	587	522	65	586	486	100	539	411	128
C							552	487	65
D							450	414	36
E							450	455	-5
F							491	388	103

Measurement (mm)	B5008			B5019 Vehicle 1			B5019 Vehicle 2		
	Pre-Test	Post Test	Diff.	Pre-Test	Post Test	Diff.	Pre-Test	Post Test	Diff.
A		Not Recorded		770	578	192	764	504	260
B				550	430	120	568	420	148
C				545	445	100	572	485	87
D				410	392	18	382	330	52
E				450	455	-5	380	380	0
F				515	440	75	518	355	163

Measurement (mm)	B5020 Vehicle 1			B502 Vehicle 2			B6026		
	Pre-Test	Post Test	Diff.	Pre-Test	Post Test	Diff.	Pre-Test	Post Test	Diff.
A	758	427	331	753	383	370	735	482	253
B	570	335	235	550	268	282	572	423	149
C	505	297	208	550	290	260	532	471	61
D	400	395	5	400	396	4	400	375	25
E	455	465	-10	455	460	-5	455	455	0
F	570	375	195	570	350	220	539	415	124

Measurement (mm)	B5021			B5028		
	Pre-Test	Post Test	Diff.	Pre-Test	Post Test	Diff.
A	740	417	323	720	495	225
B	550	363	187	558	440	118
C	555	373	182	560	440	120
D	400	381	19	395	400	-5
E	450	455	-5	455	455	0
F	540	371	169	560	475	85

Frontal Crush Measurement



Measurement (mm)	B3014			B3015		
	Pre-Test	Post Test	Crush	Pre-Test	Post Test	Crush
L	1335			1333		
L/2 – Left	4019			4022		
L/2 – Right						
C1	3945	3919	26	3950	3926	24
C2	4002	3764	238	4004	3669	335
C3	4018	3561	457	4018	3564	454
C4	4018	3410	608	4017	3539	478
C5	4002	3383	619	4005	3494	511
C6	3949	3312	637	3955	3436	519

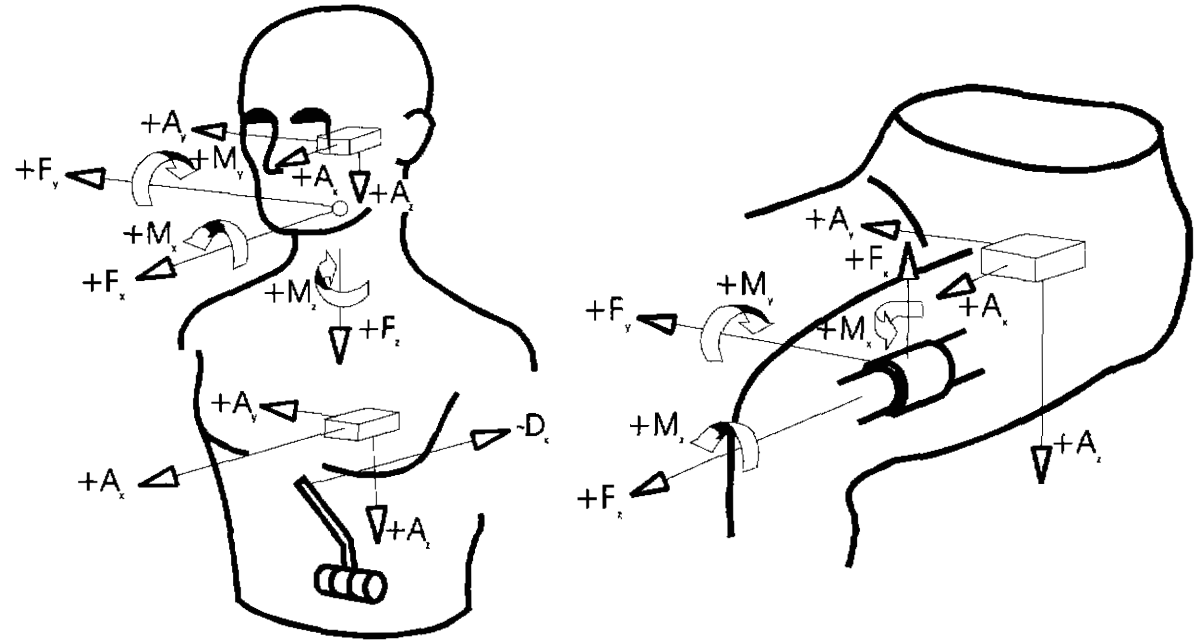
Measurement (mm)	B4009 Vehicle 1			B4009 Vehicle 2			B4054		
	Pre-Test	Post Test	Crush	Pre-Test	Post Test	Crush	Pre-Test	Post Test	Crush
L	1328	1063	265	1331	1036	295	1345	1019	326
L/2 – Left	664			665.5			672.5	145	527.5
L/2 – Right							672.5	874	-201.5
C1	3951	3957	-6	3951	3945	6	3951	3968	-17
C2	4010	3814	196	4007	3795	212	4009	3787	222
C3	4028	3677	351	4025	3608	417	4027	3560	467
C4	4022	3515	507	4022	3426	596	4022	3432	590
C5	4006	3367	639	4008	3259	749	4009	3417	592
C6	3950	3256	694	3952	3130	822	3957	3339	618

Measurement (mm)	B5008			B5019 Vehicle 1			B5019 Vehicle 2		
	Pre-Test	Post Test	Crush	Pre-Test	Post Test	Crush	Pre-Test	Post Test	Crush
L	1360	1254	106	1338	1102	236	1364	1234	130
L/2 – Left	680	481	199	669	301	368	682	397	285
L/2 – Right	680	773	-93	669	801	-132	682	837	-155
C1	3809	3829	-20	3945	3942	3	3809	3856	-47
C2	3937	3763	174	4005	3847	158	3935	3791	144
C3	3971	3617	354	4021	3722	299	3978	3626	352
C4	3962	3460	502	4017	3475	542	3965	3431	534
C5	3930	3299	631	4004	3334	670	3927	3259	668
C6	3810	3279	531	3953	3221	732	3804	3231	573

Measurement (mm)	B5020 Vehicle 1			B5020 Vehicle 2			B6026		
	Pre-Test	Post Test	Crush	Pre-Test	Post Test	Crush	Pre-Test	Post Test	Crush
L	1335	1083	252	1340	1064	276			
L/2 – Left	667.5	871	-203.5	670	818	-148			
L/2 – Right	667.5	212	455.5	670	246	424			
C1	3872	3206	666	3874	2978	896	3959	3362	597
C2	3934	3290	644	3939	3118	821	3998	3359	639
C3	3955	3476	479	3959	3350	609	4017	3463	554
C4	3948	3641	307	3953	3533	420	4004	3620	384
C5	3934	3808	126	3940	3703	237	3990	3800	190
C6	3875	3928	-53	3878	3848	30	3942	3964	-22

Measurement (mm)	B5021			B5028		
	Pre-Test	Post Test	Crush	Pre-Test	Post Test	Crush
L	1336	980	356	1339	1208	131
L/2 – Left	668	52	616	669.5	679	-9.5
L/2 – Right	668	928	-260	669.5	529	140.5
C1	3869	3901	-32	3944	3950	-6
C2	3933	3736	197	3997	3848	149
C3	3955	3545	410	4019	3666	353
C4	3949	3338	611	4014	3447	567
C5	3932	3238	694	3942	3289	653
C6	3873	3163	710	3949	3141	808

Appendix 5 – Dummy Injury Values



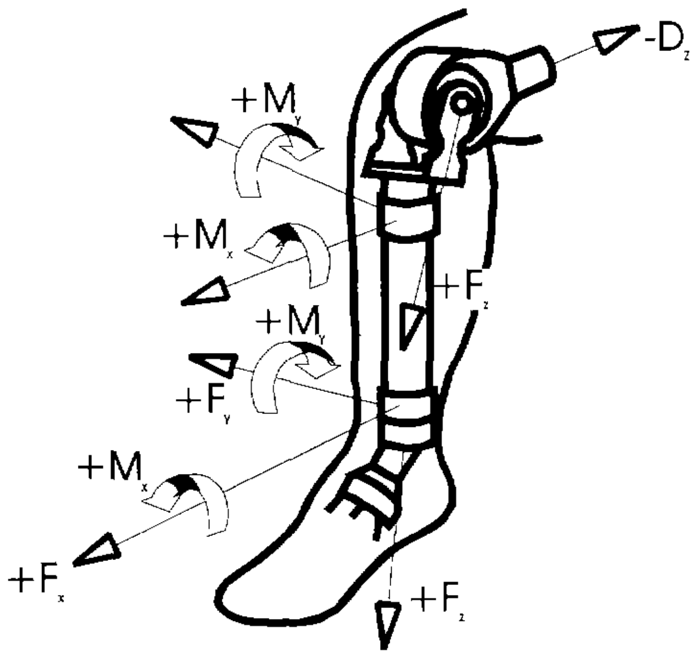
Driver Dummy:

	B3014	B3015	B4009 Vehicle 1	B4009 Vehicle 2	B4054	B5008	ADR 73 Limit
HPC	753.9	1221.0	674.5	1173.7	825.0	1356.9	1000
Head $A_{res\,3ms}$ (g)	76.3	86.2	61.4	101.9	77.0	87.3	80
Chest $A_{res\,3ms}$(g)	48.7	51.3	47.0	51.6	50.2	60.6	
Chest Compression (mm)	42.6	43.7	39.8	31.7	51.7	43.1	50
V*C (ms^{-1})	0.469	0.469	0.449	0.335	0.693	0.395	1.0
Neck Extension $M_{y\,max}$ (Nm)	36.4	48.6	53.5		31.7	42.1	57
Neck Flexion $M_{y\,min}$ (Nm)	-94.9	-99.0	-13.7		-18.2	-20.5	
Neck Tension $F_{z\,max}$ (kN)*	2.75	3.10	2.36		2.47		3.3*
Neck Shear $F_{x\,max}$ (kN)*	0.835	1.024	0.949		0.900	1.121	3.1*
Femur L (kN)*	-7.2	-8.1	-3.3	-13.7	-5.8	-2.6	-9.07*
Femur R (kN)*	-4.2	-8.4	-2.0	-1.8	-7.2	-3.7	-9.07*

* time dependent value

	B5019 Vehicle 1	B5019 Vehicle 2	B5020 Vehicle 1	B5020 Vehicle 2	B6026	B5021	B5028	ADR 73 Limit
HPC	1494 1	749.9	1110 8	1033.3	1524.0	1265.9	843.8	1000
Head $A_{res\ 3ms}$ (g)	133.0	60.1	113.7	115.9	116.9	97.9	75.6	80
Chest $A_{res\ 3ms}$(g)	53.6	52.9	40.3	46.0	54.0	54.6	44.8	
Chest Compression (mm)	37.5	30.4	13.1	14.6	43.0	45.7	45 4	50
V*C (ms^{-1})	0.597	0.277	0 057	0.045	0.589	0.865	0.729	1.0
Neck Extension $M_{y\ max}$ (Nm)	72.7	56.7	62.3	58.0	48.3	61.7	42.7	57
Neck Flexion $M_{y\ min}$ (Nm)	-45.4	-71.8	-48.7	-40.5	-43.0	-45.7	-42.1	
Neck Tension $F_{z\ max}$ (kN)*	2.32	2.36	1.97	2.25	3.15	2.49	2.29	3.3*
Neck Shear $F_{x\ max}$ (kN)*	1.155	1.224	0.844	0.885	0.735	1.065	0.889	3 1*
Femur L (kN)*	-15.1	-5.6	-1.3	-2.8	-3.0	-10.1	-6.6	-9 07*
Femur R (kN)*	-1.7	-3.3	-14.7	-4.3	-7.0	-12.3	-5.7	-9.07*

* time dependent value



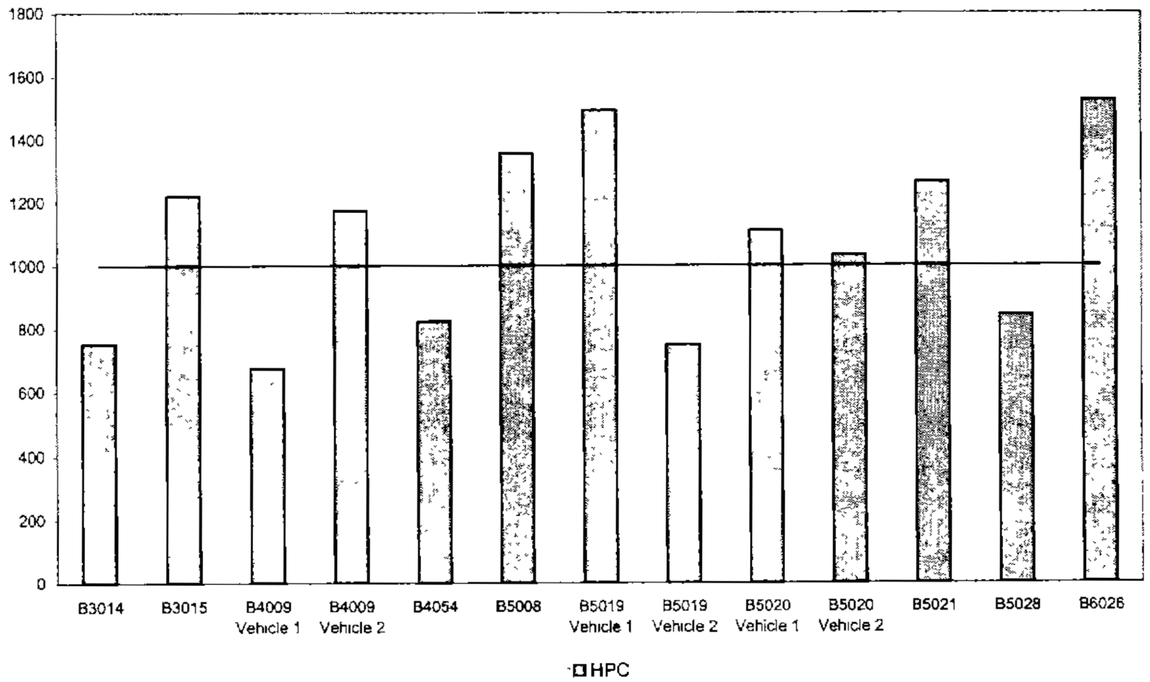
	B3014	B3015	B4009 Vehicle 1	B4009 Vehicle 2	B4054	B5008	ADR 73 Limit
Tibia $F_{z\ max}$ L kN	-1.99	-2.20	-3.05		-2.88	-3.11	8.0
Tibia $F_{z\ max}$ R kN	-1.76	-1.28	-2.37		-1.21	-2.84	8.0
TI_{upper} L	0.694	0.980	1.434		0.903	0.692	1.3
TI_{upper} R	0.496	0.360	0.715		0.509	0.533	1.3

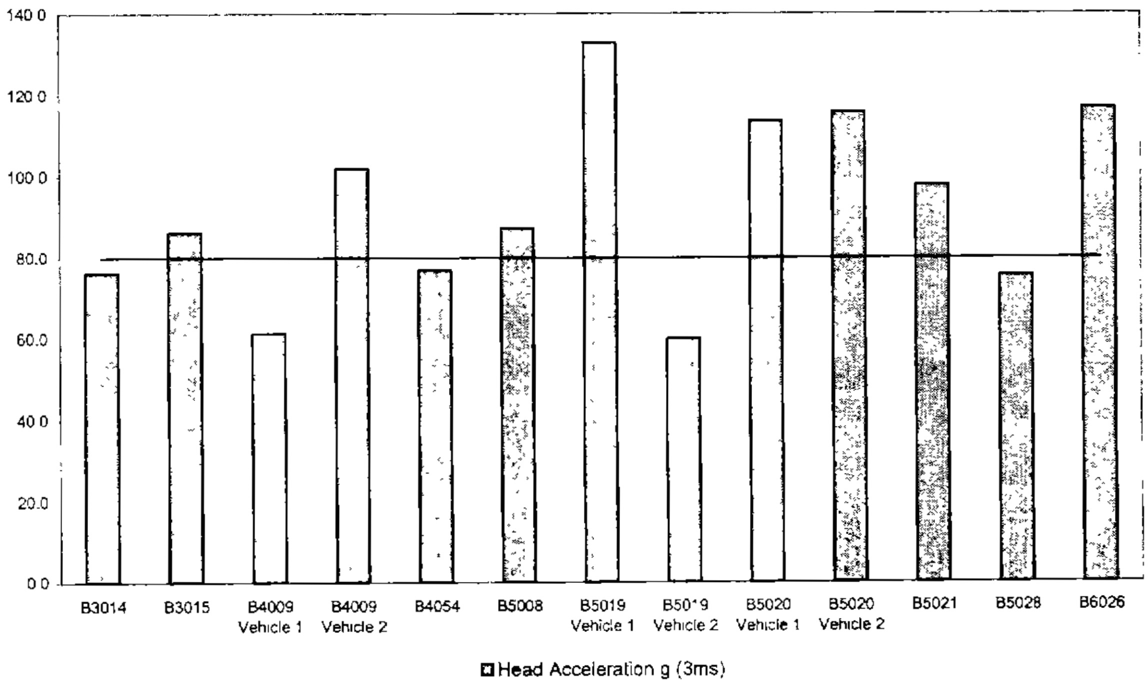
	B5019 Vehicle 1	B5019 Vehicle 2	B5020 Vehicle 1	B5020 Vehicle 2	B6026	B5021	B5028	ADR 73 Limit
Tibia $F_{z\ max}$ L	-6.97	-6.28	-2.92	-2.55	-1.59	-4.35	-4.28	8.0
Tibia $F_{z\ max}$ R	-2.05	-5.25	-6.92	-8.25	-4.94	-1.26	-1.08	8.0
TI_{upper} L					0.383	1.427	0.874	1.3
TI_{upper} R					1.394	0.470	0.409	1.3

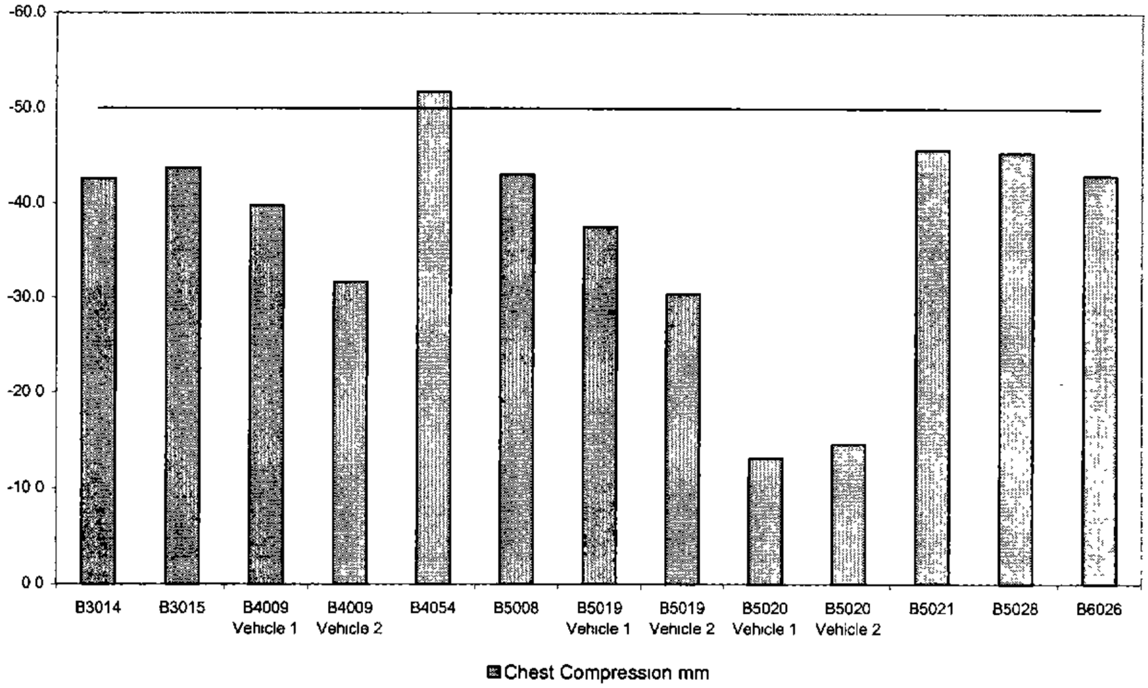
Passenger Dummy

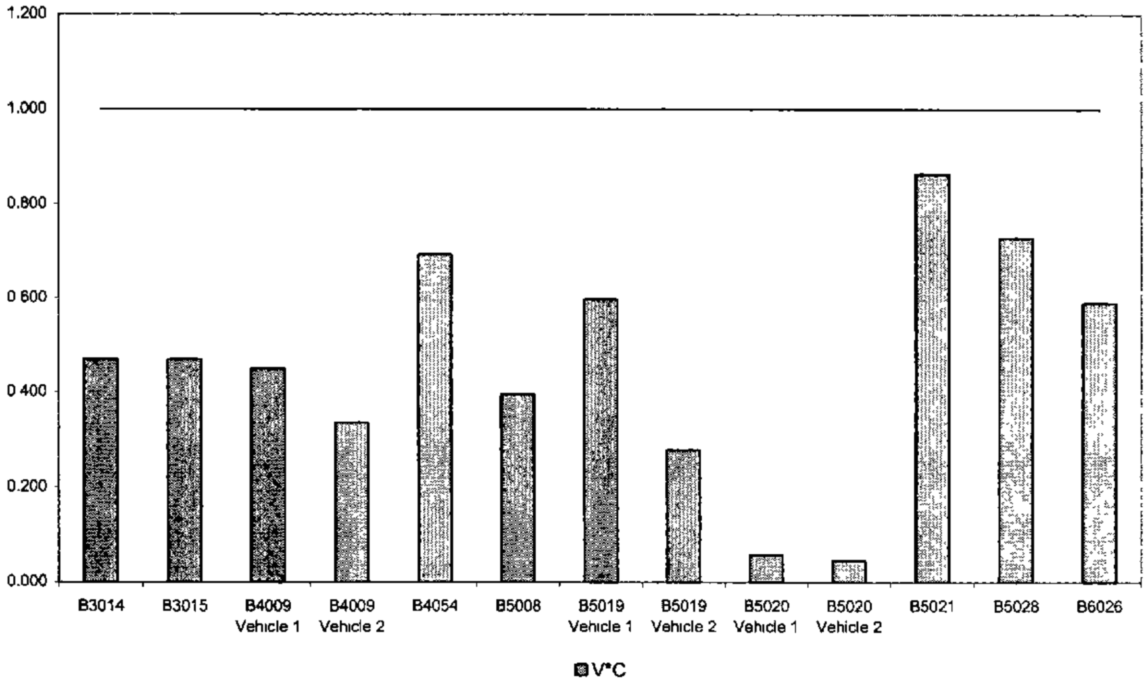
	B3014	B3015	B4054	B5008	B5021	B5028	B6026
HPC	555.2	671.0	245.0	334.2	666.8	365.8	817.0
Head $A_{res\ 3ms}$ (g)	54.5	56.8	60.8	45.7	56.7	43.6	84.9
Chest $A_{res\ 3ms}$(g)	36.4	35.7	33.5	40.8	38.0	33.1	39.1
Chest Compression (mm)	33.0	36.4	25.2	37.0	31.4	29.6	35.5
V*C (ms^{-1})	0.103	0.150	0.103	0.166	0.126	0.134	0.189
Neck Extension $M_{y\ max}$ (Nm)			21.9	33.8	34.1	29.3	32.4
Neck Flexion $M_{y\ min}$ (Nm)			-100.2	-54.6	-41.2	-69.3	-33.6
Neck Tension $F_{z\ max}$ (kN)*			1.15		2.32	1.79	2.11
Neck Shear $F_{x\ max}$ (kN)*			0.87	1.05	1.29	1.13	1.18
Femur L (kN)*	-0.8	-0.7			-1.1	-1.2	-2
Femur R (kN)*	-1.7	-1.5			-2.7	-2.4	-0.6

* time dependent value


1800
1600
1400
1200
1000
800
600
400
200
0
B3014
B3015
B4009 Vehicle 1
B4009 Vehicle 2
B4054
B5008
B5019 Vehicle 1
B5019 Vehicle 2
B5020 Vehicle 1
B5020 Vehicle 2
B5021
B5028
B6026
HPC


140 0
120 0
100 0
80.0
60.0
40 0
20.0
0 0
B3014
B3015
B4009 Vehicle 1
B4009 Vehicle 2
B4054
B5008
B5019 Vehicle 1
B50*9 Vehicle 2
B5020 Vehicle 1
B5020 Vehicle 2
B5021
B5028
B6026
Head Acceleration g (3ms)


-60.0
-50.0
-40.0
-30.0
-20 0
-10 0
0 0
B3014
B3015
B4009 Vehicle 1
B4009 Vehicle 2
B4054
B5008
B5019 Vehicle 1
B5019 Vehicle 2
B5020 Vehicle 1
B5020 Vehicle 2
B5021
B5028
B6026
Chest Compression mm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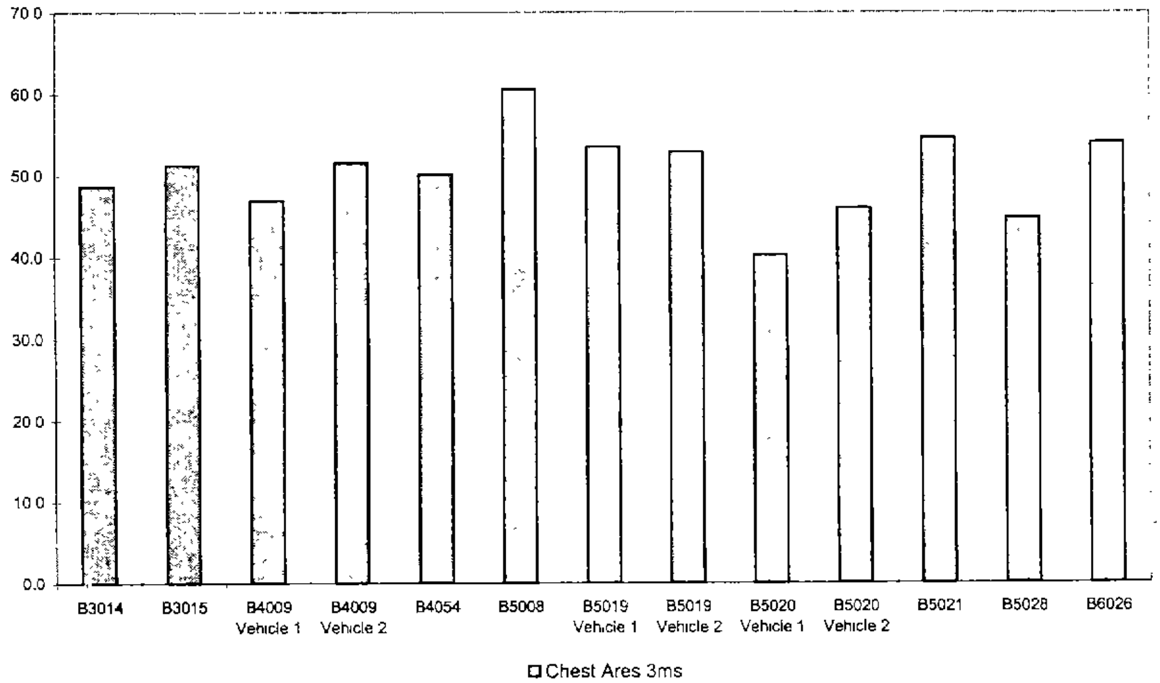
1.000
0.800
0 600
0 400
0.200
0.000
B3014
B3015
B4009 Vehicle 1
B4009 Vehicle 2
B4054
B5008
B5019 Vehicle 1
B5019 Vehicle 2
B5020 Vehicle 1
B5020 Vehicle 2
B5021
B5028
B6026
V*C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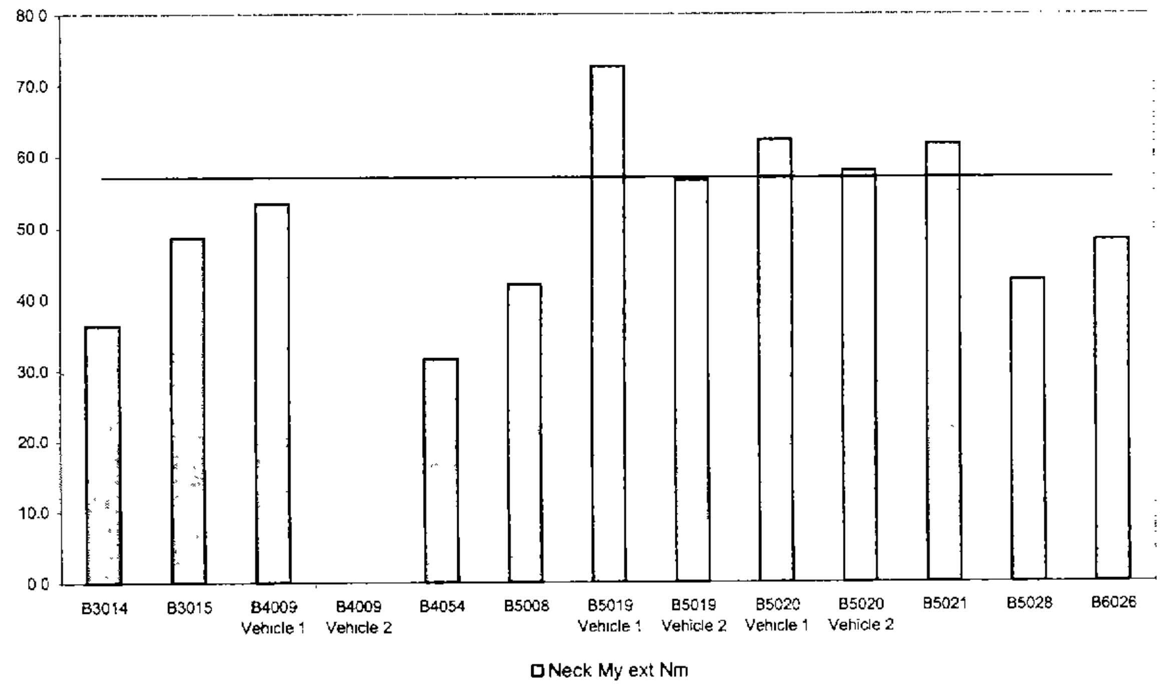
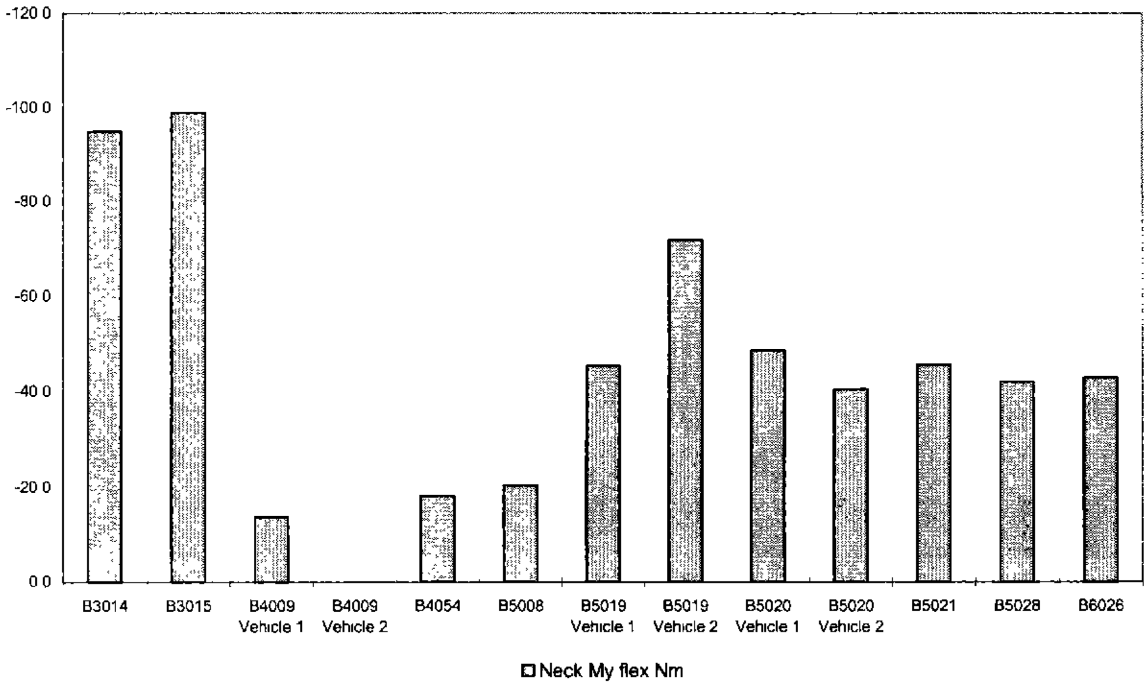
60 0
50 0
40.0
30.0
20 0
10 0
0.0
B3014
B3015
B4009 Vehicle 1
B4009 Vehicle 2
B4054
B5008
B5019 Vehicle 1
B5019 Vehicle 2
B5020 Vehicle 1
B5020 Vehicle 2
B5021
B5028
B6026
Chest Ares 3ms


80 0
70.0
60 0
50 0
40 0
30.0
20.0
10.0
0 0
B3014
B3015
B4009 Vehicle 1
B4009 Vehicle 2
B4054
B5008
B5019 Vehicle 1
B5019 Vehicle 2
B5020 Vehicle 1
B5020 Vehicle 2
B5021
B5028
B6026
Neck My ext Nm



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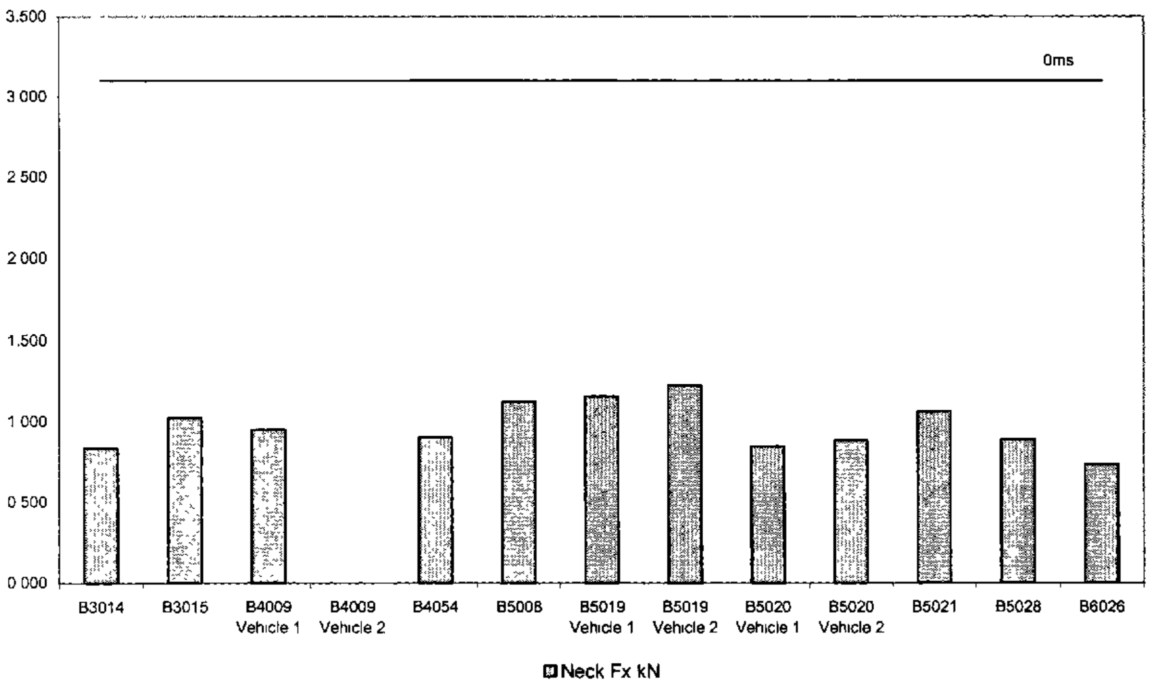
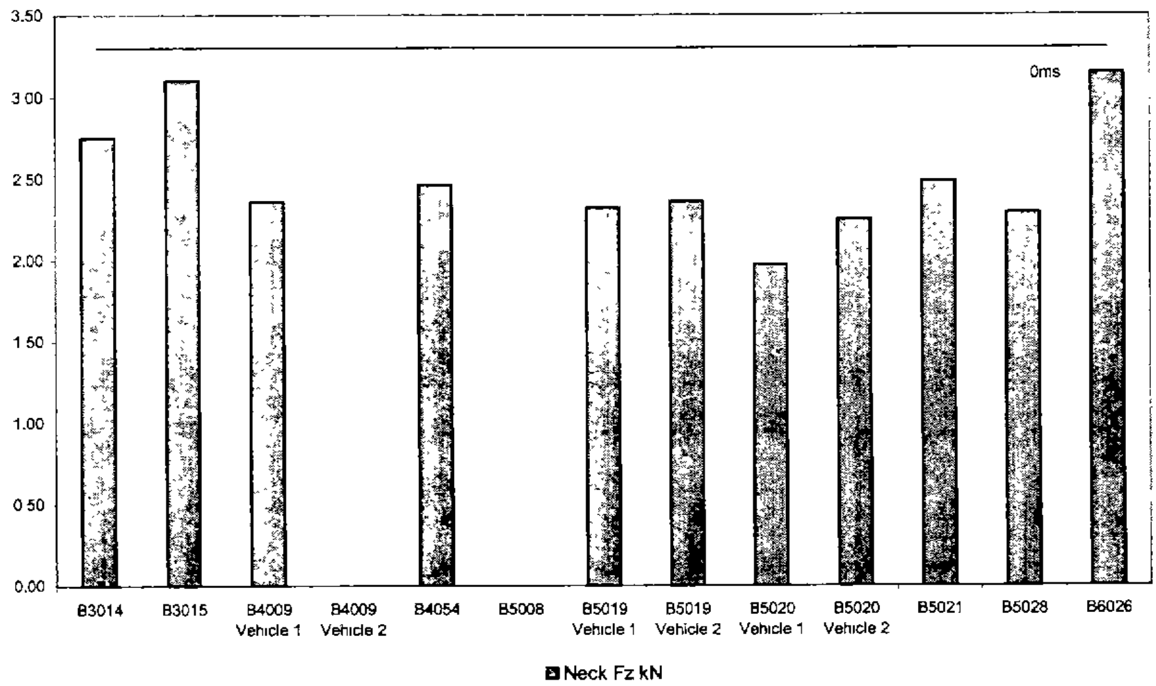
-100 0
-80 0
-60 0
-40 0
-20 0
0 0
B3014
B3015
B4009 Vehicle 1
B4009 Vehicle 2
B4054
B5008
B5019 Vehicle 1
B5019 Vehicle 2
B5020 Vehicle 1
B5020 Vehicle 2
B5021
B5028
B6026
Neck My flex Nm



3.500
3 000
2 500
2 000
1.500
1 000
0 500
0 000
0ms
B3014
B3015
B4009 Vehicle 1
B4009 Vehicle 2
B4054
B5008
B5019 Vehicle 1
B5019 Vehicle 2
B5020 Vehicle 1
B5020 Vehicle 2
B5021
B5028
B6026
Neck Fx kN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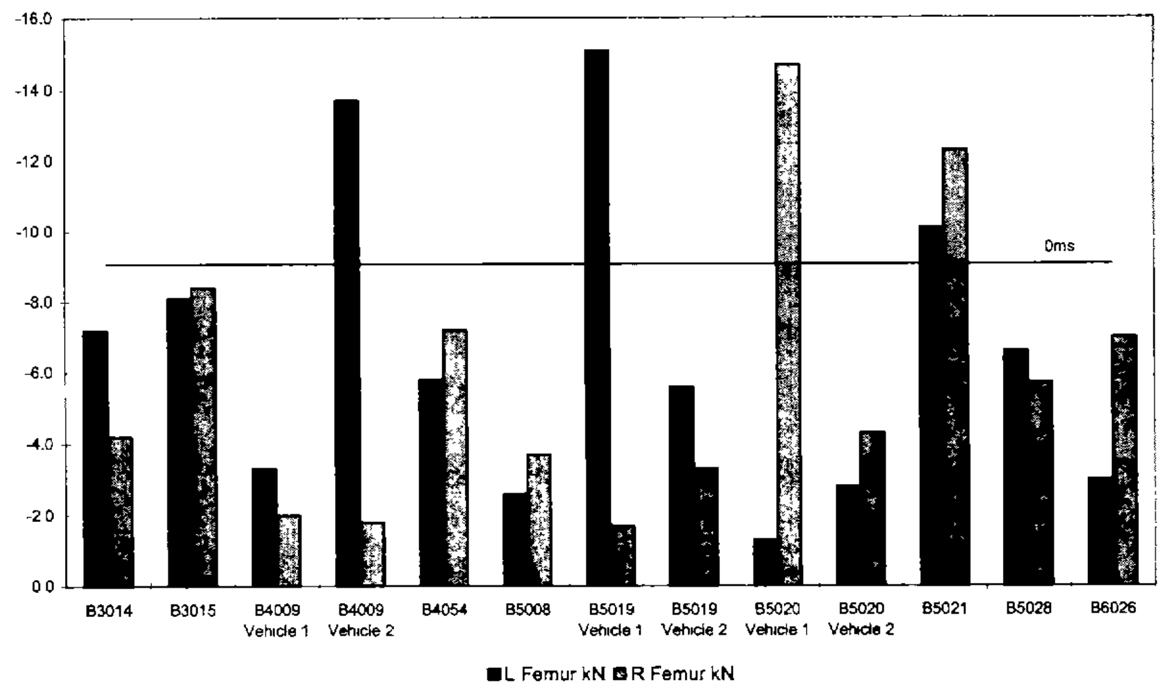
2.00
1 50
1.00
0 50
0.00
0ms
B3014
B3015
B4009 Vehicle 1
B4009 Vehicle 2
B4054
B5008
B5019 Vehicle 1
B5019 Vehicle 2
B5020 Vehicle 1
B5020 Vehicle 2
B5021
B5028
B6026
Neck Fz kN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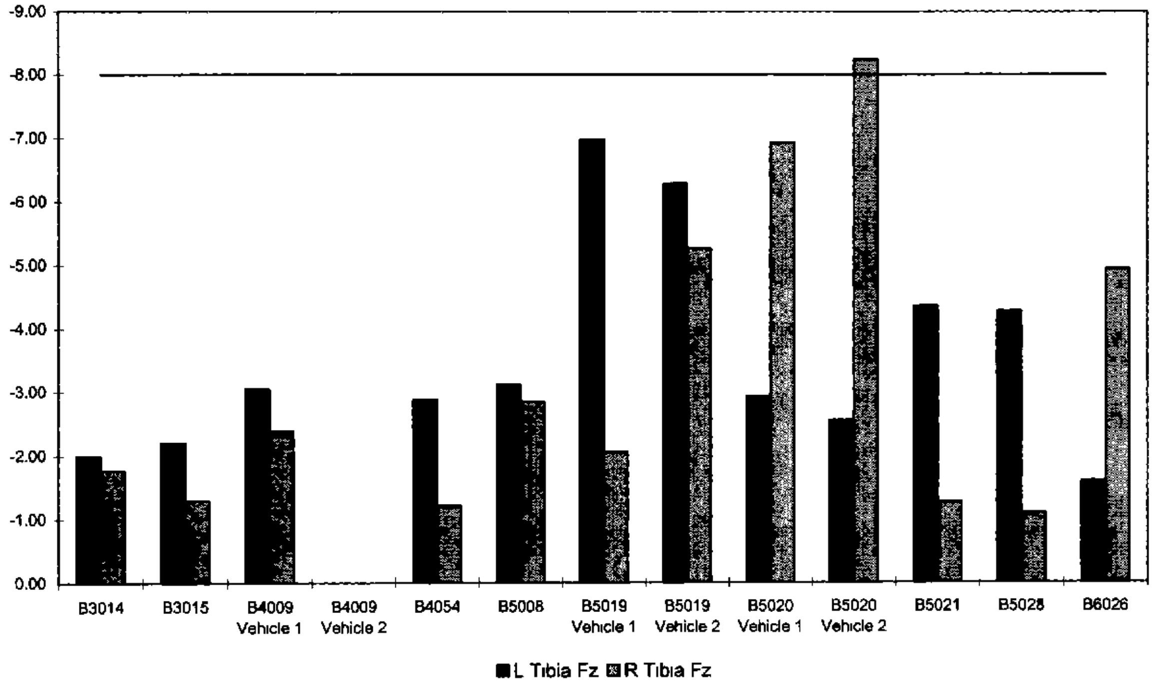
-8.0
-6.0
-4.0
-2 0
0 0
0ms
B3014
B3015
B4009 Vehicle 1
B4009 Vehicle 2
B4054
B5008
B5019 Vehicle 1
B5019 Vehicle 2
B5020 Vehicle 1
B5020 Vehicle 2
B5021
B5028
B6026
L Femur kN
R Femur kN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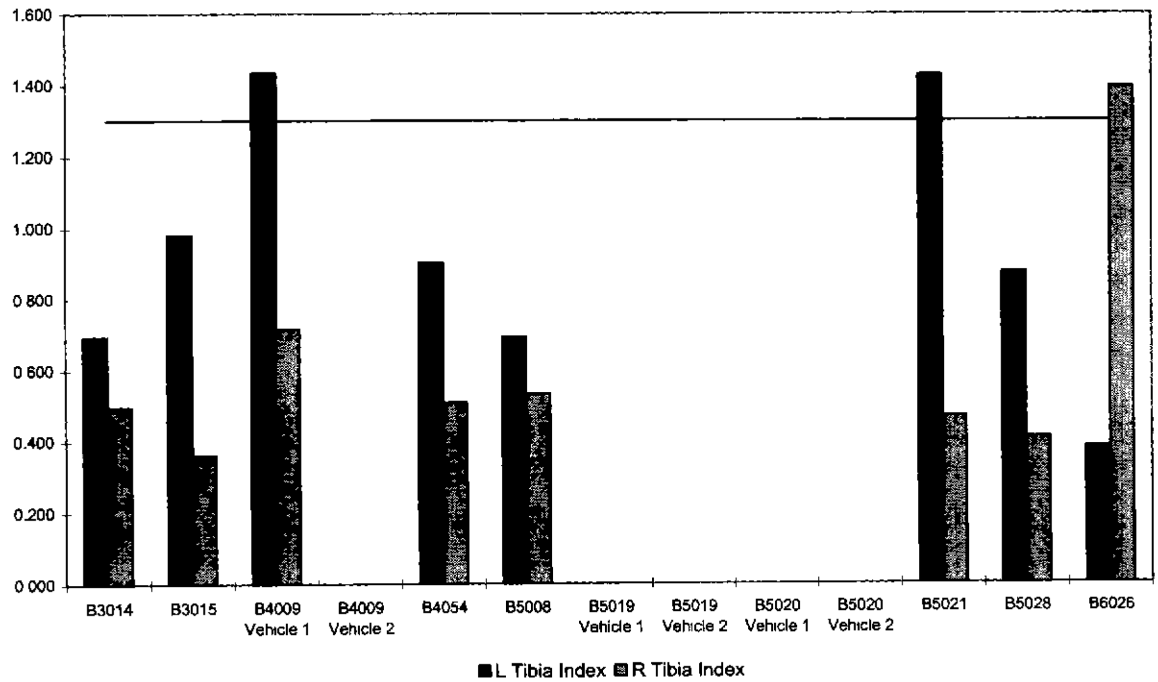
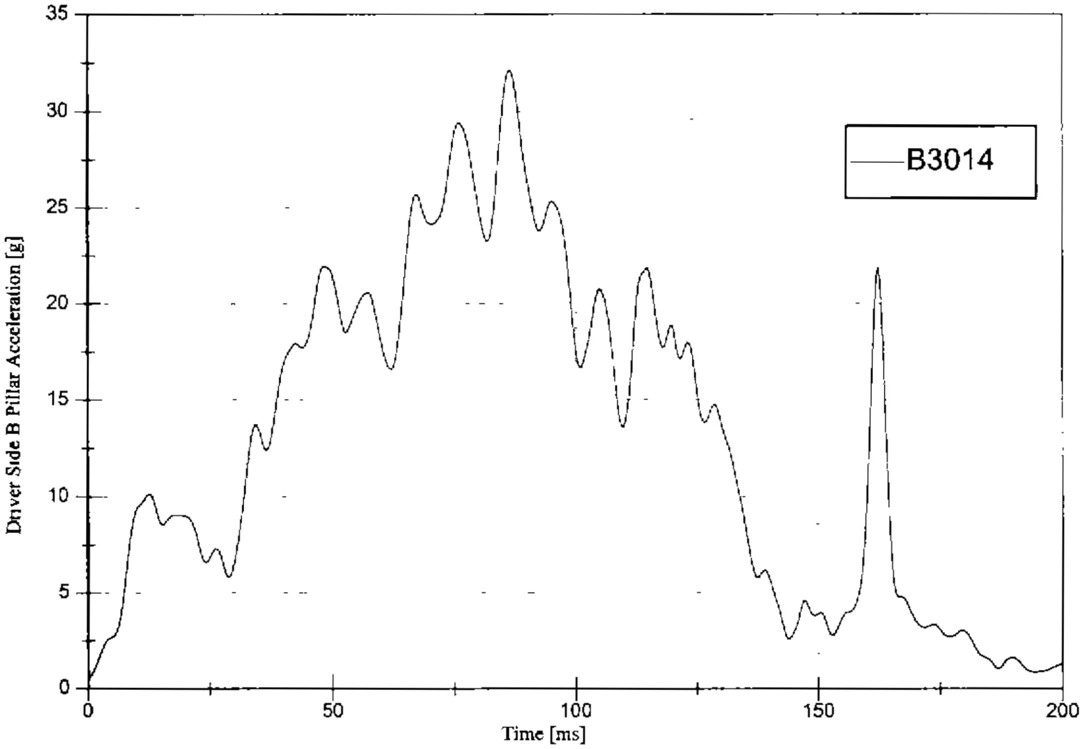
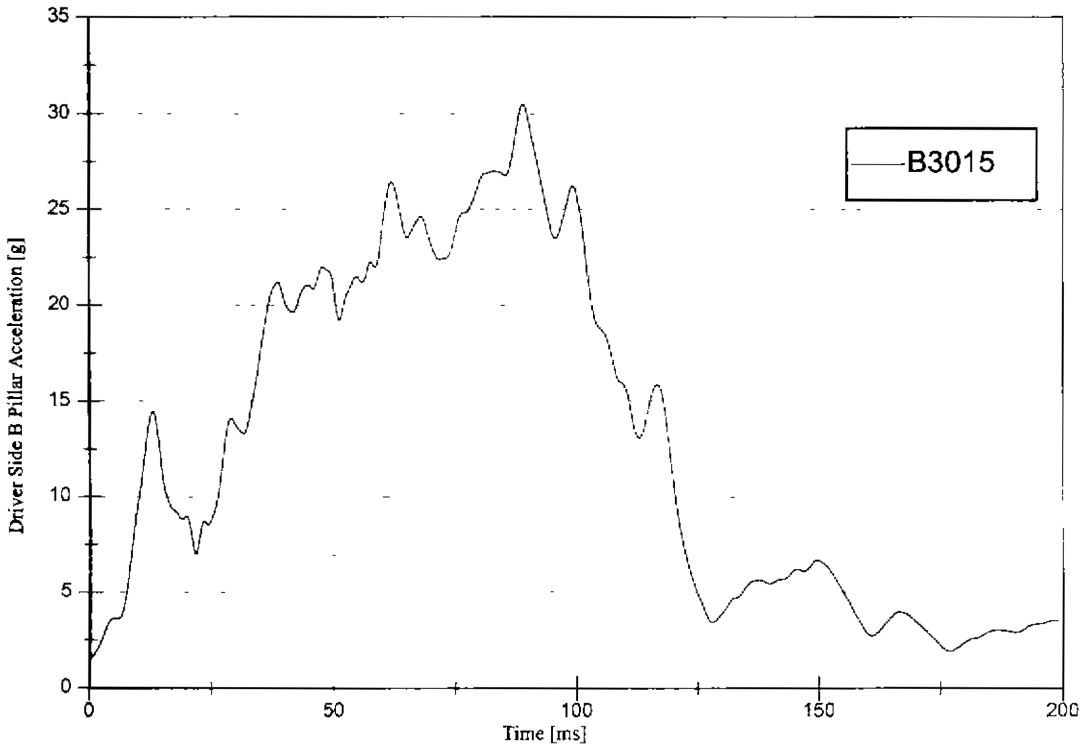
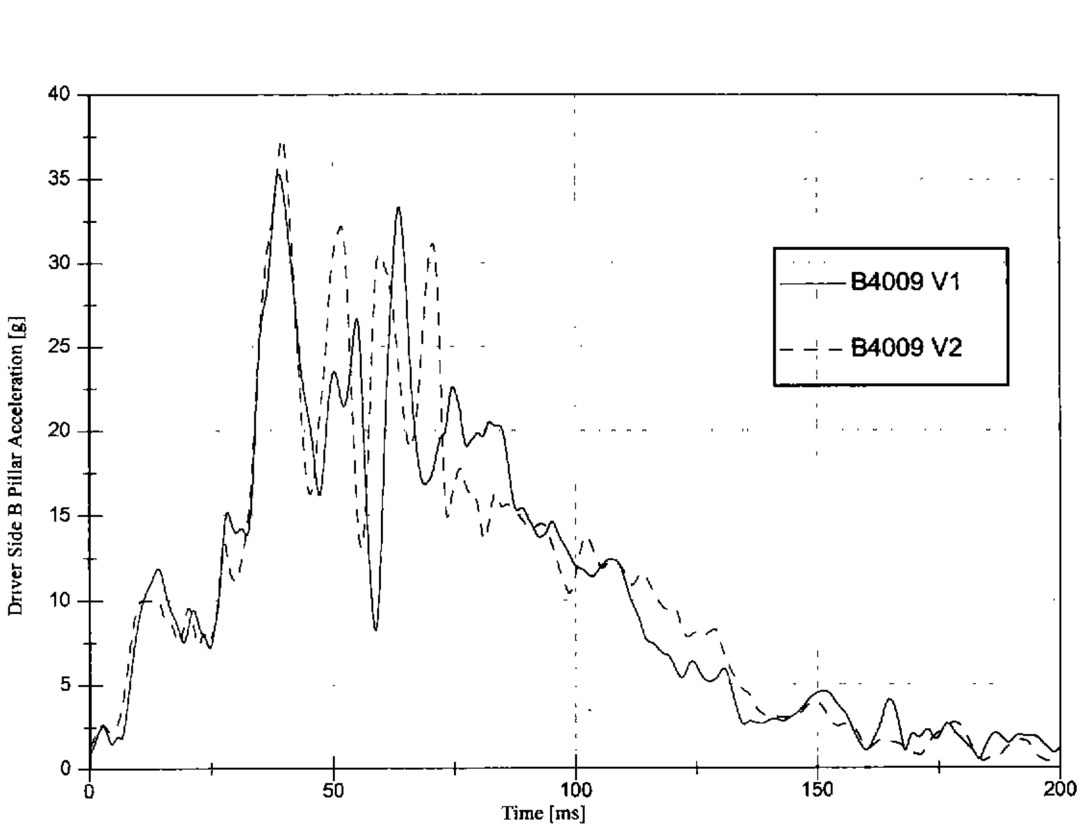
-8.00
-7.00
-6 00
-5.00
-4.00
-3.00
-2.00
-1.00
0.00
B3014
B3015
B4009 Vehicle 1
B4009 Vehicle 2
B4054
B5008
B5019 Vehicle 1
B5019 Vehicle 2
B5020 Vehicle 1
B5020 Vehicle 2
B5021
B5028
B6026
L Tibia Fz
R Tibia Fz


1.600
1.400
1.200
1.000
0 800
0 600
0.400
0.200
0 000
B3014
B3015
B4009 Vehicle 1
B4009 Vehicle 2
B4054
B5008
B5019 Vehicle 1
B5019 Vehicle 2
B5020 Vehicle 1
B5020 Vehicle 2
B5021
B5028
B6026
L Tibia Index
R Tibia Index

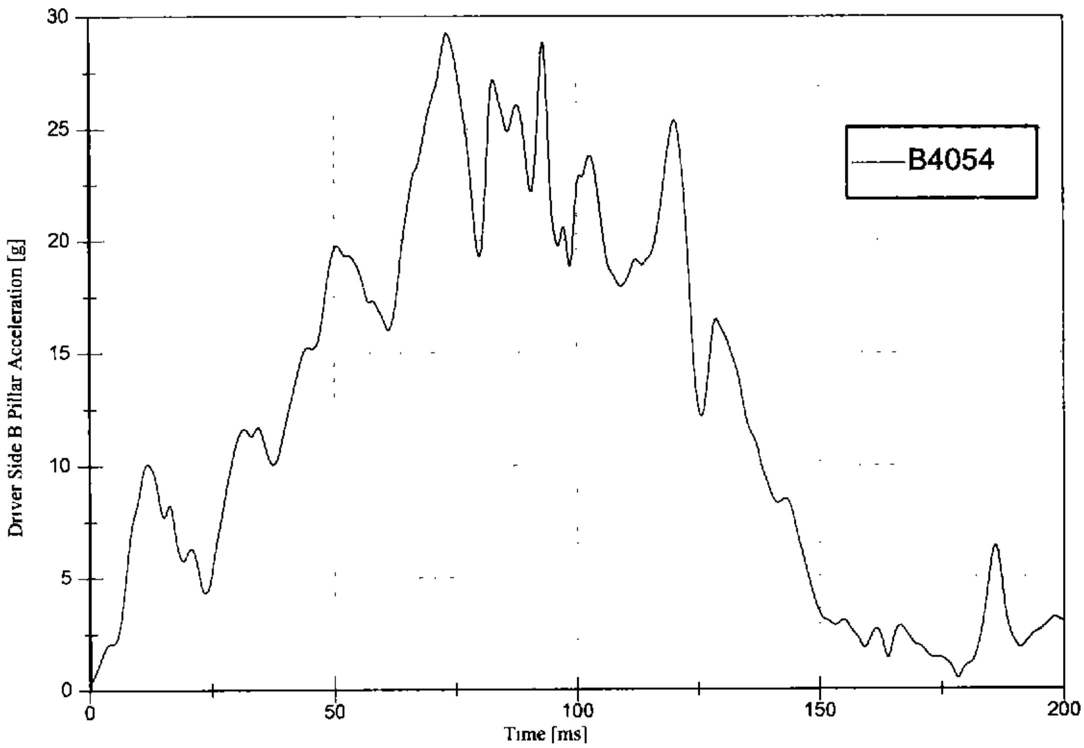
Appendix 6 – Vehicle Crash Pulses



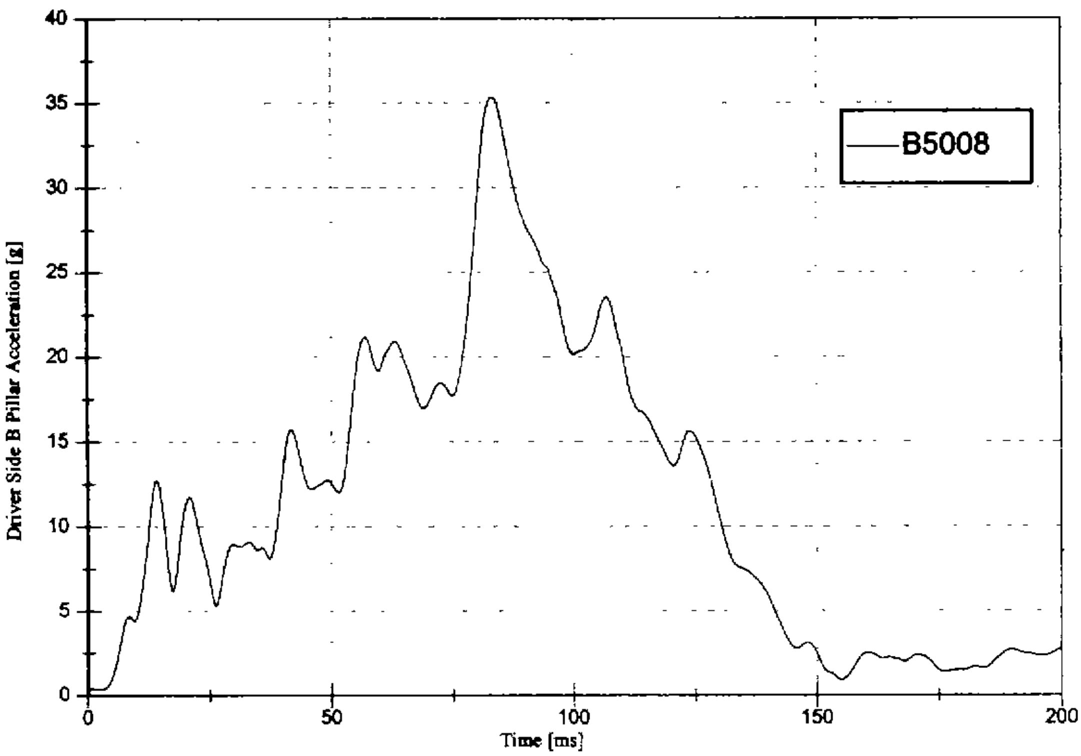


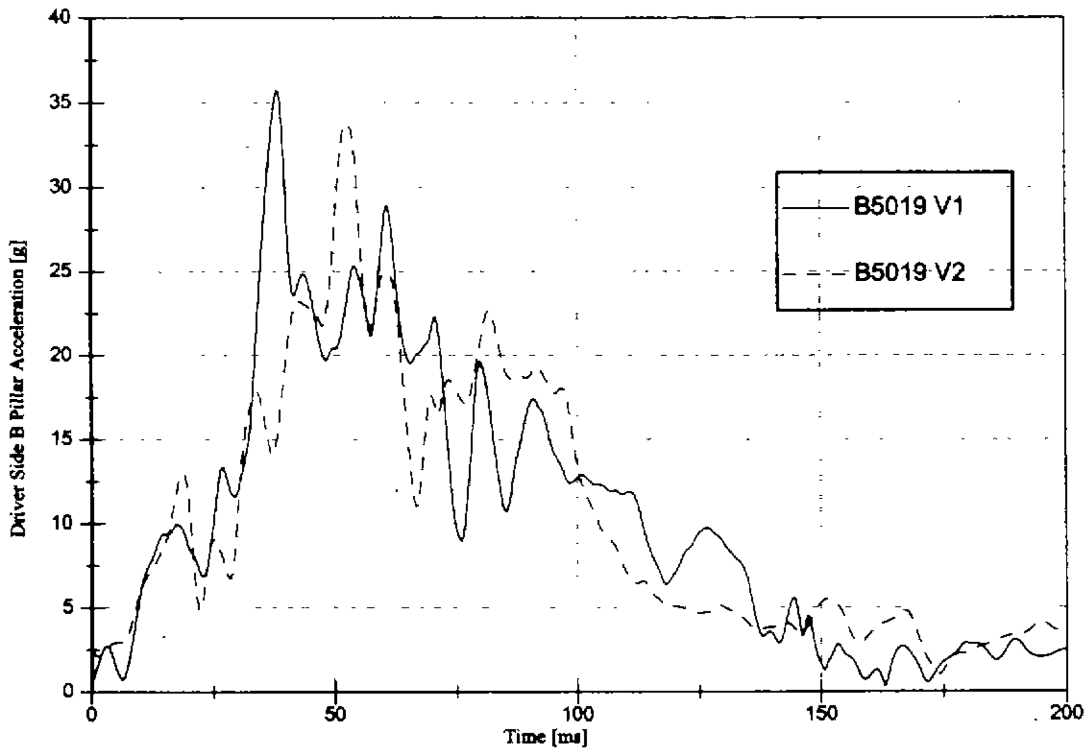


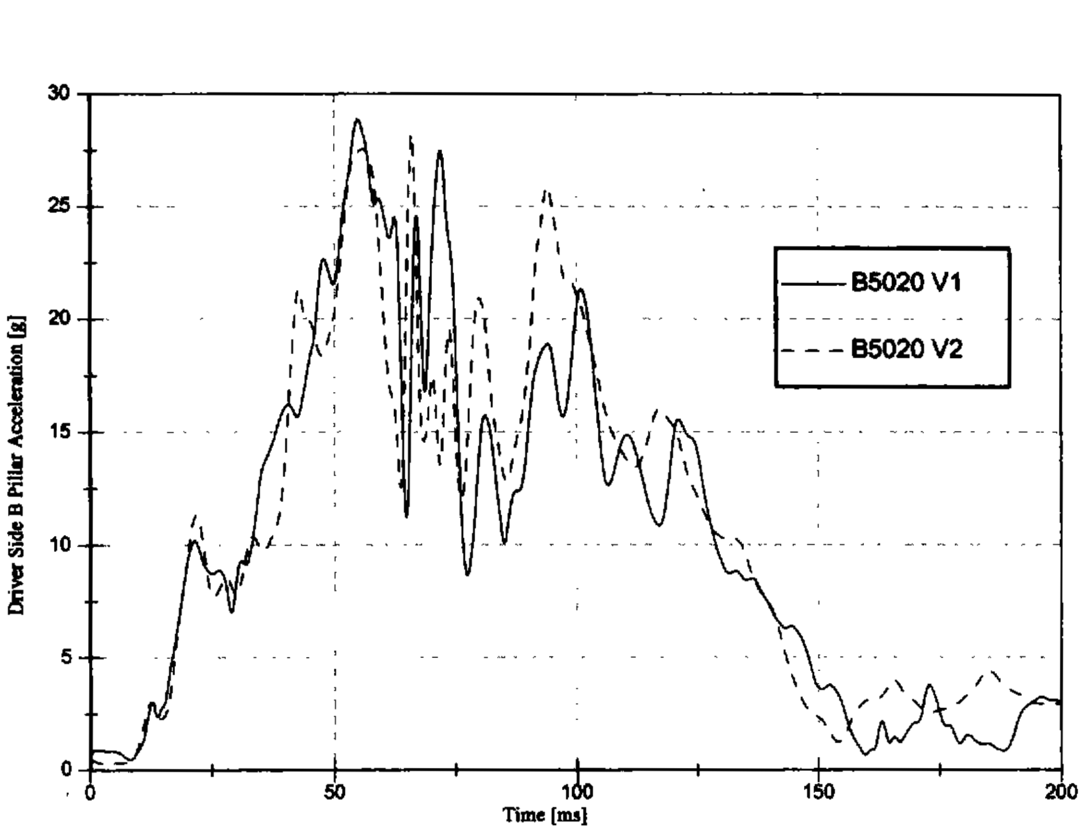
B4009 V1
B4009 V2
Driver Side B Pillar Acceleration [g]
Time [ms]
40
35
30
25
20
15
10
5
0
0
50
100
150
200

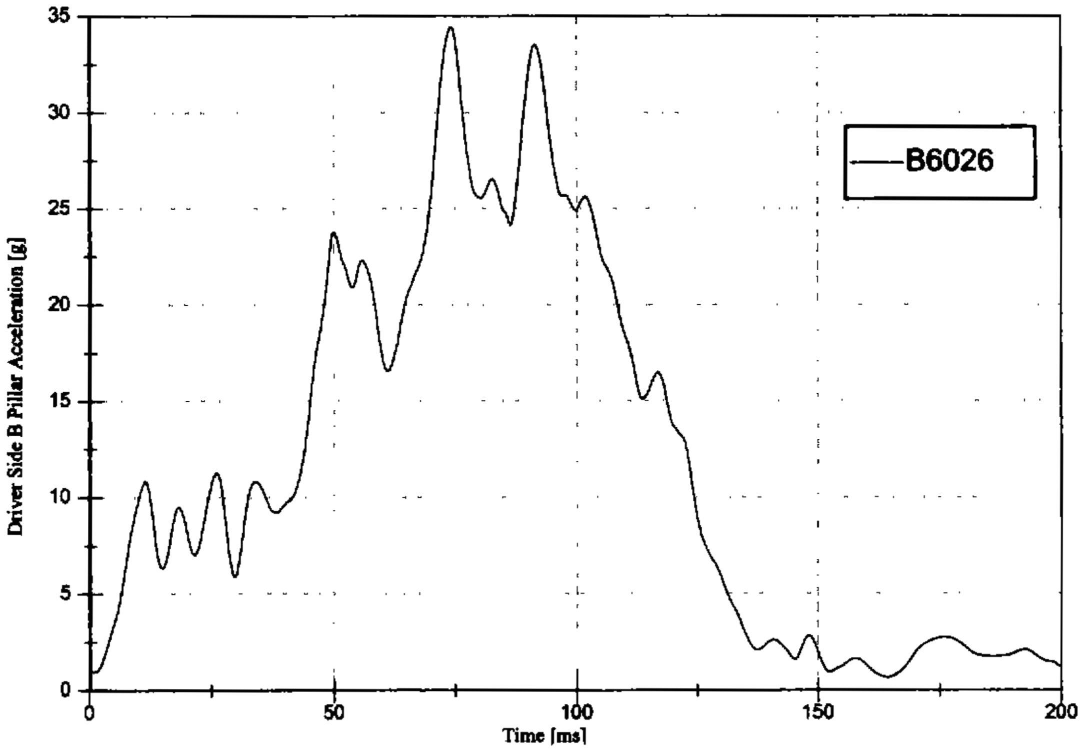


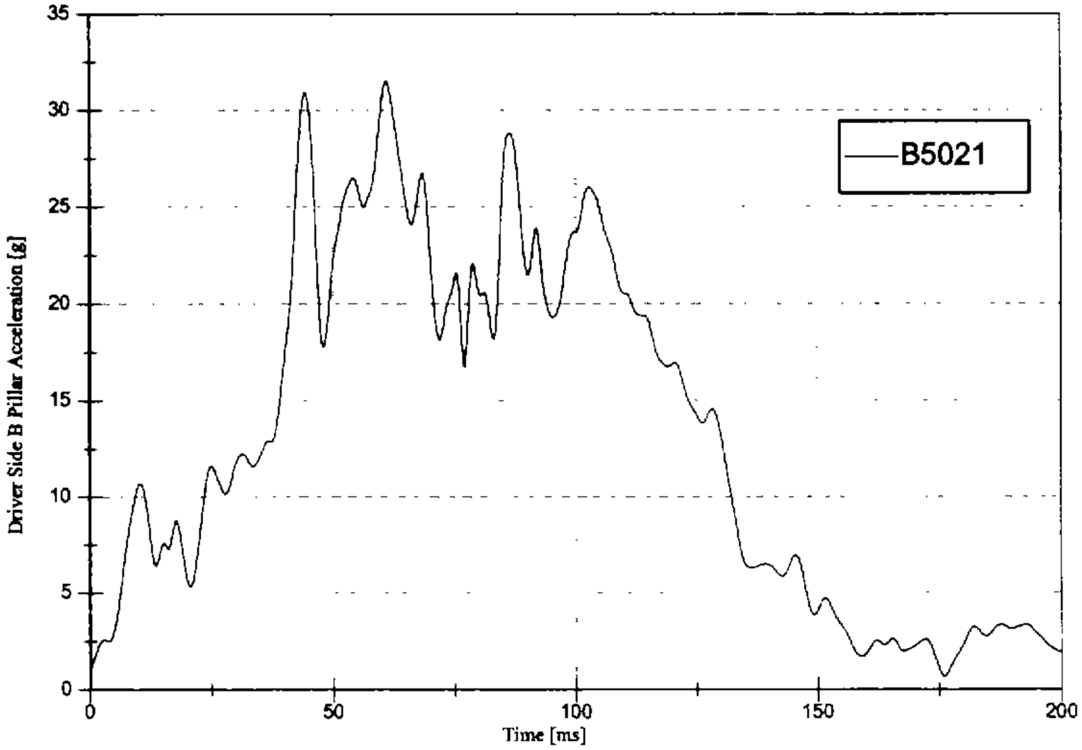
B4054
Driver Side B Pillar Acceleration [g]
Time [ms]
30
25
20
15
10
5
0
0
50
100
150
200

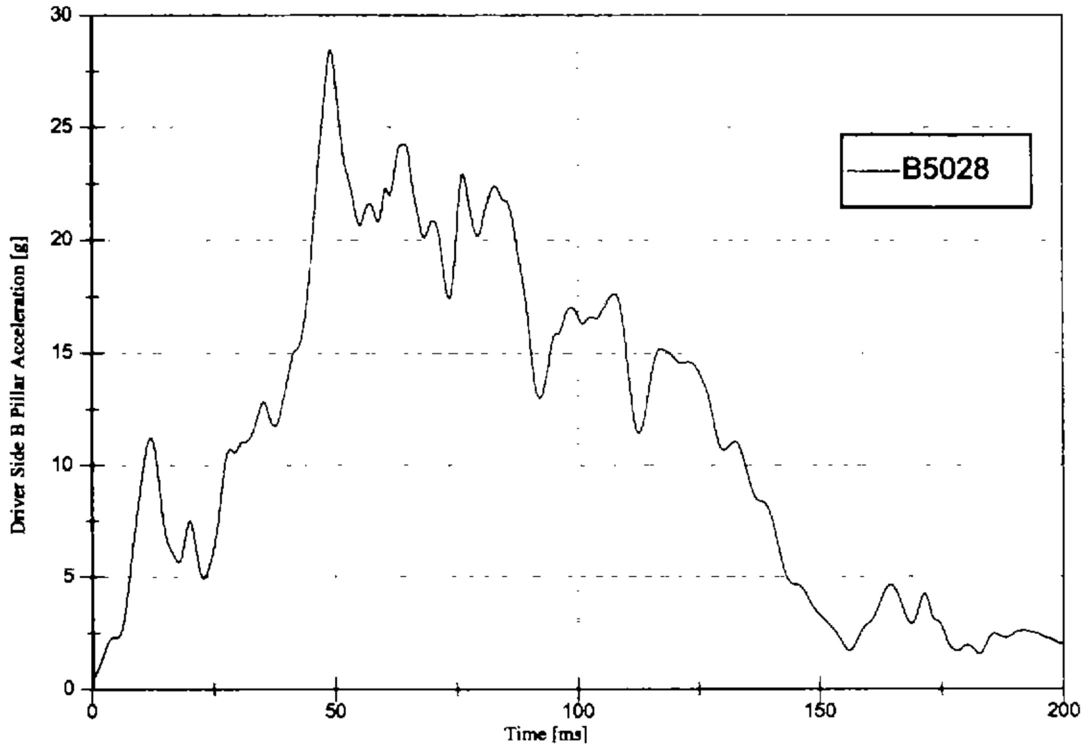

B5008
Driver Side B Pillar Acceleration [g]
Time [ms]
0
5
10
15
20
25
30
35
40
50
100
150
200


B5019 V1
B5019 V2
Driver Side B Pillar Acceleration [g]
Time [ms]
0
5
10
15
20
25
30
35
40
50
100
150
200


B5020 V1
B5020 V2
Driver Side B Pillar Acceleration [g]
Time [ms]
0
5
10
15
20
25
30
0
50
100
150
200


B6026
Driver Side B Pillar Acceleration [g]
Time [ms]
0
5
10
15
20
25
30
35
0
50
100
150
200


35
30
25
20
15
10
5
0
Driver Side B Pillar Acceleration [g]
0
50
100
150
200
Time [ms]
B5021


30
25
20
15
10
5
0
Driver Side B Pillar Acceleration [g]
0
50
100
150
200
Time [ms]
B5028

Appendix 7 – Australian Design Rule 73

MOTOR VEHICLE STANDARDS ACT
A national standard determined under section 7 of the Act

AUSTRALIAN DESIGN RULE 73/00
OFFSET FRONTAL IMPACT OCCUPANT PROTECTION

1 SHORT TITLE

1.1 This national standard may be cited as Australian Design Rule No 73/00, Offset Frontal Impact Occupant Protection.
1.2 This national standard may also be referred to as ADR 73/00

2 FUNCTION AND SCOPE

The function of this national standard is to specify crashworthiness requirements in terms of forces and accelerations measured by anthropomorphic dummies so as to minimise the likelihood of injury to the occupants in offset frontal impacts.

3 APPLICABILITY

3.1 Applicability Summary

3.1.1 This ADR applies to the design and construction of vehicles as required by clauses 3.1.2 and 3.1.3 and set out in clause 3.2

3.1.2 This rule is binding:

(a) from 1 January 2000 on all new model MA category vehicles; and with a *Gross Vehicle Mass* of less than 2.5 tonnes.

(b) from 1 January 2004 on all MA category vehicles with a *Gross Vehicle Mass* of less than 2.5 tonnes.

3.1.3 For the purposes of clause 3.1.2, a "new model" MA vehicle is a vehicle model first produced with a '*Date of Manufacture*' on or after 1 January 2000.

3.2 Applicability Table

VEHICLE CATEGORY	VEHICLE CATEGORY CODE	MANUFACTURED ON OR AFTER	ACCEPTABLE PRIOR RULES
Moped 2 wheels	LA	not applicable	
Moped 3 wheels	LB	not applicable	
Motor cycle	LC	not applicable	
Motor cycle and side-car	LD	not applicable	
Motor tricycle	LE	not applicable	
Passenger car	MA	1 January 2000 (refer clause 3 1 2 & 3.1.3)	nil
Forward-control passenger vehicle	MB	not applicable	
Off-road passenger vehicle	MC	not applicable	
Light omnibus	MD	not applicable	
Heavy omnibus	ME	not applicable	
Light goods vehicle	NA	not applicable	
Medium goods vehicle	NB	not applicable	
Heavy goods vehicle	NC	not applicable	
Very light trailer	TA	not applicable	
Light trailer	TB	not applicable	
Medium trailer	TC	not applicable	
Heavy trailer	TD	not applicable	

4 DEFINITIONS

Refer to the DEFINITIONS AND VEHICLE CATEGORIES preceding the ADRs in this volume.

5 REQUIREMENTS

5.1 Vehicles must comply with the technical requirements from ECE R 94/01 - "UNIFORM PROVISIONS CONCERNING THE APPROVAL OF VEHICLES WITH REGARD TO THE PROTECTION OF THE OCCUPANTS IN THE EVENT OF A FRONTAL COLLISION".

5.2 Appendix A is an extract from ECE R 94/01 - "UNIFORM PROVISIONS CONCERNING THE APPROVAL OF VEHICLES WITH REGARD TO THE PROTECTION OF THE OCCUPANTS IN THE EVENT OF A FRONTAL COLLISION". The document has had administrative provisions not relevant to this national standard either deleted or struck out. In the case of deletion of whole parts or annexes, that part will have the words "[NOT APPLICABLE]" placed beside its title.

5.3 Where ECE R94/01 references ECE R16 and/or ECE R14 compliance may be demonstrated with ADRs 4/xx, 3/xx and 5/xx respectively.

APPENDIX A

Regulation No. 94

AGREEMENT

CONCERNING THE ADOPTION OF UNIFORM TECHNICAL PRESCRIPTIONS FOR WHEELED VEHICLES, EQUIPMENT AND PARTS WHICH CAN BE FITTED AND/OR BE USED ON WHEELED VEHICLES AND THE CONDITIONS FOR RECIPROCAL RECOGNITION OF APPROVALS GRANTED ON THE BASIS OF THESE PRESCRIPTIONS [*/]

Addendum 93: Regulation No. 94

Incorporating the 01 series of amendments

Date of entry into force: 1 October 1998

UNIFORM PROVISIONS CONCERNING THE APPROVAL OF VEHICLES WITH REGARD TO THE PROTECTION OF THE OCCUPANTS IN THE EVENT OF A FRONTAL COLLISION

UNITED NATIONS

[*/] Former title of Agreement:

Agreement Concerning the Adoption of Uniform Conditions of Approval and Reciprocal Recognition of Approval for Motor Vehicle Equipment and Parts, done at Geneva on 20 March 1958

Regulation No. 95

UNIFORM PROVISIONS CONCERNING THE APPROVAL OF VEHICLES WITH REGARD TO THE PROTECTION OF THE OCCUPANTS IN THE EVENT OF A FRONTAL COLLISION

CONTENTS

1. SCOPE [NOT APPLICABLE]

2. DEFINITIONS

For the purposes of this Regulation:

2.1. "Protective system",

means interior fittings and devices intended to restrain the occupants and contribute towards ensuring compliance with the requirements set out in paragraph 5 below;

2.2. "Type of protective system",

means a category of protective devices which do not differ in such essential respects as:

Their technology;

Their geometry;

Their constituent materials;

2.3. "Vehicle width"

means the distance between two planes parallel to the longitudinal median plane (of the vehicle) and touching the vehicle on either side of the said plane but excluding the rear-view mirrors, side marker lamps, tyre pressure indicators, direction indicator lamps, position lamps, flexible mud-guards and the deflected part of the tyre side-walls immediately above the point of contact with the ground;

2.4. "Overlap" means the percentage of the vehicle width directly inline with the barrier face;

2.5. "Deformable barrier face"

means a crushable section mounted on the front of a rigid block;

2.6. "Vehicle type",

means a category of power-driven vehicles which do not differ in such essential respects as:

2.6.1. The length and width of the vehicle, in so far as they have a negative effect on the results of the impact test prescribed in this Regulation,

2.6.2. The structure, dimensions, lines and materials of the part of the vehicle forward of the transverse plane through the "R" point of the driver's seat, in so far as they have a negative effect on the results of the impact test prescribed in this Regulation,

2.6.3. The lines and inside dimensions of the passenger compartment and the type of protective system, in so far as they have an negative effect on the results of the impact test prescribed in this Regulation,

2.6.4. The siting (front, rear or centre) and the orientation (transversal or longitudinal) of the engine,

2.6.5. The unladen mass, in so far as there is a negative effect on the result of the impact test prescribed in this Regulation,

2.6.6. The optional arrangements or fittings provided by the manufacturer, in so far as they have a negative effect on the result of the impact test prescribed in this Regulation,

2.7. "Passenger compartment",

means the space for occupant accommodation, bounded by the roof, floor, side walls, doors, outside glazing and front bulkhead and the plane of the rear compartment bulkhead or the plane of the rear-seat back support;

2.8. "R point",

means a reference point defined for each seat by the manufacturer in relation to the vehicle's structure, as indicated in annex 6;

2.9. "H" point means,

a reference point determined for each seat by the testing service responsible for approval, in accordance with the procedure described in annex 6;

2.10. "Unladen kerb mass",

means the mass of the vehicle in running order, unoccupied and unladen but complete with fuel, coolant, lubricant, tools and a spare wheel (if these are provided as standard equipment by the vehicle manufacturer).

2.11. "Airbag "

means a device installed to supplement safety belts and restraint systems in power-driven vehicles, i.e. systems which, in the event of a severe impact affecting the vehicle, automatically deploy a flexible structure intended to limit, by compression of the gas contained within it, the gravity of the contacts of one or more parts of the body of an occupant of the vehicle with the interior of the passenger compartment.

2.12. "Passenger airbag"

means an airbag assembly intended to protect occupant(s) in seats other than the driver's in the event of a frontal collision.

2.13. "Child restraint"

means an arrangement of components which may comprise a combination of straps or flexible components with a securing buckle, adjusting devices, attachments, and in some cases a supplementary chair and/or an impact shield, capable of being anchored to a power driven vehicle. It is so designed as to diminish the risk of injury to the wearer, in the event of a collision or of abrupt deceleration of the vehicle by limiting the mobility of the wearer's body.

2.14. "Rearward-facing"

means facing in the direction opposite to the normal direction of travel of the vehicle.

3. APPLICATION FOR APPROVAL [NOT APPLICABLE]

4. APPROVAL [NOT APPLICABLE]

5. SPECIFICATIONS

5.1. General specifications applicable to all tests

5.1.1. The "H" point for each seat shall be determined in accordance with the procedure described in annex 6.

5.1.2. When the protective system for the front seating positions includes belts, the belt components shall meet the requirements of Regulation No. 16.

5.1.3. Seating positions where a dummy is installed and the protective system includes belts, shall be provided with anchorage points conforming to Regulation No. 14.

5.2. Specifications

The test of the vehicle carried out in accordance with the method described in annex 3 shall be considered satisfactory if all the conditions set out in paragraphs 5.2.1. to 5.2.6. below are all satisfied at the same time.

5.2.1. The performance criteria recorded, in accordance with annex 8, on the dummies in the front outboard seats shall meet the following conditions:

5.2.1.1. The head performance criterion (HPC) shall not exceed 1000 and the resultant head acceleration shall not exceed 80 g for more than 3 ms. The latter shall be calculated cumulatively, excluding rebound movement of the head;

5.2.1.2. The neck injury criteria (NIC) shall not exceed the values shown in Figures 1 and 2 [3];

Figure 1

Neck tension criterion

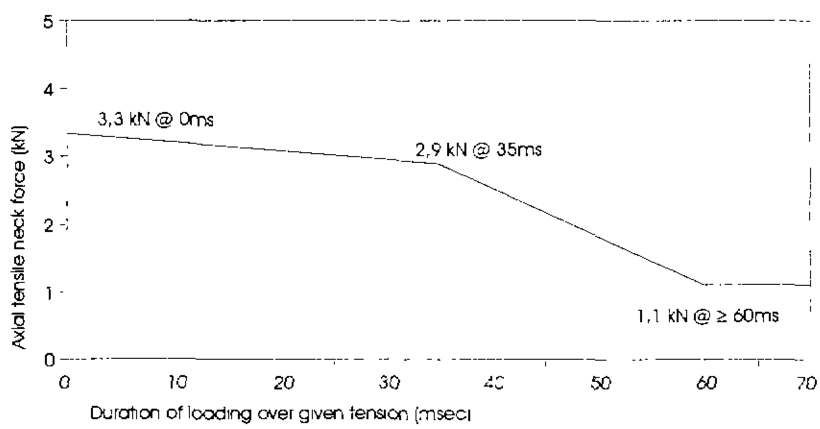
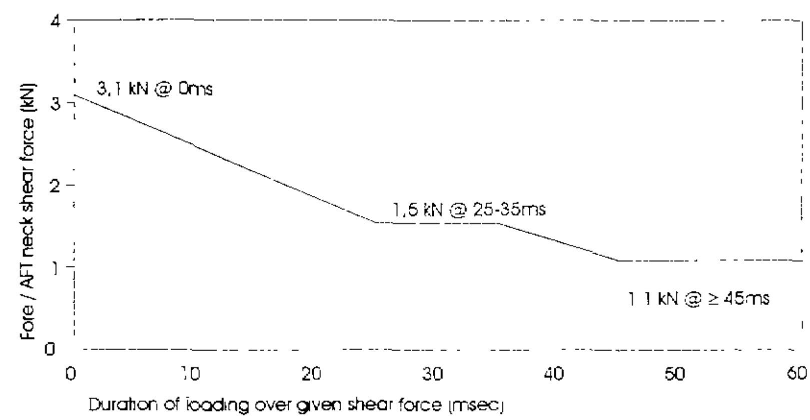


Figure 2

Neck shear criterion



5.2.1.3. The neck bending moment about the y axis shall not exceed 57 Nm in extension [3];

5.2.1.4. The thorax compression criterion (ThCC) shall not exceed 50 mm;

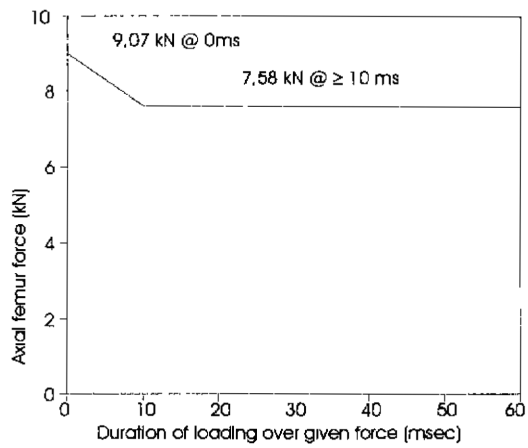
5.2.1.5. The viscous criterion (V * C) for the thorax shall not exceed 1,0 m/s;

[3] Until 1 October 1998 the values obtained for the neck shall not be pass/fail criteria for the purposes of granting approval. The results obtained shall be recorded in the test report and be collected by the approval authority. After this date, the values specified in this paragraph shall apply as pass/fail criteria unless or until alternative values are adopted.

5.2.1.6. The femur force criterion (FFC) shall not exceed the force-time performance criterion shown in Figure 3;

Figure 3

Femur force criterion



5.2.1.7. The tibia compression force criterion (TCFC) shall not exceed 8 kN;

5.2.1.8. The tibia index (TI), measured at the top and bottom of each tibia, shall not exceed 1,3 at either location;

5.2.1.9. The movement of the sliding knee joints shall not exceed 15 mm.

5.2.2. Residual steering wheel displacement, measured at the centre of the steering wheel hub, shall not exceed 80 mm in the upwards vertical direction and 100 mm in the rearward horizontal direction.

5.2.3. During the test no door shall open;

5.2.4. During the test no locking of the locking systems of the front doors shall occur;

5.2.5. After the impact, it shall be possible, without the use of tools except for those necessary to support the weight of the dummy:

5.2.5.1. To open at least one door, if there is one, per row of seats and, where there is no such door, to move the seats or tilt their backrests as necessary to allow the evacuation of all the occupants; this is, however, only applicable to vehicles having a roof of rigid construction;

5.2.5.2. To release the dummies from their restraint system which, locked, shall be capable of being released by a maximum force of 60 N on the centre of the release control;

5.2.5.3. To remove the dummies from the vehicle without adjustment of the seats.

5.2.6. In the case of a vehicle propelled by liquid fuel, no more than slight leakage of liquid from the fuel-feed installation shall occur on collision;

5.2.7. If there is continuous leakage of liquid from the fuel-feed installation after the collision, the rate of leakage shall not exceed 30 g/min; if the liquid from the fuel-feed system mixes with liquids from the other systems and the various liquids cannot easily be separated and identified, all the liquids collected shall be taken into account in evaluating the continuous leakage.

6. INSTRUCTIONS FOR USERS OF VEHICLES EQUIPPED WITH AIRBAGS

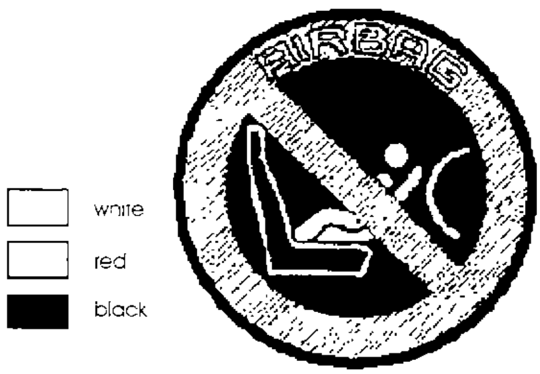
6.1. The vehicle shall carry information to the effect that it is equipped with airbags for seats.

6.1.1. For a vehicle fitted with an airbag assembly intended to protect the driver, this information shall consist of the inscription "AIRBAG" located in the interior of the circumference of the steering wheel; this inscription shall be durably affixed and easily visible.

6.1.2. For a vehicle fitted with a passenger airbag intended to protect front seat occupants other than the driver, this information shall consist of the warning label described in paragraph 6.2. below.

6.2. A vehicle fitted with one or more passenger airbags shall carry information about the extreme hazard associated with the use of rearward-facing child restraints on seats equipped with airbag assemblies.

6.2.1 As a minimum, this information shall consist of a pictogram label as indicated below.



Overall dimensions: ≥ 50 mm

6.2.2. The warning label shall be durably affixed and located such that it is easily visible in front of a person about to install a rearward-facing child restraint on the seat in question. A permanent reference should be visible at all times, in case the warning is not visible when the door is closed.

This requirement does not apply to those seats equipped with a device which automatically deactivates the airbag assembly when a rearward-facing child restraint is installed.

6.2.3. Detailed information, making reference to the label, shall be contained in the owner's manual of the vehicle; as a minimum the following text in an official ECE language, supplemented by the corresponding text in the language of the country where the vehicle is to be registered, must be included:

"Extreme Hazard! Do not use a rearward facing child restraint on a seat protected by an airbag in front of it!"

The text shall be accompanied by the pictogram mounted on the vehicle.

7.	MODIFICATION AND EXTENSION OF APPROVAL OF THE VEHICLE TYPE	[NOT APPLICABLE]
8.	CONFORMITY OF PRODUCTION	[NOT APPLICABLE]
9.	PENALTIES FOR NON-CONFORMITY OF PRODUCTION	[NOT APPLICABLE]
10.	PRODUCTION DEFINITELY DISCONTINUED	[NOT APPLICABLE]
11.	TRANSITIONAL PROVISIONS	[NOT APPLICABLE]
12.	NAMES AND ADDRESSES OF TECHNICAL SERVICES RESPONSIBLE FOR CONDUCTING APPROVAL TESTS, AND OF ADMINISTRATIVE DEPARTMENTS	[NOT APPLICABLE]

Annex 1
COMMUNICATION

[NOT APPLICABLE]

Annex 2
ARRANGEMENTS OF THE APPROVAL MARK

[NOT APPLICABLE]

Annex 3
TEST PROCEDURE

1. INSTALLATION AND PREPARATION OF THE VEHICLE

1.1. Testing ground

The test area shall be large enough to accommodate the run-up track, barrier and technical installations necessary for the test. The last part of the track, for at least 5 m before the barrier, shall be horizontal, flat and smooth.

1.2. Barrier

The front face of the barrier consists of a deformable structure as defined in annex 9 of this Regulation. The front face of the deformable structure is perpendicular within ± 1° to the direction of travel of the test vehicle. The barrier is secured to a mass of not less than 7×10^4 kg, the front face of which is vertical within ± 1°. The mass is anchored in the ground or placed on the ground with, if necessary, additional arresting devices to restrict its movement.

1.3. Orientation of the barrier

The orientation of the barrier is such that the first contact of the vehicle with the barrier is on the steering-column side. Where there is a choice between carrying out the test with a right-hand or left-hand drive vehicle, the test shall be carried out with the less favourable hand of drive as determined by the technical service responsible for the tests.

1.3.1. Alignment of the vehicle to the barrier.

The vehicle shall overlap the barrier face by 40 per cent ± 20 mm.

1.4. State of vehicle

1.4.1. General specification

The test vehicle shall be representative of the series production, shall include all the equipment normally fitted and shall be in normal running order. Some components may be replaced by equivalent masses where this substitution clearly has no noticeable effect on the results measured under paragraph 6.

1.4.2. Mass of vehicle

1.4.2.1. For the test, the mass of the vehicle submitted shall be the unladen kerb mass;

1.4.2.2. The fuel tank shall be filled with water to mass equal to 90 per cent of the mass of a full as specified by the manufacturer with a tolerance of ± 1 per cent ;

1.4.2.3. All the other systems (brake, cooling, ...) may be empty in this case, the mass of the liquids shall be carefully compensated;

1.4.2.4. If the mass of the measuring apparatus on board the vehicle exceeds the 25 kg allowed, it may be compensated by reductions which have no noticeable effect on the results measured under paragraph 6 below.

1.4.2.5. The mass of the measuring apparatus shall not change each axle reference load by more than 5%, each variation not exceeding 20 kg

1.4.2.6. The mass of the vehicle resulting from the provisions of paragraph 1.4.2.1. above shall be indicated in the report.

1.4.3. Passenger compartment adjustments

1.4.3.1. Position of steering wheel

The steering wheel, if adjustable, shall be placed in the normal position indicated by the manufacturer or, failing that, midway between the limits of its range(s) of adjustment. At the end of propelled travel, the steering wheel shall be left free, with its spokes in the position which according to the manufacturer corresponds to straight-ahead travel of the vehicle.

1.4.3.2. Glazing

The movable glazing of the vehicle shall be in the closed position. For test measurement purposes and in agreement with the manufacturer, it may be lowered, provided that the position of the operating handle corresponds to the closed position.

1.4.3.3. Gear-change lever

The gear-change lever shall be in the neutral position.

1.4.3.4. Pedals

The pedals shall be in their normal position of rest. If adjustable, they shall be set in their mid position unless another position is specified by the manufacturer.

1.4.3.5. Doors

The doors shall be closed but not locked.

1.4.3.6. Opening roof

If an opening or removable roof is fitted, it shall be in place and in the closed position. For test measurement purposes and in agreement with the manufacturer, it may be open.

1.4.3.7. Sun-visor

The sun-visors shall be in the stowed position.

1.4.3.8. Rear-view mirror

The interior rear-view mirror shall be in the normal position of use.

1.4.3.9. Arm-rests

Arm-rests at the front and rear, if movable, shall be in the lowered position, unless this is prevented by the position of the dummies in the vehicles.

1.4.3.10. Head restraints

Head restraints adjustable for height shall be in their uppermost position.

1.4.3.11. Seats

1.4.3.11.1. Position of front seats

Seats adjustable longitudinally shall be placed so that their "H" point, determined in accordance with the procedure set out in annex 6 is in the middle position of travel or in the nearest locking position thereto, and at the height position defined by the manufacturer (if independently adjustable for height). In the case of a bench seat, the reference shall be to the "H" point of the driver's place.

1.4.3.11.2. Position of the front seat-backs

If adjustable, the seat-backs shall be adjusted so that the resulting inclination of the torso of the dummy is as close as possible to that recommended by the manufacturer for normal use or, in the absence of any particular recommendation by the manufacturer, to 25° towards the rear from the vertical.

1.4.3.11.3 Rear seats

If adjustable, the rear seats or rear bench seats shall be placed in the rearmost position.

2. DUMMIES

2.1. Front seats

2.1.1. A dummy corresponding to the specifications for Hybrid III [1/-7] fitted with a 45° ankle and meeting the specifications for its adjustment shall be installed in each of the front outboard seats in accordance with the conditions set out in annex 8. The ankle of the dummy shall be certified in accordance with the procedures in annex 10.

2.1.2. The car will be tested with restraint systems, as provided by the manufacturer.

3. PROPULSION AND COURSE OF VEHICLE

3.1. The vehicle shall not be propelled by its own engine or by any other propelling device;

3.2. At the moment of impact the vehicle shall no longer be subject to the action of any additional steering or propelling device.

3.3. The course of the vehicle shall be such that it satisfies the requirements of paragraphs 1.2. and 1.3.1.

4. TEST SPEED

Vehicle speed at the moment of impact shall be 56 -0/ +1 km/h. However, if the test was performed at a higher impact speed and the vehicle met the requirements, the test shall be considered satisfactory.

5. MEASUREMENTS TO BE MADE ON DUMMY IN FRONT SEATS

5.1. All the measurements necessary for the verification of the performance criteria shall be made with measurement systems corresponding to the specifications of annex 8.

5.2. The different parameters shall be recorded through independent data channels of the following CFC (Channel Frequency Class):

5.2.1. Measurements in the head of the dummy

The acceleration (a) referring to the centre of gravity is calculated from the triaxial components of the acceleration measured with a CFC of 1000.

5.2.2. Measurements in the neck of the dummy

[1/-7] The technical specifications and detailed drawings of Hybrid III, corresponding to the principle dimensions of a fiftieth percentile male of the United States of America, and the specifications for its adjustment for this test are deposited with the Secretary-General of the United Nations and may be consulted on request at the secretariat of the Economic Commission for Europe, Palates of Nations, Geneva, Switzerland.

5.2.2.1. The axial tensile force and the fore/aft shear force at the neck/head interface are measured with a CFC of 1000.

5.2 2.2. The bending moment about a lateral axis at the neck/head interface are measured with a CFC of 600.

5.2.3. Measurements in the thorax of the dummy

The chest deflection between the sternum and the spine is measured with a CFC of 180.

5.2.4. Measurements in the femur and tibia of the dummy

5.2.4.1. The axial compressive force and the bending moments are measured with a CFC of 600.

5.2.4.2. The displacement of the tibia with respect to the femur is measured at the knee sliding joint with a CFC of 180.

6. MEASUREMENTS TO BE MADE ON THE VEHICLE

6.1. To enable the simplified test described in annex 7 to be carried out, the deceleration time history of the structure shall be determined on the basis of the value of the longitudinal accelerometers at the base of the "B" pillar on the struck side of the vehicle with a CFC of 180 by means of data channels corresponding to the requirements set out in annex 8;

6.2. The speed time history which will be used in the test procedure described in annex 7 shall be obtained from the longitudinal accelerometer at the "B" pillar on the struck side.

Annex 4
DETERMINATION OF PERFORMANCE CRITERIA

1. HEAD PERFORMANCE CRITERION (HPC)

1.1. This criterion is considered to be satisfied when, during the test, there is no contact between the head and any vehicle component.

1.2. If that is not the case, a calculation of the value of HPC is made, on the basis of the acceleration (a), measured according to paragraph 5 2.1. of annex 3 by the following expression:

$$HPC = (t_2 - t_1)\left[\frac{1}{t_2 - t_1}\int_{t_1}^{t_2} a\,dt\right]^{2\ 5}$$

in which:

1.2.1. the term 'a' is the resultant acceleration measured according to paragraph 5.2.1.of annex 3 and is measured in units of gravity, g (1 g = 9,81 m/s^2)

1.2.2. if the beginning of the head contact can be determined satisfactorily, t_1 and t_2 are the two time instants, expressed in seconds, defining an interval between the beginning of the head contact and the end of the recording for which the value of HPC is maximum;

1.2.3. if the beginning of the head contact cannot be determined, t_1 and t_2 are the two time instants, expressed in seconds, defining a time interval between the beginning and the end of the recording for which the value of HPC is maximum.

1.2.4. Values of HPC for which the time interval (t_1 - t_2) is greater than 36 ms are ignored for the purposes of calculating the maximum value.

1.3. The value of the resultant head acceleration during forward impact which is exceeded for 3 ms cumulatively is calculated from the resultant head acceleration measured according to paragraph 5.2.1. of annex 3.

2. NECK INJURY CRITERIA (NIC)

2.1. These criteria are determined by the compressive axial force, the axial tensile force and the fore/aft shear forces at the head/neck interface, expressed in kN and measured according to paragraph 5.2.2. of annex 3 and by the duration of these forces expressed in ms.

2.2. The neck bending moment criterion is determined by the bending moment, expressed in Nm, about a lateral axis at the head/neck interface and measured according to paragraph 5.2.2.of annex 3.

2.3. The neck flexion bending moment, expressed in Nm, shall be recorded.

3. THORAX COMPRESSION CRITERION (ThCC) AND VISCOUS CRITERION (V * C)

3.1. The thorax compression criterion is determined by the absolute value of the thorax deformation, expressed in mm and measured according to paragraph 5.2.3. of annex 3.

3.2. The viscous criterion (V * C) is calculated as the instantaneous product of the compression and the rate of deflection of the sternum, measured according to paragraph 6 and also paragraph 5.2.3. of annex 3.

4. FEMUR FORCE CRITERION (FFC)

4.1. This criterion is determined by the compression load expressed in kN, transmitted axially on each femur of the dummy and measured according to paragraph 5.2.4. of annex 3 and by the duration of the compressive load expressed in ms.

5. TIBIA COMPRESSIVE FORCE CRITERION (TCFC) AND TIBIA INDEX (TI)

5.1. The tibia compressive force criterion is determined by the compressive load (Fz) expressed in kN, transmitted axially on each tibia of the dummy and measured according to paragraph 5.2.4. of annex 3.

5.2. The tibia index is calculated on the basis of the bending moments (Mx and My) measured according to paragraph 5.1. by the following expression:

where:

$$TI = \left|M_R / (M_C)_R\right| + \left|F_Z / (F_C)_Z\right|$$

M_X = bending moment about the x axis

M_Y = bending moment about the y axis

$(M_C)_R$ = critical bending moment and shall be taken to be 225 Nm

F_Z = compressive axial force in the z direction

$(F_C)_Z$ = critical compressive force in the z direction and shall be taken to be 35,9 kN and

$$M_R = \sqrt{(M_x)^2 + (M_y)^2}$$

The tibia index is calculated for the top and the bottom of each tibia; however, F_Z may be measured at either location. The value obtained is used for the top and bottom TI calculations. Moments M_X and M_Y are both measured separately at both locations.

6. PROCEDURE FOR CALCULATING THE VISCOUS CRITERIA (V * C) FOR HYBRID III DUMMY

6.1. The viscous criterion is calculated as the instantaneous product of the compression and the rate of deflection of the sternum. Both are derived from the measurement of sternum deflection.

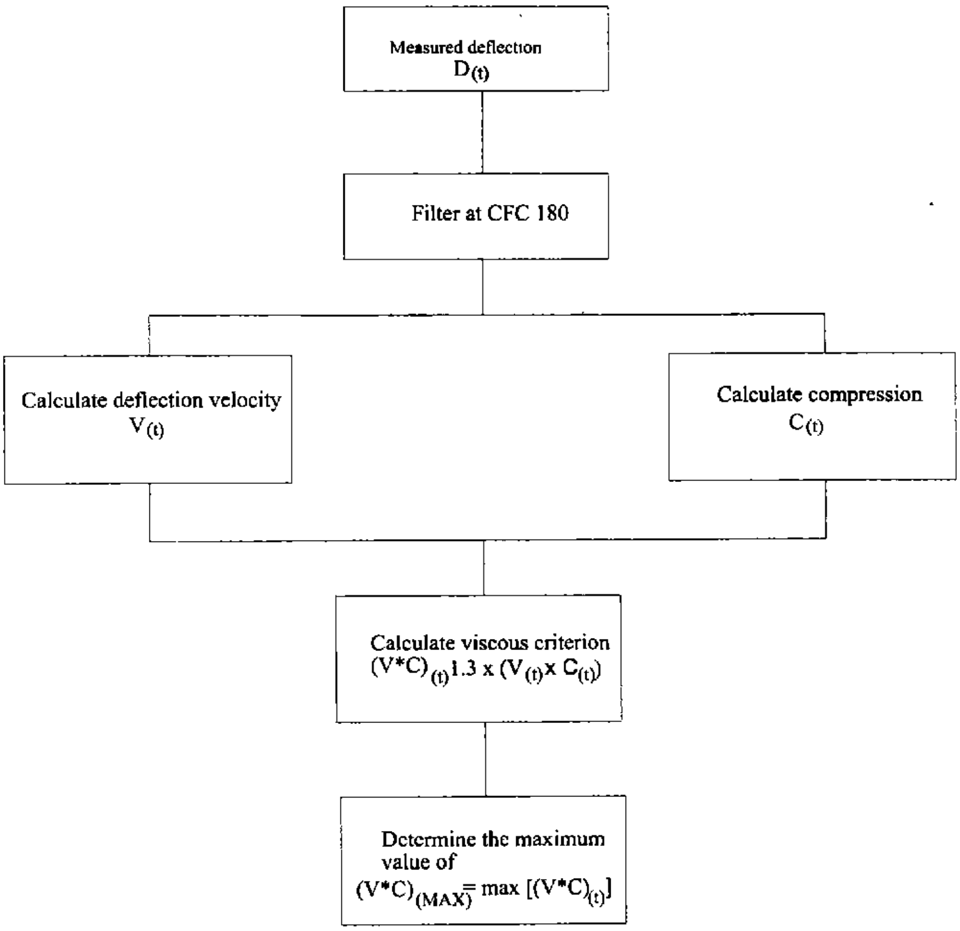
6.2. The sternum deflection response is filtered once at CFC 180. The compression at time t is calculated from this filtered signal as:

$$C_{(t)} = \frac{D_{(t)}}{0.229}$$

The sternum deflection velocity at time t is calculated from the filtered deflection as:

$$V(t) = \frac{8 \times \left(D_{(t+1)} - D_{(t-1)}\right) - \left(D_{(t+2)} - D_{(t-2)}\right)}{12\,\delta t}$$

where D(t) is the deflection at time t in metres and δ t is the time interval in seconds between the measurements of deflection. The maximum value of δ t shall be 1,25 x 10^{-4} seconds. This calculation procedure is shown diagrammatically below:



Annex 5
ARRANGEMENT AND INSTALLATION OF DUMMIES AND ADJUSTMENT OF RESTRAINT SYSTEMS

1. ARRANGEMENT OF DUMMIES

1.1. Separate seats

The plane of symmetry of the dummy shall coincide with the vertical median plane of the seat.

1.2. Front bench seat

1.2.1. Driver

The plane of symmetry of the dummy shall lie in the vertical plane passing through the steering wheel centre and parallel to the longitudinal median plane of the vehicle. If the seating position is determined by the shape of the bench, such seat shall be regarded as a separate seat.

1.2.2. Outer passenger

The plane of symmetry of the dummy shall be symmetrical with that of the driver dummy relative to the longitudinal median plane of the vehicle. If the seating position is determined by the shape of the bench, such seat shall be regarded as a separate seat.

1.3. Bench seat for front passengers (not including driver)

The planes of symmetry of the dummy shall coincide with the median planes of the seating positions defined by the manufacturer.

2 INSTALLATION OF DUMMIES

2.1. Head

The transverse instrumentation platform of the head shall be horizontal within 2.5 °. To level the head of the test dummy in vehicles with upright seats with non-adjustable backs, the following sequences must be followed. First adjust the position of the "H" point within the limits set forth in paragraph 2.4.3.1. below to level the transverse instrumentation platform of the head of the test dummy. If the transverse instrumentation platform of the head is still not level, then adjust the pelvic angle of the test dummy within the limits provided in paragraph 2.4.3.2. below. If the transverse instrumentation platform of the head is still not level, then adjust the neck bracket of the test dummy the minimum amount necessary to ensure that the transverse instrumentation platform of the head is horizontal within 2.5 °.

2.2. Arms

2.2.1. The driver's upper arms shall be adjacent to the torso with the centrelines as close to a vertical plane as possible.

2.2.2. The passenger's upper arms shall be in contact with the seat back and the sides of the torso.

2.3. Hands

2.3.1. The palms of the driver test dummy shall be in contact with the outer part of the steering wheel rim at the rim's horizontal centreline The thumbs shall be over the steering wheel rim and shall be lightly taped to the steering wheel rim so that if the hand of the test dummy is pushed upward by a force of not less than 9 N and not more than 22 N, the tape shall release the hand from the steering wheel rim.

2.3.2. The palms of the passenger test dummy shall be in contact with outside of thigh. The little finger shall be in contact with the seat cushion.

2.4. Torso

2.4.1. In vehicles equipped with bench seats, the upper torso of the driver and passenger test dummies shall rest against the seat back. The midsagittal plane of the driver dummy shall be vertical and parallel to the vehicle's longitudinal centreline, and pass through the centre of the steering wheel rim. The midsagittal plane of the passenger dummy shall be vertical and parallel to the vehicle's longitudinal centreline and the same distance from the vehicle's longitudinal centreline as the midsagittal plane of the driver dummy.

2.4.2 In vehicles equipped with individual seat(s), the upper torso of the driver and passenger test dummies shall rest against the seat back. The midsagittal plane of the driver and the passenger dummy shall be vertical and shall coincide with the longitudinal centreline of the individual seat(s).

2.4.3. Lower torso

2.4.3.1. "H" point

The "H" point of the driver and passenger test dummies shall coincide within 13 mm in the vertical dimension and 13 mm in the horizontal dimension with a point 6 mm below the position of the 'H' point determined using the procedure described in annex 6 except that the length of the lower leg and thigh segments of the "H" point machine shall be adjusted to 414 and 401 mm, instead of 432 and 417 mm respectively."

2.4.3.2. Pelvic angle

As determined using the pelvic angle gauge (GM) drawing 78051-532 incorporated by reference in Part 572 which is inserted into the "H" point gauging hole of the dummy, the angle measured from the horizontal on the 76.2 mm (3 inch) flat surface of the gauge shall be 22 1/2 degrees plus or minus 2 1/2 degrees.

2.5. Legs

The upper legs of the driver and passenger test dummies shall rest against the seat cushion to the extent permitted by placement of the feet. The initial distance between the outboard knee clevis flange surface shall be 270 mm ± 10 mm. To the extent practicable, the left leg of the driver dummy and both legs of the passenger dummy shall be in vertical longitudinal planes. To the extent practicable, the right leg of the driver dummy shall be in a vertical plane. Final adjustment to accommodate placement of feet in accordance with paragraph 2.6. for various passenger compartment configurations is permitted.

2.6. Feet

2.6.1. The right foot of the driver test dummy shall rest on the undepressed accelerator with the rearmost point of the heel on the floor surface in the plane of the pedal. If the foot cannot be placed on the accelerator pedal, it shall be positioned perpendicular to the tibia and placed as far forward as possible in the direction of the centreline of the pedal with the rearmost point of the heel resting on the floor surface. The heel of the left foot shall be placed as far forward as possible and shall rest on the floor pan. The left foot shall be positioned as flat as possible on the toeboard. The longitudinal centreline of the left foot shall be placed as parallel as possible to the longitudinal centreline of the vehicle.

2.6.2. The heels of both feet of the passenger test dummy shall be placed as far forward as possible and shall rest on the floor pan. Both feet shall be positioned as flat as possible on the toeboard. The longitudinal centreline of the feet shall be placed as parallel as possible to the longitudinal centreline of the vehicle.

2.7. The measuring instruments installed shall not in any way affect the movement of the dummy during impact.

2.8. The temperature of the dummies and the system of measuring instruments shall be stabilised before the test and maintained so far as possible within a range between 19 °C and 22 °C.

2.9. Dummy clothing

2.9.1. The instrumented dummies will be clothed in formfitting cotton stretch garments with short sleeves and mid-calf length trousers specified in FMVSS 208, drawings 78051-292 and 293 or their equivalent.

2.9.2. A size 11EE shoe, specified in FMVSS 208, drawings 78501-294 (left) and 78501-295 (right) or their equivalent, will be placed on each foot of the test dummies.

3. ADJUSTMENT OF RESTRAINT SYSTEM

With the test dummy at its designated seating position as specified by the appropriate requirements of paragraphs 2.1. through 2.6., place the belt around the test dummy and fasten the latch. Remove all slack from the lap belt. Pull the upper torso webbing out of the retractor and allow it to retract. Repeat this operation four times. Apply a 9 to 18 N tension load to the lap belt. If the belt system is equipped with a tension-relieving device, introduce the maximum amount of slack into the upper torso belt that is recommended by the manufacturer for normal use in the owner's manual for the vehicle. If the belt system is not equipped with a tension-relieving device, allow the excess webbing in the shoulder belt to be retracted by the retractive force of the retractor.

Annex 6

PROCEDURE FOR DETERMINING THE "H" POINT AND THE ACTUAL TORSO ANGLE FOR SEATING POSITIONS IN MOTOR VEHICLES

1. PURPOSE

The procedure described in this annex is used to establish the "H" point location and the actual torso angle for one or several seating positions in a motor vehicle and to verify the relationship of measured data to design specifications given by the vehicle manufacturer. [1/-8]

2. DEFINITIONS

For the purposes of this annex:

2.1. "Reference data"

means one or several of the following characteristics of a seating position

2.1.1. the "H" point and the "R" point and their relationship,

2 1.2. the actual torso angle and the design torso angle and their relationship.

2.2. "Three-dimensional 'H' point machine"

(3-D H machine) means the device used for the determination of "H" points and actual torso angles. This device is described in appendix 1 to this annex;

2.3. "'H' point"

[1/-8] In any seating position other than seats where the "H" point cannot be determined using the "Three-Dimensional 'H' point machine" or procedures, the "R" point indicated by the manufacturer may be taken as a reference at the discretion of the competent authority means the pivot centre of the torso and the thigh of the 3-D H machine installed in the vehicle seat in accordance with paragraph 4 below. The "H" point is located in the centre of the centreline of the device which is between the "H" point sight buttons on either side of the 3-D H machine. The "H" point corresponds theoretically to the "R" point (for tolerances see paragraph 3.2.2.below). Once determined in accordance with the procedure described in paragraph 4, the "H" point is considered fixed in relation to the seat-cushion structure and to move with it when the seat is adjusted;

2.4. "'R' point" or "seating reference point"

means a design point defined by the vehicle manufacturer for each seating position and established with respect to the three-dimensional reference system;

2.5. "Torso-line"

means the centreline of the probe of the 3-D H machine with the probe in the fully rearward position;

2.6. "Actual torso angle"

means the angle measured between a vertical line through the "H" point and the torso line using the back angle quadrant on the 3-D H machine. The actual torso angle corresponds theoretically to the design torso angle (for tolerances see paragraph 3.2.2. below):

2.7. "Design torso angle"

means the angle measured between a vertical line through the "R" point and the torso line in a position which corresponds to the design position of the seat-back established by the vehicle manufacturer;

2.8. "Centreplane of occupant"

(C/LO) means the median plane of the 3-D H machine positioned in each designated seating position; it is represented by the co-ordinate of the "H" point on the "Y" axis. For individual seats, the centreplane of the seat coincides with the centreplane of the occupant. For other seats, the centreplane of the occupant is specified by the manufacturer;

2.9. "Three-dimensional reference system"

means a system as described in appendix 2 to this annex;

2.10. "Fiducial marks"

are physical points (holes, surfaces, marks or indentations) on the vehicle body as defined by the manufacturer;

2.11. "Vehicle measuring attitude"

means the position of the vehicle as defined by the co-ordinates of fiducial marks in the three-dimensional reference system.

3. REQUIREMENTS

3.1. Data presentation

For each seating position where reference data are required in order to demonstrate compliance with the provisions of the present Regulation, all or an appropriate selection of the following data shall be presented in the form indicated in appendix 3 to this annex:

3.1.1. the co-ordinates of the "R" point relative to the three-dimensional reference system;

3.1 2. the design torso angle;

3.1.3 all indications necessary to adjust the seat (if it is adjustable) to the measuring position set out in paragraph 4.3 below.

3.2. Relationship between measured data and design specifications

3.2.1. The co-ordinates of the "H" point and the value of the actual torso angle obtained by the procedure set out in paragraph 4. below shall be compared, respectively, with the co-ordinates of the "R" point and the value of the design torso angle indicated by the vehicle manufacturer.

3.2 2. The relative positions of the "R" point and the "H" point and the relationship between the design torso angle and the actual torso angle shall be considered satisfactory for the seating position in question if the "H" point, as defined by its co-ordinates, lies within a square of 50 mm side length with horizontal and vertical sides whose diagonals intersect at the "R" point, and if the actual torso angle is within 5° of the design torso angle.

3.2 3. If these conditions are met, the "R" point and the design torso angle, shall be used to demonstrate compliance with the provisions of this Regulation.

3.2.4. If the "H" point or the actual torso angle does not satisfy the requirements of paragraph 3.2.2. above, the "H" point and the actual torso angle shall be determined twice more (three times in all). If the results of two of these three operations satisfy the requirements, the conditions of paragraph 3.2.3. above shall apply.

3.2.5. If the results of at least two of the three operations described in paragraph 3.2.4. above do not satisfy the requirements of paragraph 3.2.2 above, or if the verification cannot take place because the vehicle manufacturer has failed to supply information regarding the position of the "R" point or regarding the design torso angle, the centroid of the three measured points or the average of the three measured angles shall be used and be regarded as applicable in all cases where the "R" point or the design torso angle is referred to in this Regulation.

4. PROCEDURE FOR "H" POINT AND ACTUAL TORSO ANGLE DETERMINATION

4.1. The vehicle shall be preconditioned at the manufacturer's discretion, at a temperature of 20 ± 10°C to ensure that the seat material reached room temperature. If the seat to be checked has never been sat upon, a 70 to 80 kg person or device shall sit on the seat twice for one minute to flex the cushion and back. At the manufacturer's request, all seat assemblies shall remain unloaded for a minimum period of 30 min prior to installation of the 3-D H machine.

4.2. The vehicle shall be at the measuring attitude defined in paragraph 2.11. above.

4.3. The seat, if it is adjustable, shall be adjusted first to the rearmost normal driving or riding position, as indicated by the vehicle manufacturer, taking into consideration only the longitudinal adjustment of the seat, excluding seat travel used for purposes other than normal driving or riding positions. Where other modes of seat adjustment exist (vertical, angular, seat-back, etc.) these will then be adjusted to the position specified by the vehicle manufacturer. For suspension seats, the vertical position shall be rigidly fixed corresponding to a normal driving position as specified by the manufacturer.

4.4. The area of the seating position contacted by the 3-D H machine shall be covered by a muslin cotton, of sufficient size and appropriate texture, described as a plain cotton fabric having 18.9 threads per cm^2 and weighing 0.228 kg/m^2 or knitted or non-woven fabric having equivalent characteristics. If the test is run on a seat outside the vehicle, the floor on which the seat is placed shall have the same essential characteristics [2/-9] as the floor of the vehicle in which the seat is intended to be used.

4.5. Place the seat and back assembly of the 3-D H machine so that the centre plane of the occupant (C/LO) coincides with the centre plane of the 3-D H machine. At the manufacturer's request, the 3-D

[2/-9] Tilt angle, height difference with a seat mounting, surface texture, etc.

H machine may be moved inboard with respect to the C/LO if the 3-D H machine is located so far outboard that the seat edge will not permit levelling of the 3-D H machine.

4.6. Attach the foot and lower leg assemblies to the seat pan assembly, either individually or by using the T-bar and lower leg assembly. A line through the "H" point sight buttons shall be parallel to the ground and perpendicular to the longitudinal centre plane of the seat.

4.7. Adjust the feet and leg positions of the 3-D H machine as follows:

4.7.1. Designated seating position: driver and outside front passenger

4.7.1.1. Both feet and leg assemblies shall be moved forward in such a way that the feet take up natural positions on the floor, between the operating pedals if necessary. Where possible the left foot shall be located approximately the same distance to the left of the centre plane of the 3-D H machine as the right foot is to the right. The spirit level verifying the transverse orientation of the 3-D H machine is brought to the horizontal by readjustment of the seat pan if necessary, or by adjusting the leg and foot assemblies towards the rear. The line passing through the "H" point sight buttons shall be maintained perpendicular to the longitudinal centre plane of the seat.

4.7.1.2. If the left leg cannot be kept parallel to the right leg and the left foot cannot be supported by the structure, move the left foot until it is supported. The alignment of the sight buttons shall be maintained.

4.7.2. Designated seating position: outboard rear

For rear seats or auxiliary seats, the legs are located as specified by the manufacturer. If the feet then rest on parts of the floor which are at different levels, the foot which first comes into contact with the front seat shall serve as a reference and the other foot shall be so arranged that the spirit level giving the transverse orientation of the seat of the device indicates the horizontal.

4.7.3. Other designated seating positions:

The general procedure indicated in paragraph 4.7.1. above shall be followed except that the feet shall be placed as specified by the vehicle manufacturer.

4.8. Apply lower leg and thigh weights and level the 3-D H machine.

4.9. Tilt the back pan forward against the forward stop and draw the 3-D H machine away from the seat-back using the T-bar. Reposition the 3-D H machine on the seat by one of the following methods:

4.9.1. If the 3-D H machine tends to slide rearward, use the following procedure. Allow the 3-D H machine to slide rearward until a forward horizontal restraining load on the T-bar is no longer required i.e. until the seat pan contacts the seat-back. If necessary, reposition the lower leg.

4.9.2. If the 3-D H machine does not tend to slide rearward, use the following procedure. Slide the 3-D H machine rearwards by applying a horizontal rearward load to the T-bar until the seat pan contacts the seat-back (see figure 2 of appendix 1 to this annex).

4.10. Apply a 100 ± 10 N load to the back and pan assembly of the 3-D H machine at the intersection of the hip angle quadrant and the T-bar housing. The direction of load application shall be maintained along a line passing by the above intersection to a point just above the thigh bar housing (see figure 2 of appendix 1 to this annex). Then carefully return the back pan to the seat-back. Care must be exercised throughout the remainder of the procedure to prevent the 3-D H machine from sliding forward.

4.11. Install the right and left buttock weights and then, alternately, the eight torso weights. Maintain the 3-D H machine level.

4.12. Tilt the back pan forward to release the tension on the seat-back. Rock the 3-D H machine from side to side through a 10° arc (5° to each side of the vertical centre plane) for three complete cycles to release any accumulated friction between the 3-D H machine and the seat.

During the rocking action, the T-bar of the 3-D H machine may tend to diverge from the specified horizontal and vertical alignment. The T-bar must therefore be restrained by applying an appropriate lateral load during the rocking motions. Care shall be exercised in holding the T-bar and rocking the 3-D H machine to ensure that no inadvertent exterior loads are applied in a vertical or fore and aft direction.

The feet of the 3-D H machine are not to be restrained or held during this step. If the feet change position, they should be allowed to remain in that attitude for the moment.

Carefully return the back pan to the seat-back and check the two spirits levels for zero position. If any movement of the feet has occurred during the rocking operation of the 3-D H machine, they must be repositioned as follows.

Alternately, lift each foot off the floor the minimum necessary amount until no additional foot movement is obtained. During this lifting, the feet are to be free to rotate; and no forward or lateral loads are to be applied. When each foot is placed back in the down position, the heel is to be in contact with the structure designed for this.

Check the lateral spirit level for zero position; if necessary, apply a lateral load to the top of the back pan sufficient to level the 3-D H machine's seat pan on the seat.

4.13. Holding the T-bar to prevent the 3-D H machine from sliding forward on the seat cushion, proceed as follows:

(a) return the back pan to the seat-back;

(b) alternately apply and release a horizontal rearward load, not to exceed 25 N, to the back angle bar at a height approximately at the centre of the torso weights until the hip angle quadrant indicates that a stable position has been reached after load release. Care shall be exercised to ensure that no exterior downward or lateral loads are applied to the 3-D H machine. If another level adjustment of the 3-D H machine is necessary, rotate the back pan forward, re-level, and repeat the procedure from paragraph 4.12.

4.14. Take all measurements:

4.14.1. The co-ordinates of the "H" point are measured with respect to the three-dimensional reference system.

4.14.2. The actual torso angle is read at the back angle quadrant of the 3-D H machine with the probe in its fully rearward position.

4.15. If a re-run of the installation of the 3-D H machine is desired, the seat assembly should remain unloaded for a minimum period of 30 min prior to the re-run. The 3-D H machine should not be left loaded on the seat assembly longer than the time required to perform the test.

4.16. If the seats in the same row can be regarded as similar (bench seat, identical seats, etc.) only one "H" point and one "actual torso angle" shall be determined for each row of seats, the 3-D H machine described in appendix 1 to this annex being seated in a place regarded as representative for the row. This place shall be:

4.16.1. in the case of the front row, the driver's seat;

4.16.2. in the case of the rear row or rows, an outer seat.

Annex 6 - Appendix 1
DESCRIPTION OF THE THREE-DIMENSIONAL "H" POINT MACHINE */-10

(3-D H machine)

1. Back and seat pans

The back and seat pans are constructed of reinforced plastic and metal; they simulate the human torso and thigh and are mechanically hinged at the "H" point. A quadrant is fastened to the probe hinged at the "H" point to measure the actual torso angle. An adjustable thigh bar, attached to the seat pan, establishes the thigh centreline and serves as a baseline for the hip angle quadrant.

2. Body and leg elements

Lower leg segments are connected to the seat pan assembly at the T-bar joining the knees, which is a lateral extension of the adjustable thigh bar. Quadrants are incorporated in the lower leg segments to measure knee angles. Shoe and foot assemblies are calibrated to measure the foot angle. Two spirit levels orient the device in space. Body element weights are placed at the corresponding centres of gravity to provide seat penetration equivalent to a 76 kg male. All joints of the 3-D H machine should be checked for free movement without encountering noticeable friction.

*/-10 For details of the construction of the 3-D H machine refer to Society of Automobile Engineers (SAE), 400 Commonwealth Drive, Warrendale, Pennsylvania 15096, United States of America. The machine corresponds to that described in ISO Standard 6549-1980.

Figure 1 - 3-D H machine elements designation

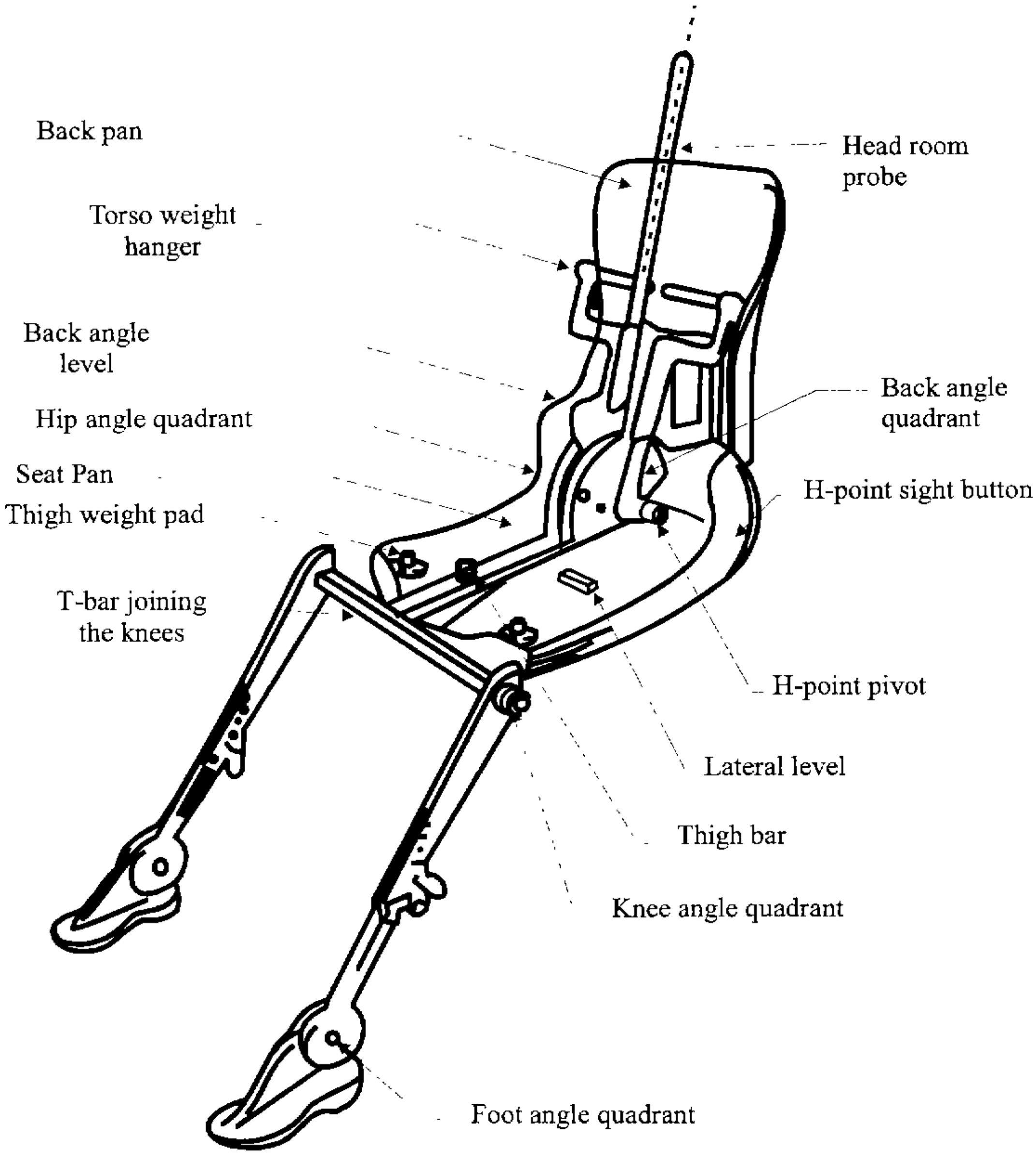
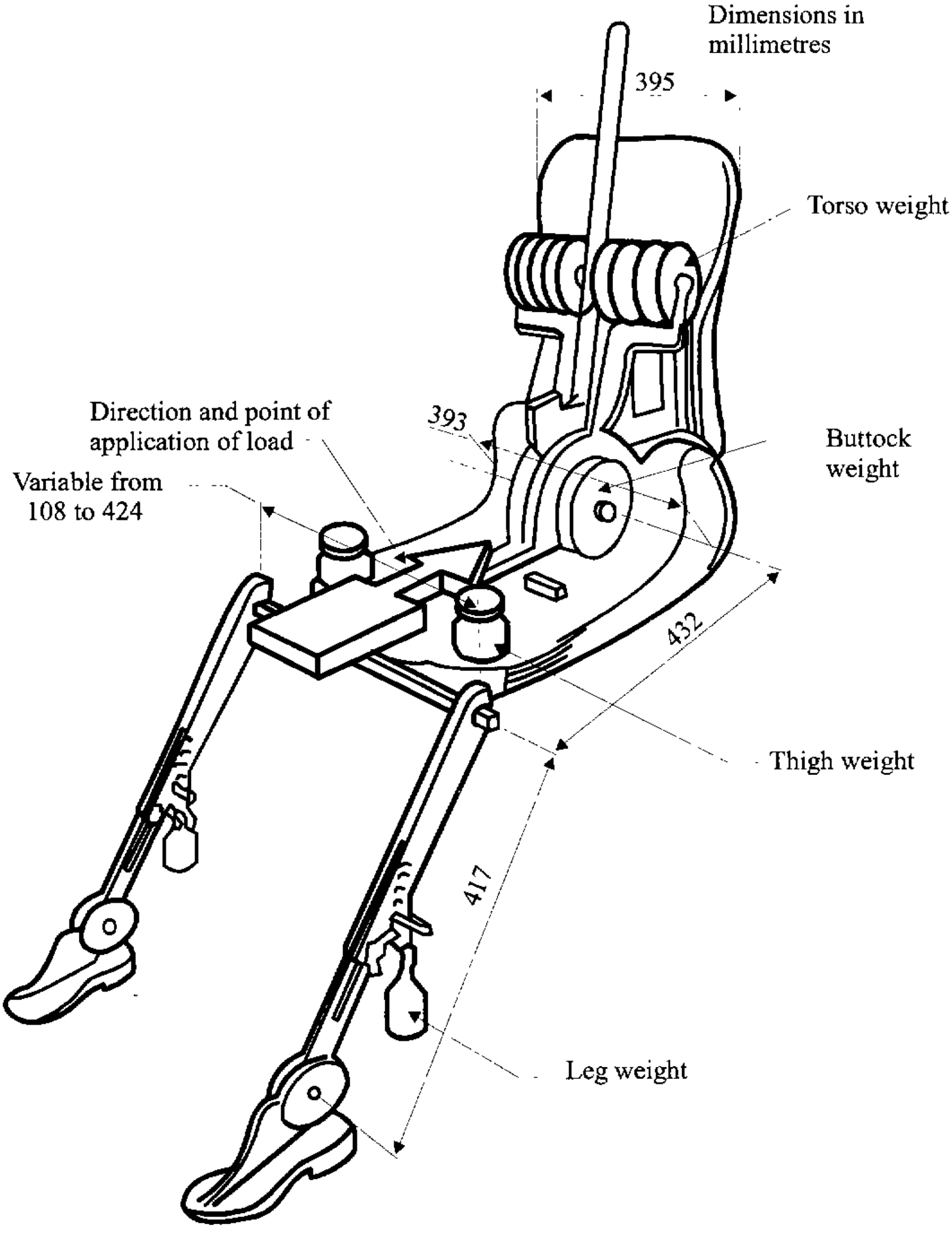


Figure 2 –

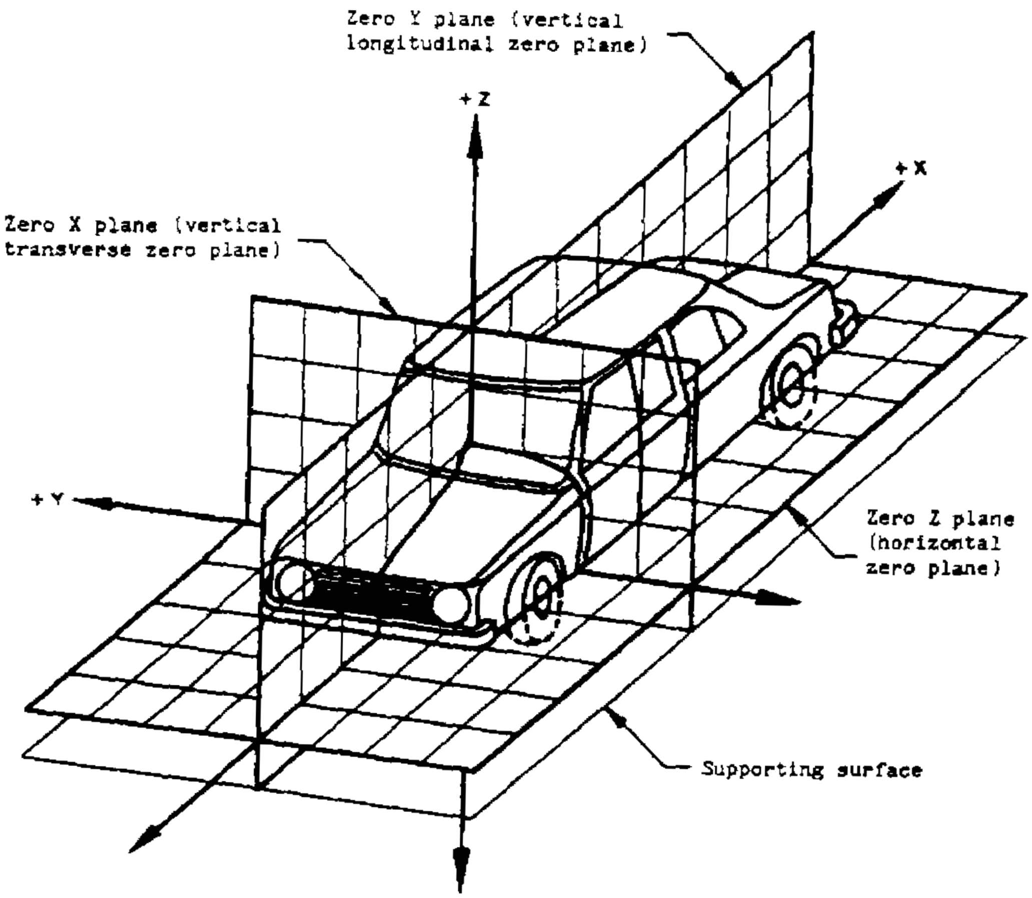
Dimensions of the 3-D H machine elements and load distribution



Annex 6 - Appendix 2
THREE-DIMENSIONAL REFERENCE SYSTEM

1. The three-dimensional reference system is defined by three orthogonal planes established by the vehicle manufacturer (see figure). [*/-11]

2. The vehicle measuring attitude is established by positioning the vehicle on the supporting surface such that the co-ordinates of the fiducial marks correspond to the values indicated by the manufacturer.



3. The co-ordinates of the "R" point and the "H" point are established in relation to the fiducial marks defined by the vehicle manufacturer.

[*/-11] The reference system coresponds to ISO Standard 4130, 1978.

Annex 6 - Appendix 3
REFERENCE DATA CONCERNING SEATING POSITIONS

1. Coding of reference data

Reference data are listed consecutively for each seating position. Seating positions are identified by a two-digit code. The first digit is an Arabic numeral and designates the row of seats, counting from the front to the rear of the vehicle. The second digit is a capital letter which designates the location of the seating position in a row, as viewed in the direction of forward motion of the vehicle; the following letters shall be used:

L = left

C = centre

R = right

2. Description of vehicle measuring attitude

2.1. Co-ordinates of fiducial marks

X ....

Y ....

Z ....

3. List of reference data

3.1. Seating position: ....

3.1.1. Co-ordinates of "R" point

X ....

Y ....

Z ....

3.1.2. Design torso angle: ....

3.1.3. Specifications for seat adjustment [*/-12]

horizontal : ....

vertical : ....

angular : ....

torso angle: ....

Note: List reference data for further seating positions under 3.2., 3.3., etc.

[*/-12] Strike out what does not apply.

Annex 7
TEST PROCEDURE WITH TROLLEY

1. TEST INSTALLATION AND PROCEDURE

1.1. Trolley

The trolley shall be so constructed that no permanent deformation appears after the test. It shall be so guided that, during the impact phase, the deviation in the vertical plane does not exceed 5° and 2° in the horizontal plane.

1.2. State of the structure

1.2.1. General

The structure tested shall be representative of the series production of the vehicles concerned. Some components may be replaced or removed where such replacement or removal clearly has no effect on the test results.

1.2.2. Adjustments

Adjustments shall conform to those set out in paragraph 1.4.3. of annex 3 to this Regulation, taking into account what is stated in paragraph 1.2.1.

1.3. Attachment of the structure

1 3.1. The structure shall be firmly attached to the trolley in such a way that no relative displacement occurs during the test.

1.3.2. The method used to fasten the structure to the trolley shall not have the effect of strengthening the seat anchorages or restraint devices, or of producing any abnormal deformation of the structure.

1.3.3 The attachment device recommended is that whereby the structure rests on supports placed approximately in the axis of the wheels or, if possible, whereby the structure is secured to the trolley by the fastenings of the suspension system

1.3.4. The angle between the longitudinal axis of the vehicle and the direction of motion of the trolley shall be 0° ± 2°.

1.4. Dummies

The dummies and their positioning shall conform to the specifications in annex 3, paragraph 2.

1.5. Measuring apparatus

1.5.1. Deceleration of the structure

The position of the transducers measuring the deceleration of the structure during the impact shall be parallel to the longitudinal axis of the trolley according to the specifications of annex 8 (CFC 180).

1.5.2. Measurements to be made on the dummies

All the measurements necessary for checking the listed criteria are set out in annex 3, paragraph 5.

1.6. Deceleration curve of the structure

The deceleration curve of the structure during the impact phase shall be such that the "variation of speed in relation to time" curve obtained by integration at no point differs by more than ± 1 m/s from the "variation of speed in relation to time" reference curve of the vehicle concerned as defined in appendix to this annex. A displacement with regard to the time axis of the reference curve may be used to obtain the structure velocity inside the corridor.

1.7. Reference curve $\Delta V = f(t)$ of the vehicle concerned

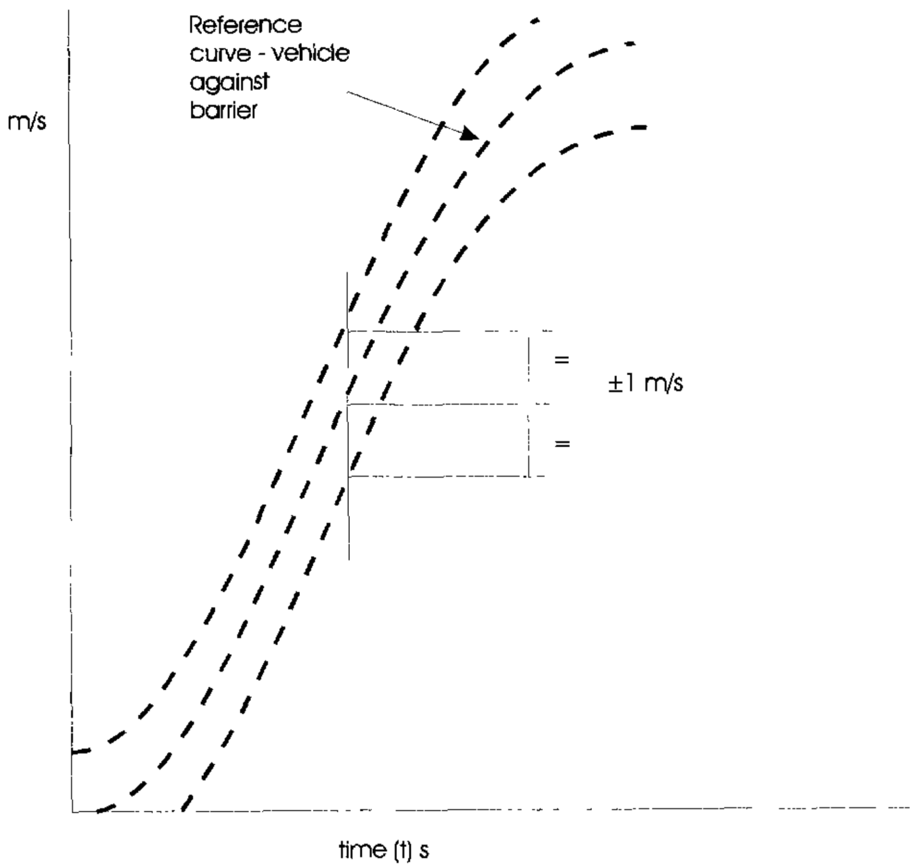
This reference curve is obtained by integration of the deceleration curve of the vehicle concerned measured in the frontal collision test against a barrier as provided for in paragraph 6 of annex 3 to this Regulation.

1.8. Equivalent method

The test may be performed by some other method than that of deceleration of a trolley, provided that such method complies with the requirement concerning the range of variation of speed described in paragraph 1.6.

Annex 7 – Appendix 1

EQUIVALENCE CURVE - TOLERANCE BAND FOR CURVE Δ V = f(t)



Annex 8
TECHNIQUE OF MEASUREMENT IN MEASUREMENT TESTS: INSTRUMENTATION

1. DEFINITIONS

1.1. Data channel

A data channel comprises all the instrumentation from a transducer (or multiple transducers whose outputs are combined in some specified way) up to and including any analysis procedures that may alter the frequency content or the amplitude content of data.

1.2. Transducer

The first device in a data channel used to convert a physical quantity to be measured into a second quantity (such as an electrical voltage) which can be processed by the remainder of the channel.

1.3. Channel amplitude class: CAC

The designation for a data channel that meets certain amplitude characteristics as specified in this annex. The CAC number is numerically equal to the upper limit of the measurement range.

1.4. Characteristic frequencies F_H, F_L, F_N

These frequencies are defined in figure 1.

1.5. Channels frequency class: CFC

The channel frequency class is designated by a number indicating that the channel frequency response lies within the limits specified in figure 1. This number and the value of the frequency F_H in Hz are numerically equal.

1.6. Sensitivity coefficient

The slope of the straight line representing the best fit to the calibration values determined by the method of least square within the channel amplitude class.

1.7. Calibration factor of a data channel

The mean value of the sensitivity coefficients evaluated over frequencies which are evenly spaced on a logarithmic scale between F_L and $F_H/2.5$

1.8. Linearity error

The ratio, in per cent, of the maximum difference between the calibration value and the corresponding value read on the straight line defined in paragraph 1.6. at the upper limit of the channel amplitude class.

1.9. Cross sensitivity

The ratio of the output signal to the input signal, when an excitation is applied to the transducer perpendicular to the measurement axis. It is expressed as a percentage of the sensitivity along the measurement axis.

1.10. Phase delay time

The phase delay time of a data channel is equal to the phase delay (in radians) of a sinusoidal signal, divided by the angular frequency of that signal (in radians/second).

1.11. Environment

The aggregate, at a given moment, of all external conditions and influences to which the data channel is subjected.

2. PERFORMANCE REQUIREMENTS

2.1. Linearity error

The absolute value of the linearity error of a data channel at any frequency in the CFC, shall be equal to or less than 2.5 per cent of the value of the CAC, over the whole measurement range.

2.2. Amplitude against frequency

The frequency response of a data channel shall lie within the limiting curves given in figure 1. The zero dB line is determined by the calibration factor.

2.3. Phase delay time

The phase delay time between the input and the output signals of a data channel shall be determined and shall not vary by more than 1/10 F_H seconds between 0.03 F_H and F_H.

2.4. Time

2.4.1. Time base

A time base shall be recorded and shall at least give 1/100 s with an accuracy of 1 per cent.

2.4.2. Relative time delay

The relative time delay between the signal of two or more data channels, regardless of their frequency class, must not exceed 1 ms excluding delay caused by phase shift.

Two or more data channels of which the signals are combined shall have the same frequency class and shall not have relative time delay greater than 1/10 FH seconds.

This requirement applies to analogue signals as well as to synchronisation pulses and digital signals.

2.5. Transducer cross sensitivity

The transducer cross sensitivity shall be less than 5 per cent in any direction.

2.6. Calibration

2.6.1. General

A data channel shall be calibrated at least once a year against reference equipment traceable to known standards. The methods used to carry out a comparison with reference equipment shall not introduce an error greater than 1 per cent of the CAC. The use of the reference equipment is limited to the frequency range for which they have been calibrated. Subsystems of a data channel may be evaluated individually and the results factored into the accuracy of the total data channel. This can be done for example by an electrical signal of known amplitude simulating the output signal of the transducer which allows a check to be made on the gain factor of the data channel, excluding the transducer.

2.6.2. Accuracy of reference equipment for calibration

The accuracy of the reference equipment shall be certified or endorsed by an official metrology service.

2.6.2.1. Static calibration

2.6.2.1.1. Accelerations

The errors shall be less than ± 1.5 per cent of the channel amplitude class.

2.6.2.1.2. Forces

The error shall be less than ± 1 per cent of the channel amplitude class.

2.6.2.1.3. Displacements

The error shall be less than ± 1 per cent of the channel amplitude class.

2.6.2.2. Dynamic calibration

2.6.2.2.1. Accelerations

The error in the reference accelerations expressed as a percentage of the channel amplitude class shall be less than ± 1.5 per cent below 400 Hz, less than ± 2 per cent between 400 Hz and 900 Hz, and less than ± 2.5 per cent above 900 Hz.

2.6.2.3. Time

The relative error in the reference time shall be less than 10^{-5}.

2.6.3. Sensitivity coefficient and linearity error

The sensitivity coefficient and the linearity error shall be determined by measuring the output signal of the data channel against a known input signal for various values of this signal. The calibration of the data channel shall cover the whole range of the amplitude class. For bi-directional channels, both the positive and negative values shall be used. If the calibration equipment cannot produce the required input owing to the excessively high values of the quantity to be measured, calibrations shall be carried out within the limits of the calibration standards and these limits shall be recorded in the test report.

A total data channel shall be calibrated at a frequency or at a spectrum of frequencies having a significant value between F_L and $F_H/2.5$.

2.6.4. Calibration of the frequency response

The response curves of phase and amplitude against frequency shall be determined by measuring the output signals of the data channel in terms of phase and amplitude against a known input signal, for various values of this signal varying between F_L and 10 times the CFC or 3,000 Hz, whichever is lower.

2.7. Environmental effects

A regular check shall be made to identify any environmental influence (such as electric or magnetic flux, cable velocity, etc.). This can be done for instance by recording the output of spare channels equipped with dummy transducers. If significant output signals are obtained corrective action shall be taken, for instance by replacement of cables.

2.8. Choice and designation of the data channel

The CAC and CFC define a data channel.

The CAC shall be 1, 2 or 5 to a power of ten.

3. MOUNTING OF TRANSDUCERS

Transducers should be rigidly secured so that their recordings are affected by vibration as little as possible. Any mounting having a lowest resonance frequency equal to at least 5 times the frequency F_H of the data channel considered shall be considered valid. Acceleration transducers in particular should be mounted in such a way that the initial angle of the real measurement axis to the corresponding axis of the reference axis system is not greater than 5° unless an analytical or experimental assessment of the effect of the mounting on the collected data is made. When multi-axial accelerations at a point are to be measured, each acceleration transducer axis should pass within 10 mm of that point, and the centre of seismic mass of each accelerometer should be within 30 mm of that point.

4. RECORDING

4.1. Analogue magnetic recorder

Tape speed should be stable to within not more than 0.5 per cent of the tape speed used. The signal-to-noise ratio of the recorder should not be less than 42 dB at the maximum tape speed. The total harmonic distortion should be less than 3 per cent and the linearity error should be less than 1 per cent of the measurement range.

4.2. Digital magnetic recorder

Tape speed should be stable to within not more than 10 per cent of the tape speed used.

4.3. Paper tape recorder

In case of direct data recording the paper speed in mm/s should be at least 1.5 times the number expressing F_H in Hz. In other cases the paper speed should be such that equivalent resolution is obtained.

5. DATA PROCESSING

5.1. Filtering

Filtering corresponding to the frequencies of the data channel class may be carried out during either recording or processing of data. However, before recording, analogical filtering at a higher level than CFC should be effected in order to use at least 50 per cent of the dynamic range of the recorder and to reduce the risk of high frequencies saturating the recorder or causing aliasing errors in the digitilising process.

5.2. Digitilising

5.2.1. Sampling frequency

The sampling frequency should be equal to at least 8 F_H. In the case of analogical recording, when the recording and reading speeds are different, the sampling frequency can be divided by the speed ratio.

5.2.2. Amplitude resolution

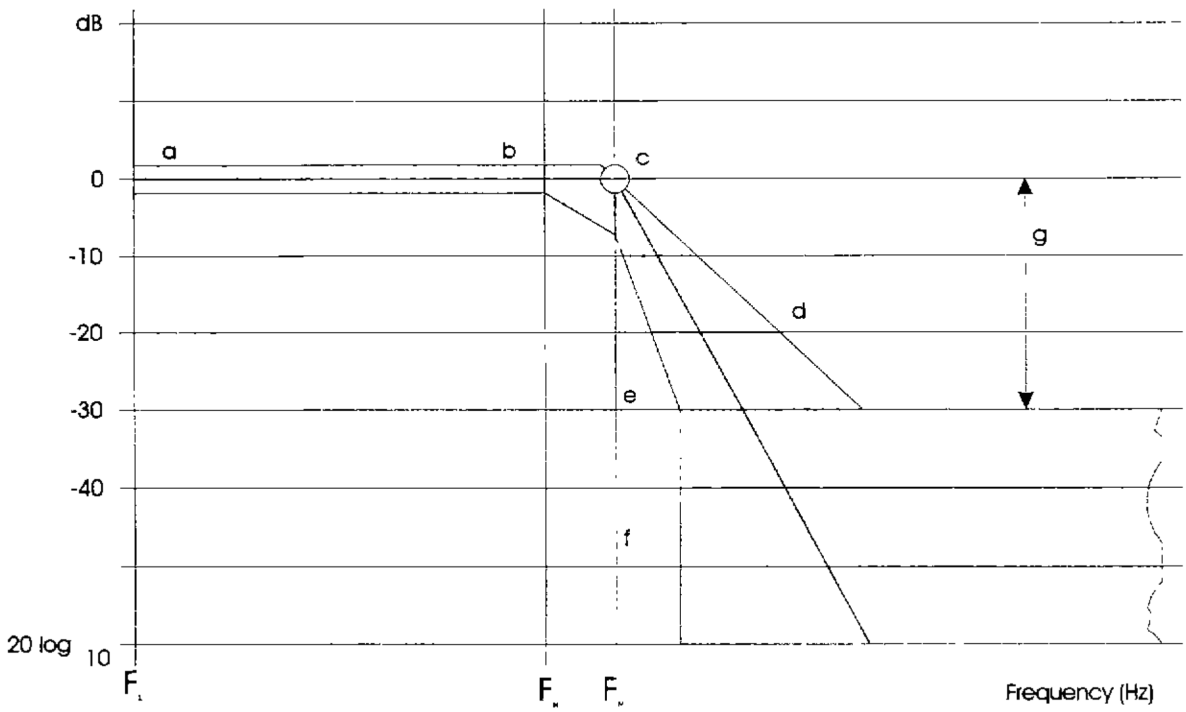
The size of digital words should be at least 7 bits and a parity bit.

6. PRESENTATION OF RESULTS

The results should be presented on A4 size paper (ISO/R 216). Results presented as diagrams should have axes scaled with a measurement unit corresponding to a suitable multiple of the chosen unit (for example, 1, 2, 5, 10, 20 millimetres). SI units shall be used, except for vehicle velocity, where km/h may be used, and for accelerations due to impact where g, with $g = 9.81$ m/s^2, may be used.

Figure 1.

Frequency response curve



CFC	F_L Hz	F_H Hz	F_N Hz	N	Logarithmic scale	
				a	± 0.5	dB
				b	+0.5;-1	dB
				c	+0.5;-4	dB
1,000	≤ 0.1	1,000	1,650	d	-9	dB/octave
600	≤ 0.1	600	1,000	e	-20	dB/octave
180	≤ 0.1	180	300	f	∞	dB/octave
60	≤ 0.1	60	100	g	-30	dB

Annex 9
DEFINITION OF DEFORMABLE BARRIER

1. COMPONENT AND MATERIAL SPECIFICATIONS

The dimensions of the barrier are illustrated in Figure 1 of this annex. The dimensions of the individual components of the barrier are listed separately below.

1.1. Main honeycomb block

Dimensions : All dimensions should allow a tolerance of ± 2,5 mm

Height: 650 mm (in direction of honeycomb ribbon axis)

Width: 1000 mm

Depth: 450 mm (in direction of honeycomb cell axes)

Material: Aluminium 3003 (ISO 209, part 1)

Foil Thickness: 0.076 mm

Cell Size: 19.14 mm

Density: 28.6 kg/m^3

Crush Strength: 0.342 MPa +0% -10% [1/]

1.2. Bumper element

Dimensions: All dimensions should allow a tolerance of ± 2,5 mm

Height: 330 mm (in direction of honeycomb ribbon axis)

Width: 1000 mm

Depth: 90 mm (in direction of honeycomb cell axes)

Material: Aluminium 3003 (ISO 209, part 1)

Foil Thickness: 0.076 mm

Cell size: 6.4 mm

Density: 82.6 kg/m^3

Crush Strength: 1.711 MPa +0% -10% [1/]

1.3. Backing sheet

Dimensions

Height: 800 mm ± 2,5 mm

Width: 1000 mm ± 2,5 mm

Thickness: 2.0 mm ± 0.1 mm

1.4. Cladding sheet

[1/] In accordance with the certification procedure described in paragraph 2 of this annex.

Dimensions

Length: 1700 mm ± 2,5 mm

Width: 1000 mm ± 2,5 mm

Thickness: 0.81 ± 0.07 mm

Material: Aluminium 5251/5052 (ISO 209, part 1)

1.5. Bumper facing sheet

Dimensions

Height: 330 mm ± 2,5 mm

Width: 1000 mm ± 2,5 mm

Thickness: 0.81 mm ± 0.07 mm

Material: Aluminium 5251/5052 (ISO 209, part 1)

1.6. Adhesive:

The adhesive to be used throughout should be a two-part polyurethane (such as Ciba-Geigy XB5090/1 resin with XB5304 hardener, or equivalent).

2. ALUMINIUM HONEYCOMB CERTIFICATION

A complete testing procedure for certification of aluminium honeycomb is given in NHTSA TP-214D. The following is a summary of the procedure that should be applied to materials for the frontal impact barrier, these materials having a crush strength of 0.342 MPa and 1.711 MPa respectively.

2.1. Sample locations

To ensure uniformity of crush strength across the whole of the barrier face, eight samples shall be taken from four locations evenly spaced across the honeycomb block. For a block to pass certification, seven of these eight samples shall meet the crush strength requirements of the following sections.

The location of the samples depends on the size of the honeycomb block. First, four samples, each measuring 300 mm x 300 mm x 50 mm thick shall be cut from the block of barrier face material. Please refer to Figure 2 for an illustration of how to locate these sections within the honeycomb block. Each of these larger samples shall be cut into samples for certification testing (150 mm x 150 mm x 50 mm).Certification shall be based on the testing of two samples from each of these four locations. The other two should be made available to the applicant, upon request.

2.2. Sample size

Samples of the following size shall be used for testing:

Length: 150 mm ± 6 mm

Width: 150 mm ± 6 mm

Thickness: 50 mm ± 2 mm

The walls of incomplete cells around the edge of the sample shall be trimmed as follows:

In the "W" direction, the fringes shall be no greater than 1.8 mm (see Figure 3).

In the "L" direction, half the length of one bonded cell wall (in the ribbon direction) shall be left at either end of the specimen (see Figure 3).

2.3. Area measurement

The length of the sample shall be measured in three locations,12.7 mm from each end and in the middle, and recorded as L1, L2 and L3 (Figure 3). In the same manner, the width shall be measured and recorded as W1, W2 and W3 (Figure 3). These measurements shall betaken on the centreline of the thickness. The crush area shall then be calculated as:

$$A = \frac{(L1 + L2 + L3)}{3} X \frac{(W1 + W2 + W3)}{3}$$

2.4. Crush rate and distance

The sample shall be crushed at a rate of not less than 5.1 mm/min and not more than 7.6 mm/min. The minimum crush distance shall be 16.5 mm.

2.5. Data collection

Force versus deflection data are to be collected in either analog or digital form for each sample tested. If analog data are collected then a means of converting this to digital shall be available. All digital data shall be collected at a rate of not less than 5 Hz (5 points per second).

2.6. Crush strength determination

Ignore all data prior to 6.4 mm of crush and after 16.5 mm of crush. Divide the remaining data into three sections or displacement intervals (n = 1, 2, 3) (see Figure 4) as follows:

(1) 06.4 mm - 09.7 mm inclusive,

(2) 09.7 mm - 13.2 mm exclusive,

(3) 13.2 mm - 16.5 mm inclusive.

Find the average for each section as follows:

$$F(n) = \frac{[F(n)1 + F(n)2 + ... F(n)m]}{m}; m = 1, 2, 3$$

where m represents the number of data points measured in each of the three intervals. Calculate the crush strength of each section as follows:

$$S(n) = \frac{F(n)}{A}; n = 1,2,3$$

2.7. Sample crush strength specification

For a honeycomb sample to pass this certification, the following conditions shall be met:

0.308 MPa $\leq$ S(n) $\leq$ 0.342 MPa for 0.342 MPa material

1.540 MPa $\leq$ S(n) $\leq$ 1.711 MPa for 1.711 MPa material

n = 1, 2, 3.

2.8. Block crush strength specification

Eight samples are to be tested from four locations, evenly spaced across the block. For a block to pass certification, seven of the eight samples shall meet the crush strength specification of the previous section.

3. ADHESIVE BONDING PROCEDURE

3.1. Immediately before bonding, aluminium sheet surfaces to be bonded shall be thoroughly cleaned using a suitable solvent, such as 1-1-1 Trichloroethane.

This is to be carried out at least twice or as required to eliminate grease or dirt deposits. The cleaned surfaces shall then be abraded using 120 grit abrasive paper.

Metallic/Silicon Carbide abrasive paper is not to be used. The surfaces shall be thoroughly abraded and the abrasive paper changed regularly during the process to avoid clogging, which may lead to a polishing effect. Following abrading, the surfaces shall be thoroughly cleaned again, as above. In total, the surfaces shall be solvent cleaned at least four times. All dust and deposits left as a result of the abrading process shall be removed, as these will adversely affect bonding.

3.2. The adhesive should be applied to one surface only, using a ribbed rubber roller. In cases where honeycomb is to be bonded to aluminium sheet, the adhesive should be applied to the aluminium sheet only. A maximum of 0.5 kg/m^2 shall be applied evenly over the surface, giving a maximum film thickness of 0.5 mm.

4. CONSTRUCTION

4.1. The main honeycomb block shall be bonded to the backing sheet with adhesive such that the cell axes are perpendicular to the sheet.

The cladding shall be bonded to the front surface of the honeycomb block. The top and bottom surfaces of the cladding sheet shall not be bonded to the main honeycomb block but should be positioned closely to it. The cladding sheet shall be adhesively bonded to the backing sheet at the mounting flanges.

4.2. The bumper element shall be adhesively bonded to the front of the cladding sheet such that the cell axes are perpendicular to the sheet.

The bottom of the bumper element shall be flush with the bottom surface of the cladding sheet. The bumper facing sheet shall be adhesively bonded to the front of the bumper element.

4.3. The bumper element shall then be divided into three equal sections by means of two horizontal slots.

These slots shall be cut through the entire depth of the bumper section and extend the whole width of the bumper. The slots shall be cut using a saw; their width shall be the width of the blade used and shall not exceed 4.0 mm.

4.4. Clearance holes for mounting the barrier are to be drilled in the mounting flanges (shown in Figure 5).

The holes shall be of 9.5 mm diameter. Five holes shall be drilled in the top flange at a distance of 40 mm from the top edge of the flange and five in the bottom flange, 40 mm from the bottom edge of that flange. The holes shall be at 100 mm, 300 mm, 500 mm, 700 mm, 900 mm from either edge of the barrier distances. All holes shall be drilled to ± 1 mm of the nominal

5. MOUNTING

5.1. The deformable barrier shall be rigidly fixed to the edge of a mass of not less than 7 x 10^4 kg or to some structure attached thereto.

The attachment of the barrier face shall be such that the vehicles shall not contact any part of the structure more than 75 mm from the top surface of the barrier (excluding the upper flange) during any stage of the impact[2/]. The front face of the surface to which the deformable barrier is attached shall be flat and continuous over the height and width of the face and shall be vertical ± 1° and

[2/] A mass, the end of which is between 925 mm and 1,000 mm high and at least 1.000 mm deep, is considered to satisfy this requirement.

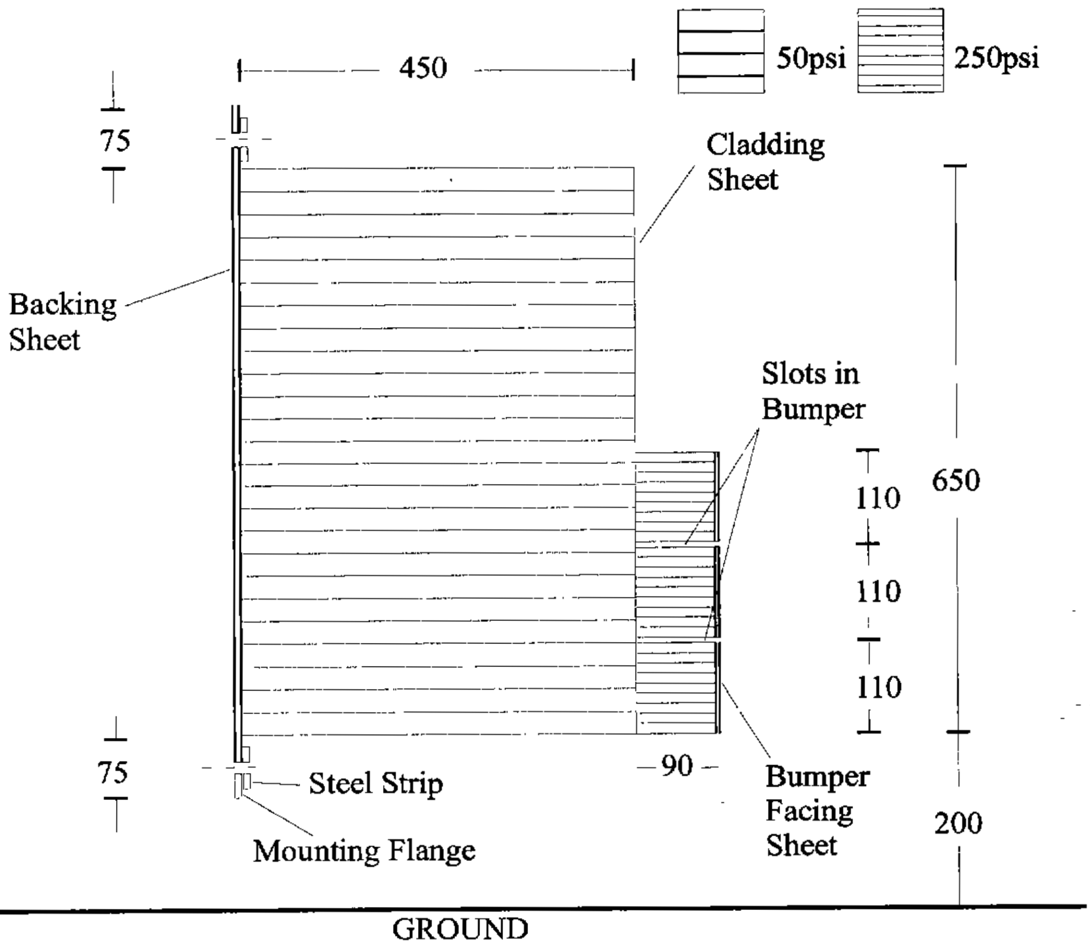
perpendicular ± 1° to the axis of the run-up track. The attachment surface shall not be displaced by more than 10 mm during the test. If necessary, additional anchorage or arresting devices shall be used to prevent displacement of the concrete block. The edge of the deformable barrier shall be aligned with the edge of the concrete block appropriate for the side of the vehicle to be tested.

5.2. The deformable barrier shall be fixed to the concrete block by means of ten bolts, five in the top mounting flange and five in the bottom.

These bolts shall be of at least 8 mm diameter. Steel clamping strips shall be used for both the top and bottom mounting flanges (see Figures 1 and 5). These strips shall be 60 mm high and 1000 mm wide and have a thickness of at least 3 mm. Five clearance holes of 9.5 mm diameter shall be drilled in both strips to correspond with those in the mounting flange on the barrier (see paragraph 4). None of the fixtures shall fail in the impact test.

Figure 1

Deformable barrier for frontal impact testing

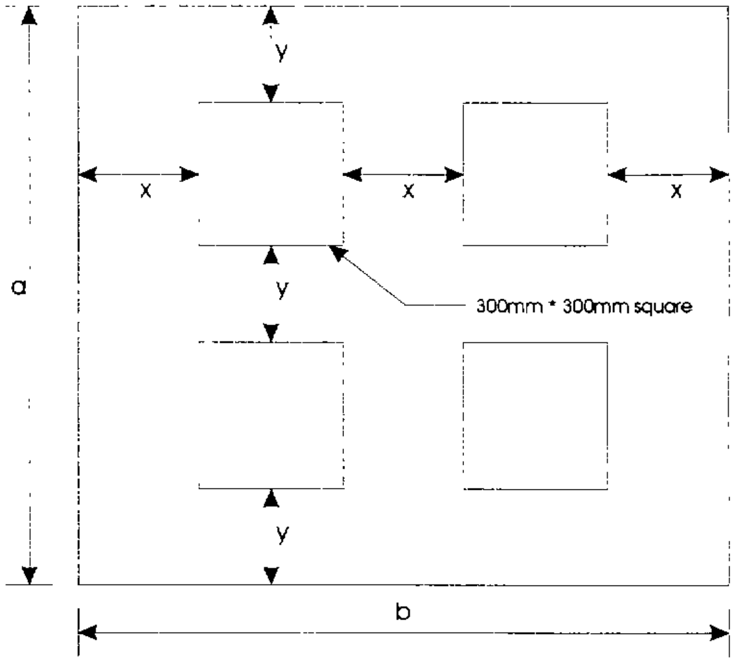


Barrier width = 1000 mm.

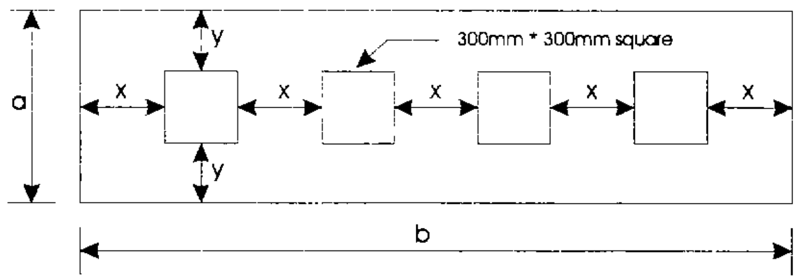
All dimensions in mm.

Figure 2

Locations of samples for certification



If a ≥ 900mm: x = 1/3(b-600mm) and y = 1/3(a-600mm) (for a ≤ b)



If a < 900mm: x = 1/5(b-1200mm) and y = ½ (a-300mm) for a ≤ b)

Figure 3

Honeycomb axes and measured dimensions

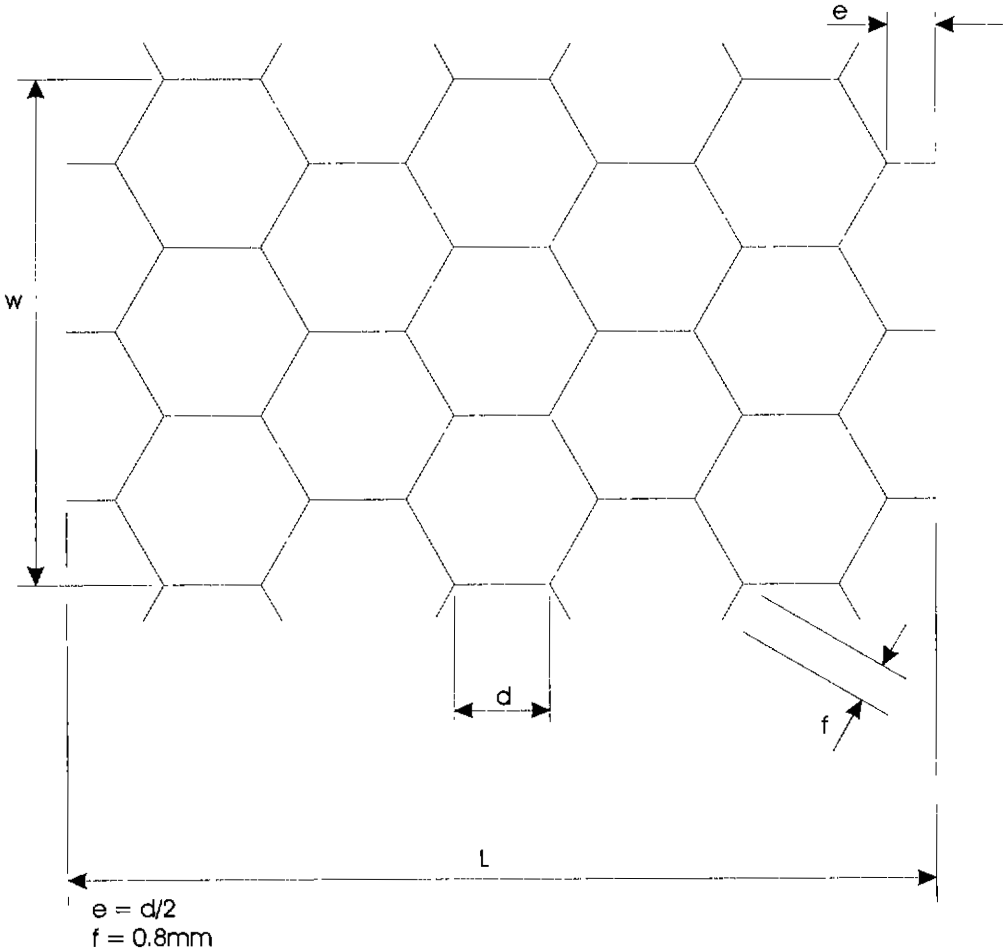


Figure 4

Crush force and displacement

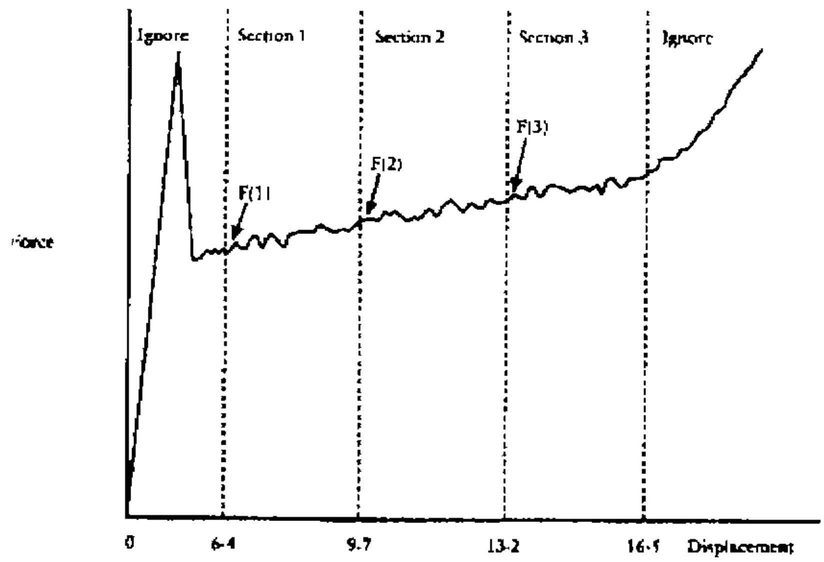
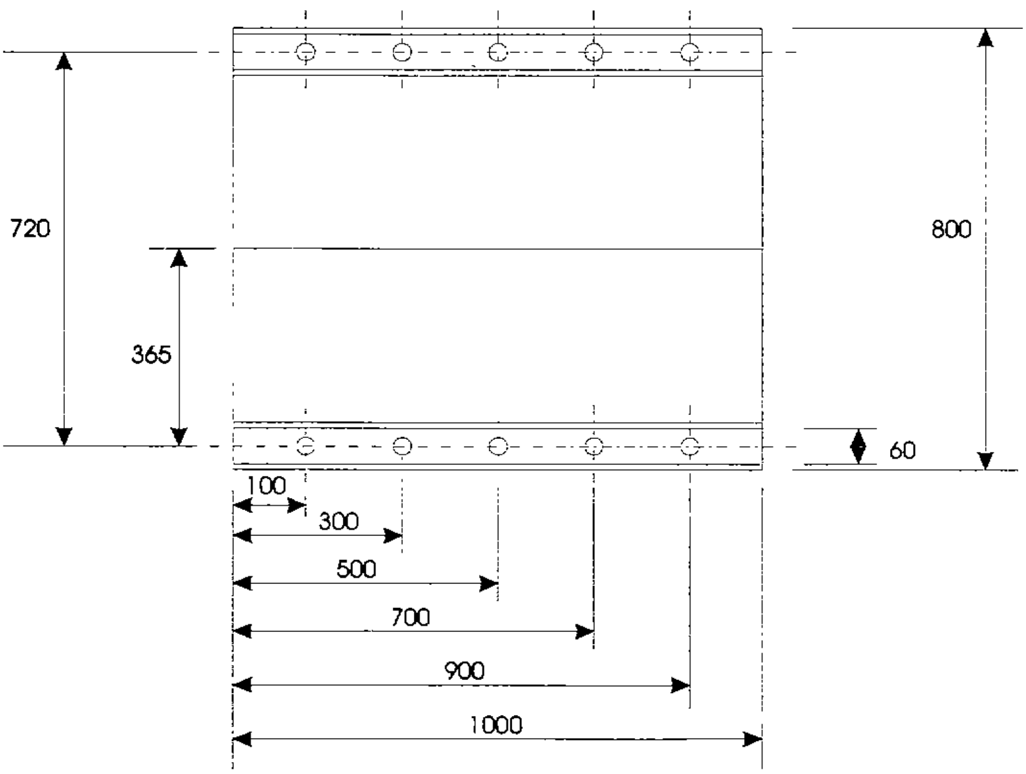


Figure 5

Positions of holes for barrier mounting



Hole diameters 9,5 mm.

All dimensions in mm.

Annex 10
CERTIFICATION PROCEDURE FOR THE DUMMY LOWER LEG AND FOOT

1. TIBIA IMPACT TEST

1.1. The objective of this test is to measure the response of Hybrid III tibia skin and insert to well-defined, hard-faced pendulum impacts.

1.2. Left and right Hybrid III leg assemblies, from the knee clevis joint down, shall be used. Each shall be attached rigidly to the test fixture.

1.3. Test procedure

1.3.1. Each leg assembly shall be maintained (soaked) for 4 hours prior to the test at a temperature of 22 ± 3°C and a relative humidity of 40 ± 30 per cent. The soak period shall not include the time required to reach steady state conditions.

1.3.2. Align the impactor accelerometer with its sensitive axis parallel to the impactor longitudinal centre line.

1.3.3. Clean the impact surface of the skin and also the impactor face with isopropyl alcohol or equivalent prior to the test.

1.3.4. Mount the leg assembly to the fixture at the knee clevis joint, as shown in Figure 1. The test fixture shall be rigidly secured to prevent movement during impact. The test fixture shall be constructed such that there is no contact with any part of the leg assembly, other than at the fixing point, during the test. The line between the knee clevis joint and the centre of the ankle joint shall be vertical ± 5°. Adjust the knee and ankle joint to 1,5 ± 0,5 g range before each test.

1.3.5. The rigid impactor shall have a mass of 5,0 ± 0,2 kg including instrumentation. The impact face shall be a half cylinder with its principal axis horizontal ± 1° and perpendicular to the direction of impact. The radius of the impact surface shall be 40 ± 2 mm and the width of the impact surface shall be at least 80 mm. The impactor shall strike the tibia at a point midway between the knee clevis joint and the ankle pivot along the centre line of the tibia. The impactor shall strike the tibia so that the horizontal centre line of the impactor falls within 0,5° of a horizontal line parallel to the femur load cell simulator at time-zero. The impactor shall be guided to exclude significant lateral, vertical or rotational movement at time-zero .

1.3.6. Allow a period of at least 30 minutes between successive tests on the same leg.

1.3.7. The data acquisition system, including transducers, shall conform to the specifications for CFC 600, as described in annex 8.

1.4. Performance specification

1.4.1. When each tibia is impacted at 2.1 ± 0,3 m/s in accordance with paragraph 1.3., the impact force, which is the product of the pendulum mass and the deceleration, shall be 2.3 ± 0,3 kN.

2. UPPER FOOT IMPACT TEST

2.1. The objective of this test is to measure the response of the Hybrid III foot and ankle to well-defined, hard-faced pendulum impacts.

2.2. The complete Hybrid III lower leg assembly, left (86-5001-001) and right (86-5001-002), equipped with the foot and ankle assembly, left (78051-614) and right (78051-615), shall be used, including the knee assembly. The load cell simulator (78051-319 Rev A) shall be used to secure the knee-cap assembly (78051-16 Rev B) to the test fixture.

2.3. Test procedure

2.3.1. Each leg assembly shall be maintained (soaked) for 4 hours prior to the test at a temperature of 22 ± 3°C and a relative humidity of 40 ± 30 per cent. The soak period shall not include the time required to reach steady state conditions.

2.3.2. a) Clean the impact surface of the skin and also the impactor face with isopropyl alcohol or equivalent prior to the test.

b)Align the impactor accelerometer with its sensitive axis parallel to the direction of impact at contact with the foot.

2.3.3. Mount the leg assembly to the fixture shown in Figure 1a. The test fixture shall be secured rigidly to prevent movement during the impact test. The centre line of the femur load cell simulator (78051-319) shall be vertical ± 0,5°. Adjust the mount such that the line joining the knee clevis joint and the ankle attachment bolt is horizontal ± 3° with the heel resting on two sheets of low-friction (PTFE) material. Ensure that the tibia flesh is located towards the knee end of the tibia. Adjust the ankle such that the plane of the underside of the foot is vertical ± 3°. Adjust the knee and ankle joint to 1,5 ± 0,5 g range before each test.

2 3.4. The rigid impactor comprises a horizontal cylinder diameter 50 ± 2 mm and a pendulum support arm diameter 19 ± 1 mm (Figure 3a). The cylinder has a mass of 1,25 ± 0,02 kg including instrumentation and any part of the support arm within the cylinder. The pendulum arm has a mass of 285 ± 5 g. The mass of any rotating part of the axle to which the support arm is attached should not be greater than100 g. The length between the central horizontal axis of the impactor cylinder and the axis of rotation of the whole pendulum shall be 1250 ± 1 mm. The impact cylinder is mounted with its longitudinal axis horizontal and perpendicular to the direction of impact. The pendulum shall impact the underside of the foot, at a distance of 185 ± 2 mm from the base of the heel resting on the rigid horizontal platform, so that the longitudinal centre line of the pendulum arm falls within 1° of a vertical line at impact. The impactor shall be guided to exclude significant lateral, vertical or rotational movement at time-zero.

2.3 5. Allow a period of at least 30 minutes between successive tests on the same leg.

2.3.6. The data acquisition system, including transducers, shall conform to the specifications for CFC 600, as described in annex 8.

2.4. Performance specifications

2.4.1. When the ball of each foot is impacted at 6,7 ± 0,2 m/s in accordance with paragraph 2 3., the maximum tibia bending moment about they-axis (My) shall be between 100 Nm and 140 Nm.

3. LOWER FOOT IMPACT TEST

3.1. The objective of this test is to measure the response of the Hybrid III foot skin and insert to well-defined, hard-faced pendulum impacts.

3.2. The complete Hybrid III lower leg assembly, left (86-5001-001) and right (86-5001-002), equipped with the foot and ankle assembly, left (78051-614) and right (78051-615), shall be used, including the knee assembly. The load cell simulator (78051-319 Rev A) shall be used to secure the knee-cap assembly (78051-16 Rev B) to the test fixture.

3.3. Test procedure

3.3.1. Each leg assembly shall be maintained (soaked) for 4 hours prior to the test at a temperature of 22 ± 3°C and a relative humidity of 40 ± 30 per cent. The soak period shall not include the time required to reach steady state conditions.

3.3.2. Align the impactor accelerometer with its sensitive axis parallel to the impactor longitudinal centre line.

3.3.3. Clean the impact surface of the skin and also the impactor face with isopropyl alcohol or equivalent prior to the test.

3.3.4. Mount the leg assembly to the fixture shown in Figure 1b. The test fixture shall be secured rigidly to prevent movement during the impact test. The centre line of the femur load cell simulator (78051-319) shall be vertical ± 0,5°. Adjust the mount such that the line joining the knee clevis joint and the ankle attachment bolt is horizontal ± 3° with the heel resting on two sheets of low-friction (PTFE) material. Ensure that the tibia flesh is located towards the knee end of the tibia. Adjust the ankle such that the plane of the underside of the foot is vertical ± 3°. Adjust the knee and ankle joint to 1,5 ± 0,5 g range before each test.

3.3.5. The rigid impactor comprises a horizontal cylinder diameter 50 ± 2 mm and a pendulum support arm diameter 19 ± 1 mm (Figure 3a). The cylinder has a mass of 1,25 ± 0,02 kg including instrumentation and any part of the support arm within the cylinder. The pendulum arm has a mass of 285 ± 5 g. The mass of any rotating part of the axle to which the support arm is attached should not be greater than 100 g. The length between the central horizontal axis of the impactor cylinder and the axis of rotation of the whole pendulum shall be 1250 ± 1 mm. The impact cylinder is mounted with its longitudinal axis horizontal and perpendicular to the direction of impact. The pendulum shall impact the underside of the foot, at a distance of 62 ± 2 mm from the base of the heel resting on the rigid horizontal platform, so that the longitudinal centre line of the pendulum arm falls within 1° of a vertical line at impact. The impactor shall be guided to exclude significant lateral, vertical or rotational movement at time-zero.

3.3.6. Allow a period of at least 30 minutes between successive tests on the same leg.

3.3.7. The data acquisition system, including transducers, shall conform to the specifications for CFC 600, as described in annex 8.

3.4. Performance specification

3.4.1. When the heel of each foot is impacted at 4,4 ± 0,2 m/s in accordance with paragraph 3.3., the maximum impactor acceleration shall be 340 ± 50 g.

Figure 1

Tibia impact test - test set-up specifications

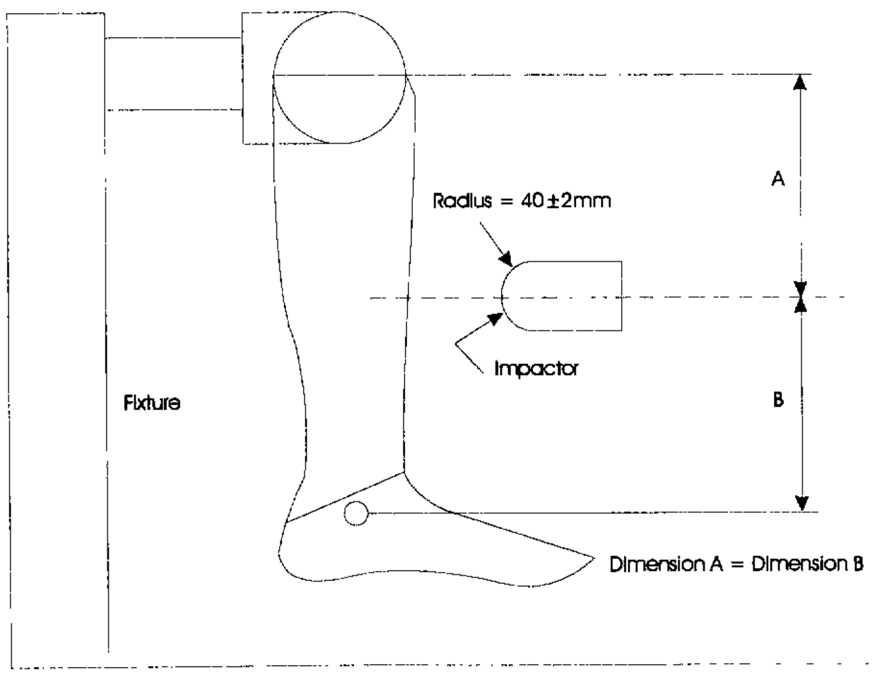


Figure 1a

Upper foot impact test - test set-up specifications

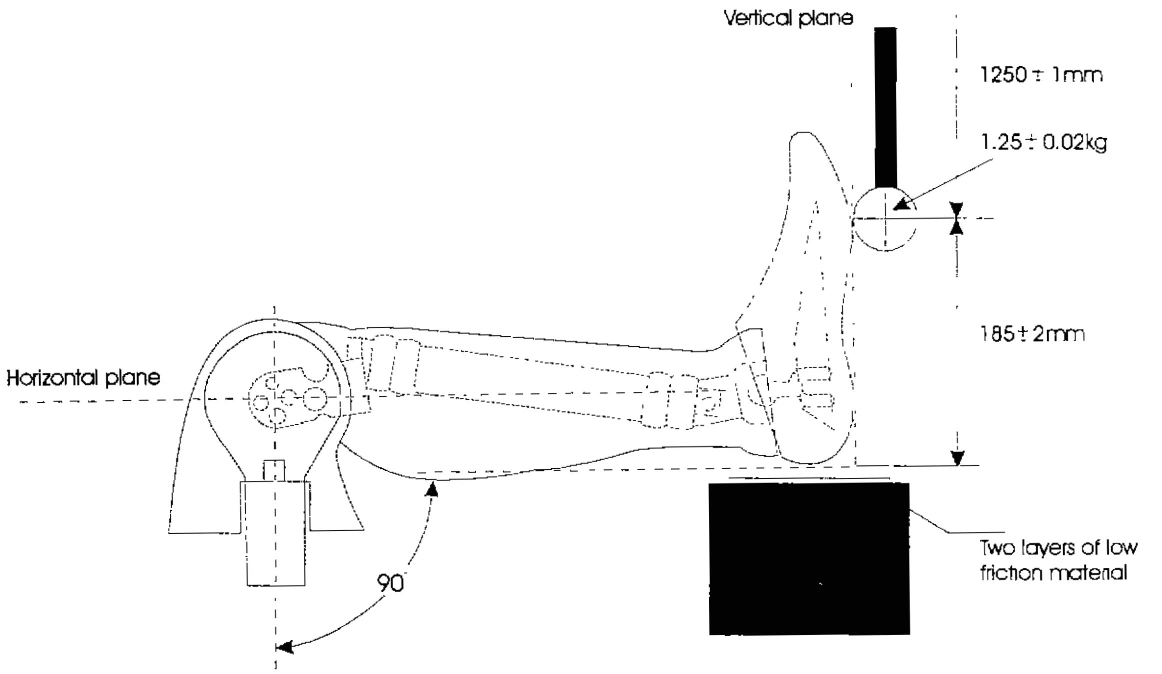


Figure 1b

Lower foot impact test - test set-up specifications

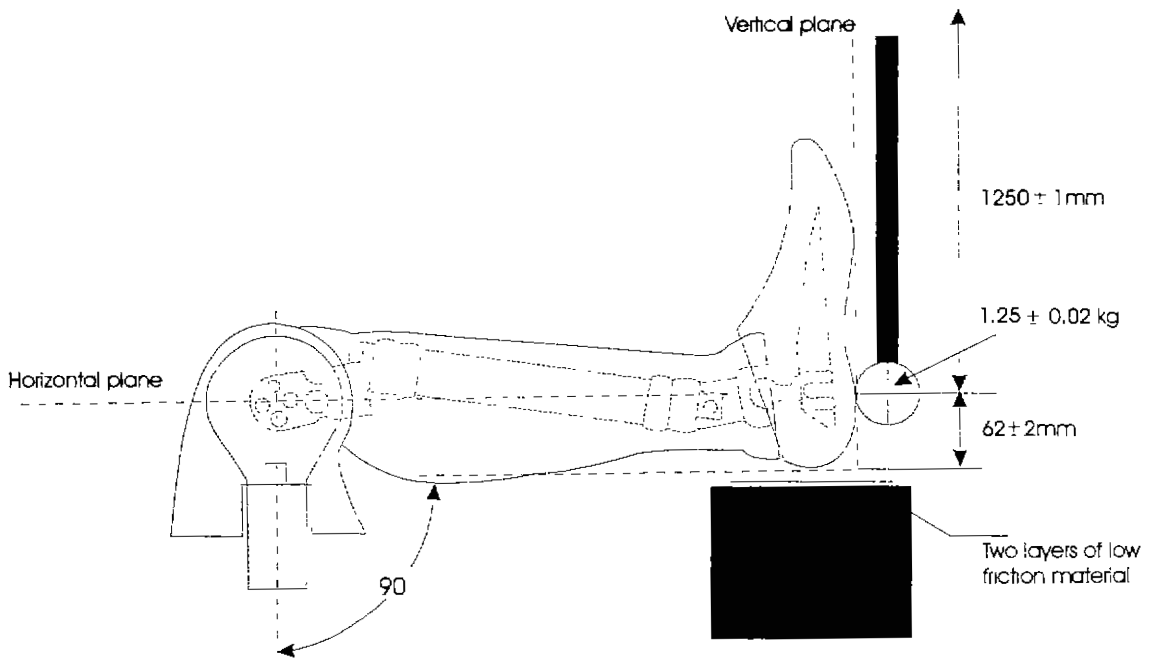


Figure 2

Upper foot impact test - test set-up specifications

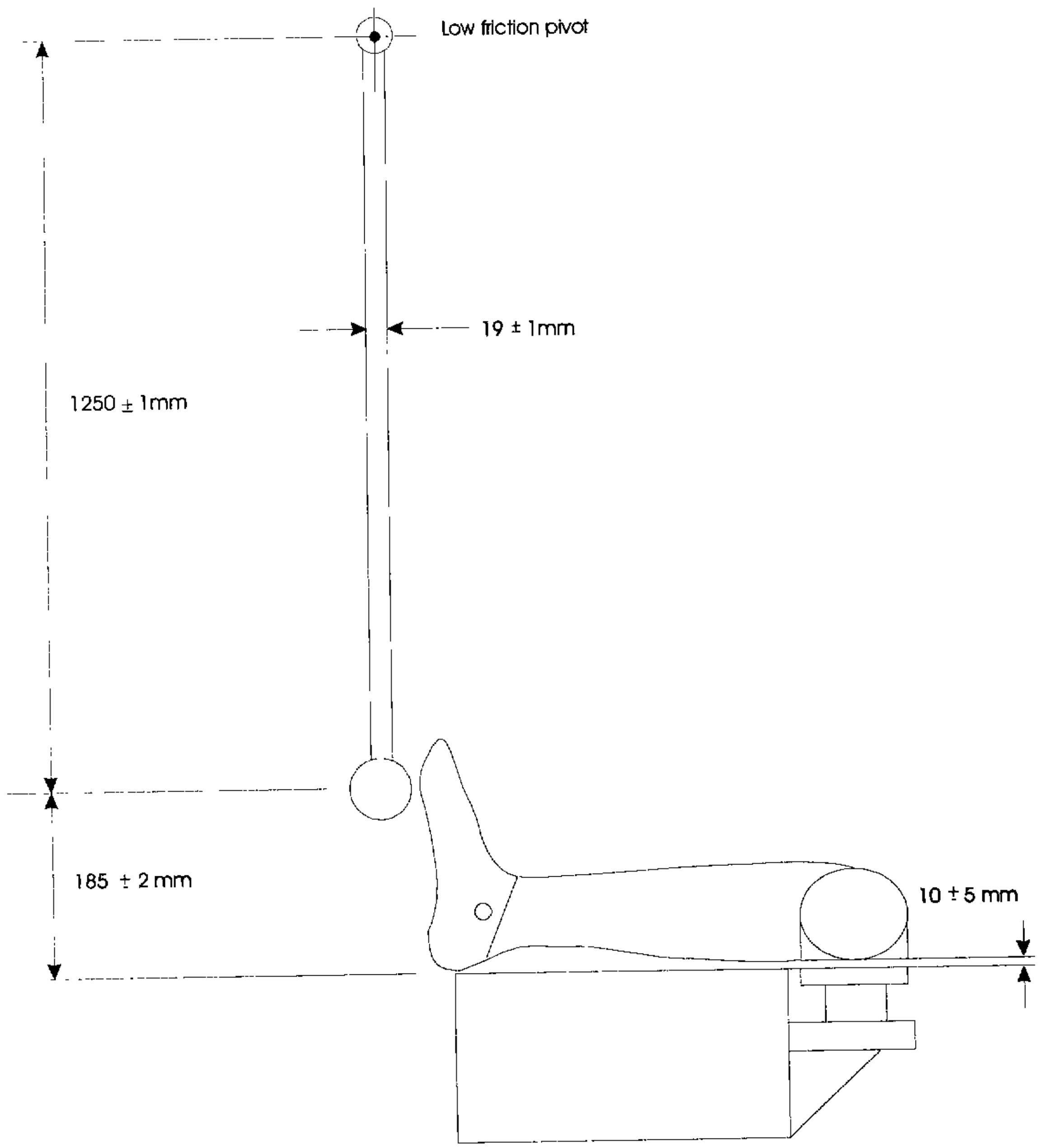


Figure 3

Lower foot impact test - test set-up specifications

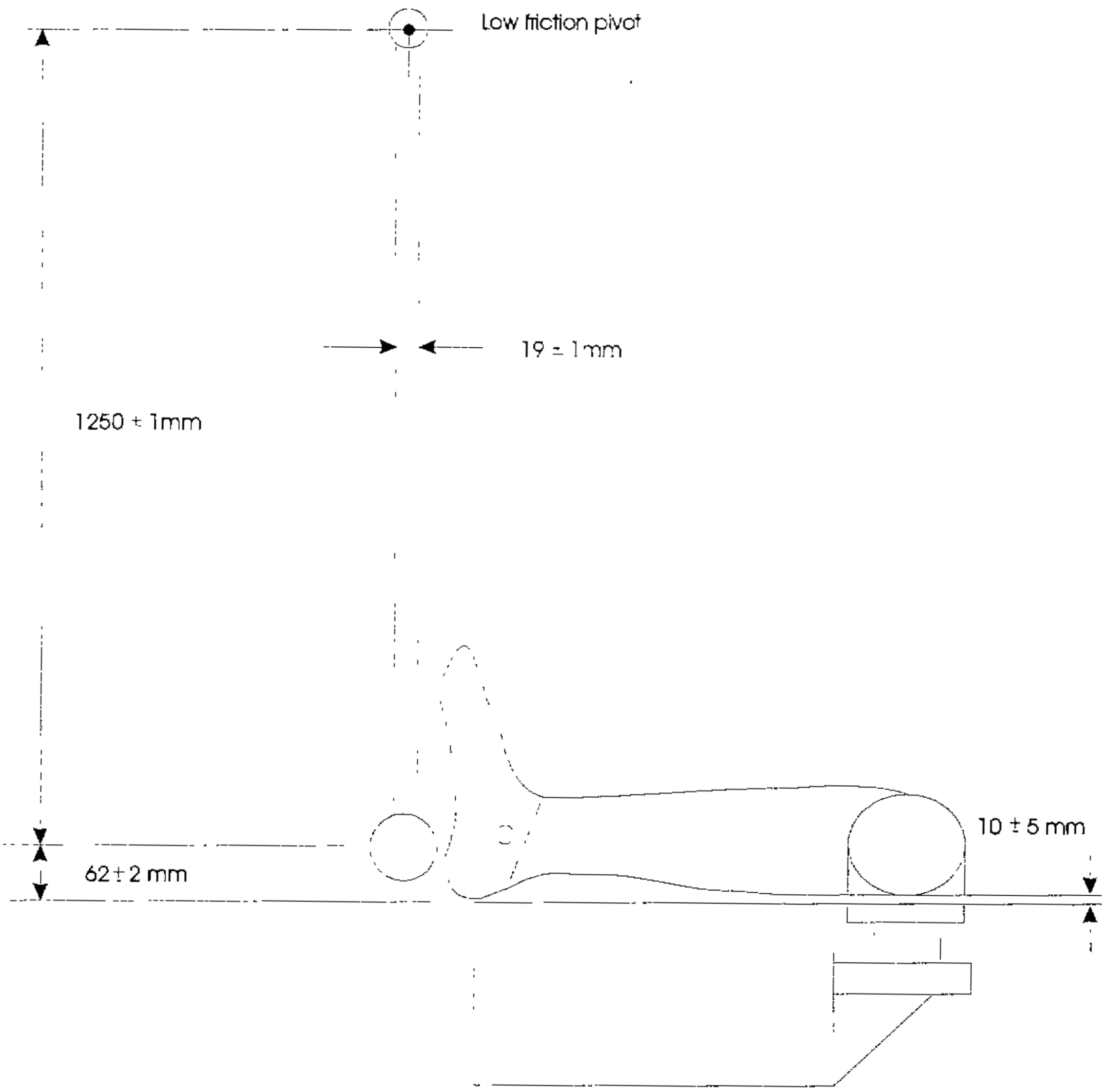
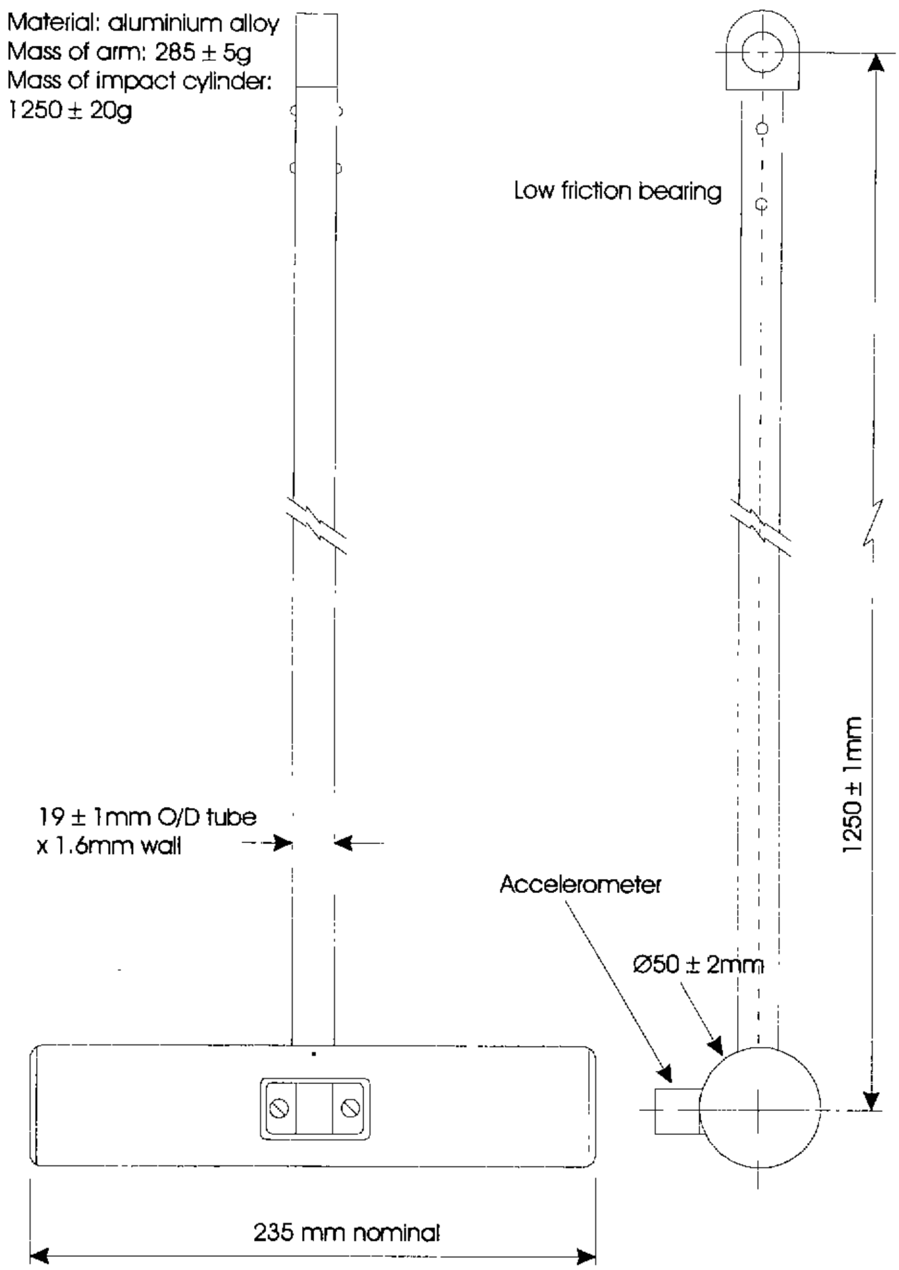


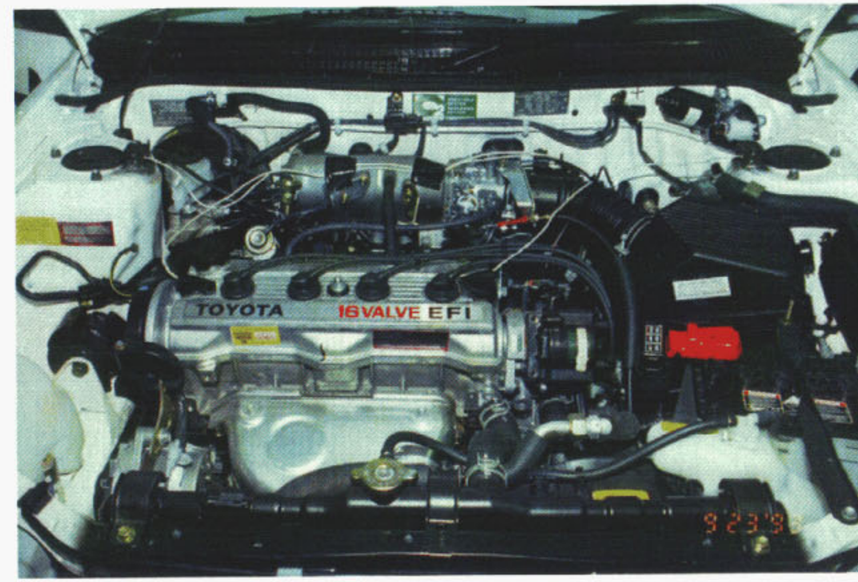
Figure 3a

Pendulum impactor

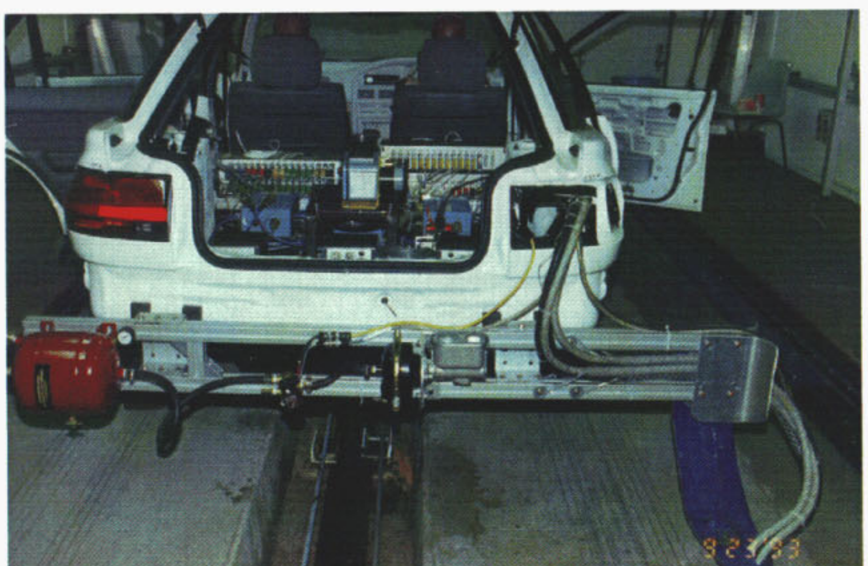


Appendix 8 – Pre and Post Test Photos of Test Vehicles

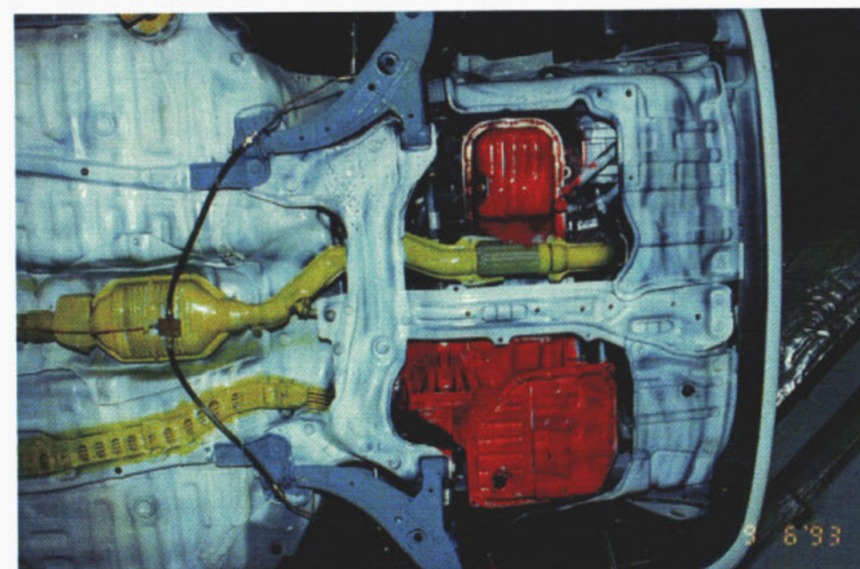
Typical Corolla pre test - front view



Typical Corolla pre test - engine compartment



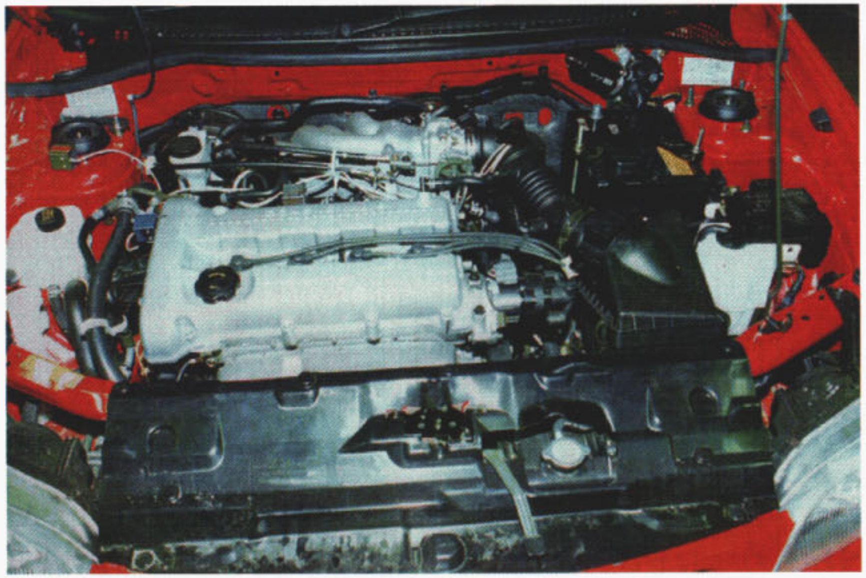
Typical Corolla pre test - rear view showing brake abort system



Typical Corolla pre test - underside view

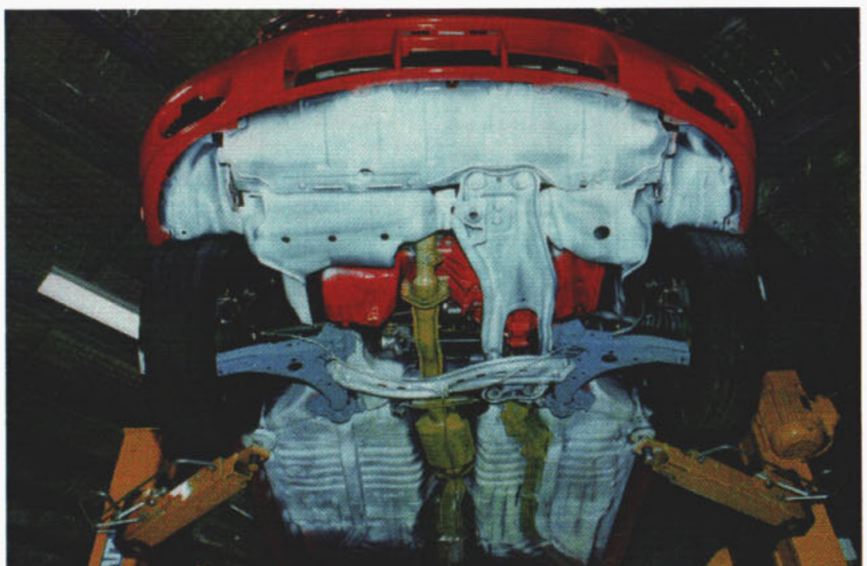
Typical Corolla pre test - driver dummy position

Typical Corolla pre test - passenger dummy position



Typical Laser pre test - engine compartment

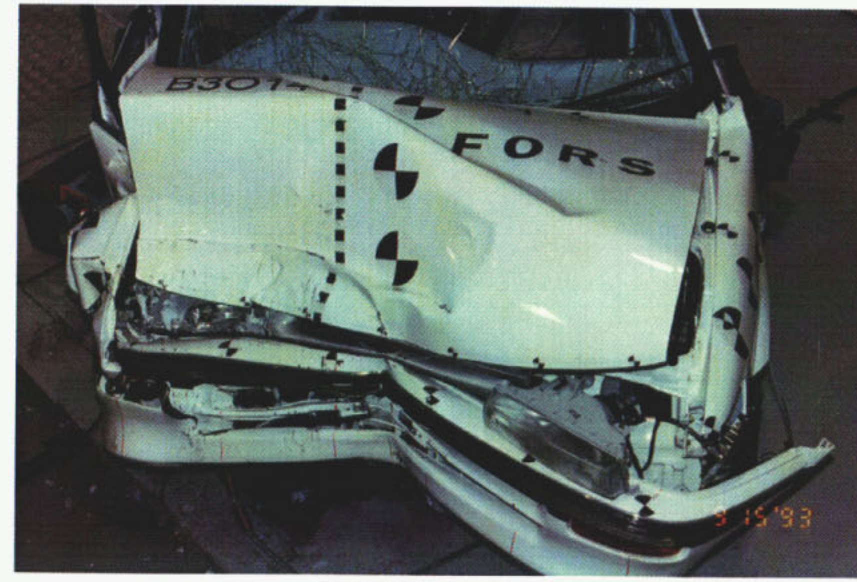
Typical Laser pre test - driver dummy position



Typical Laser pre test - underside view

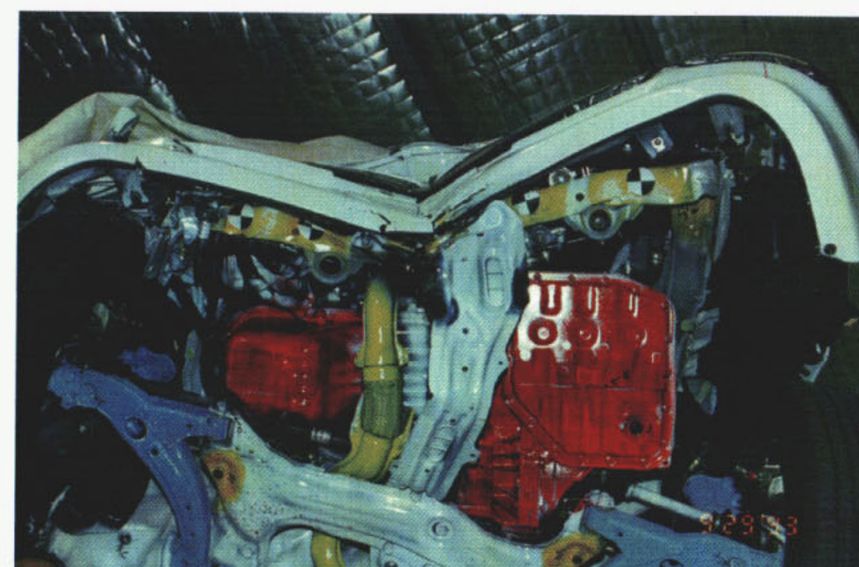
Typical Laser pre test - passenger dummy position

B3014 post test - front view



B3014 post test - front overhead view

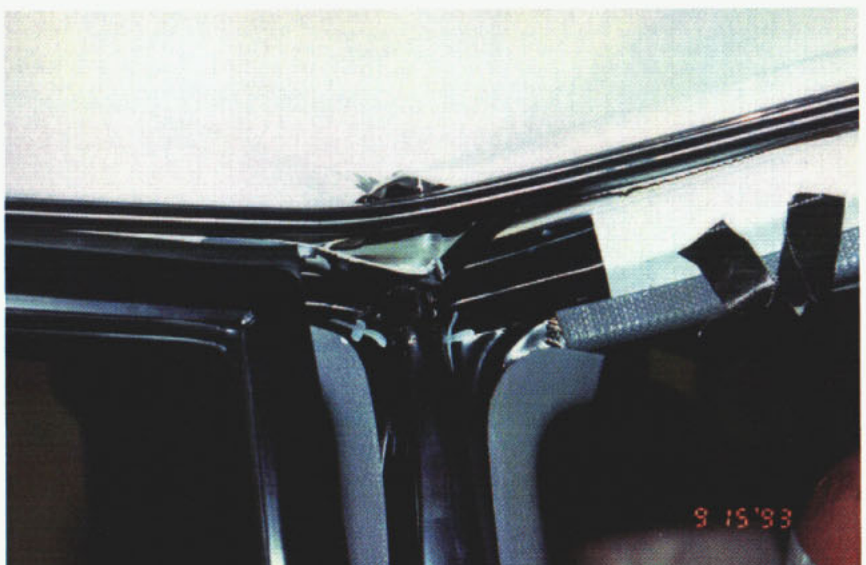
B3014 post test - front right 3/4 view



B3014 post test - underside view

B3014 post test - driver dummy position (close up)

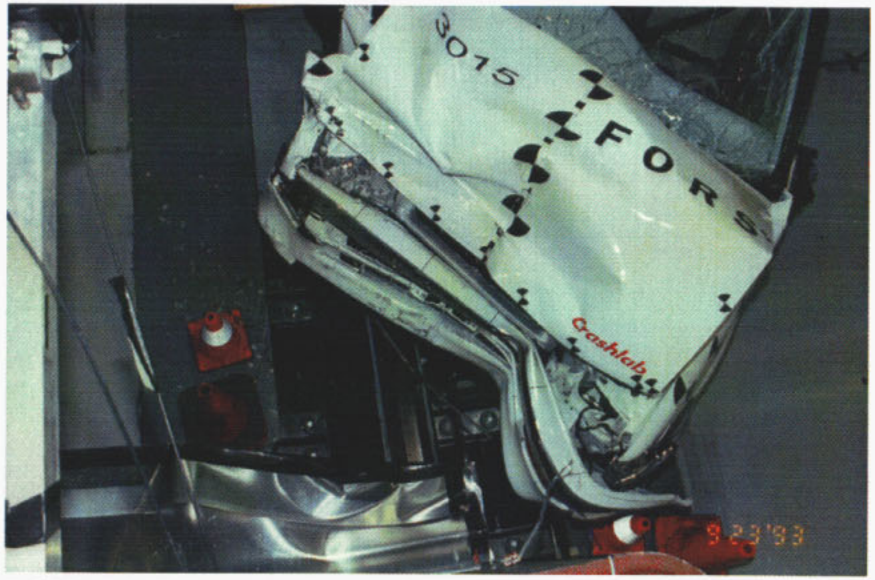
B3014 post test - passenger footwell



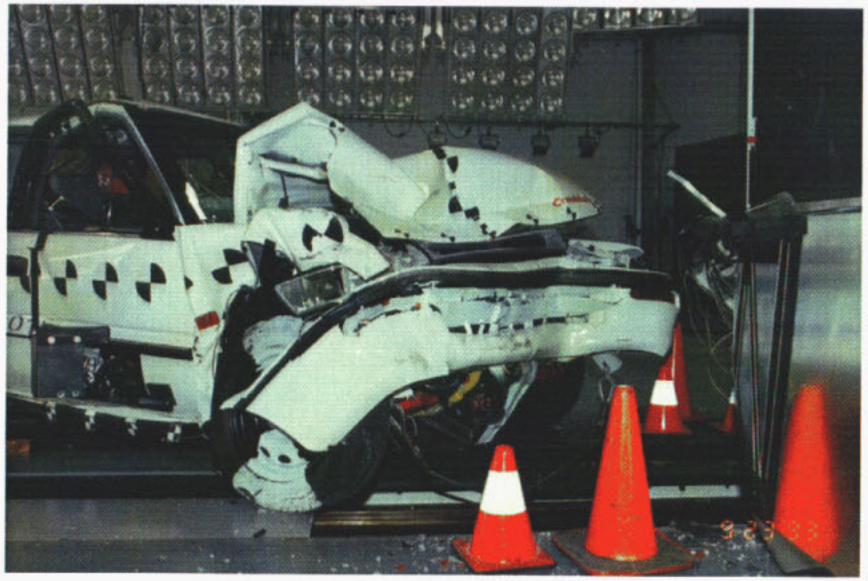
B3014 post test - driver side roof line

B3014 post test - steering wheel

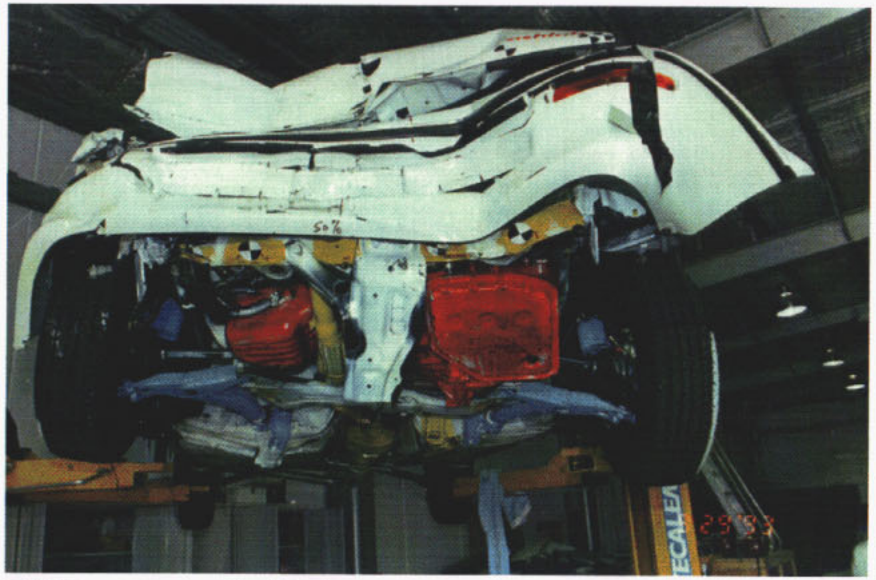
B3015 post test - rear 3/4 view



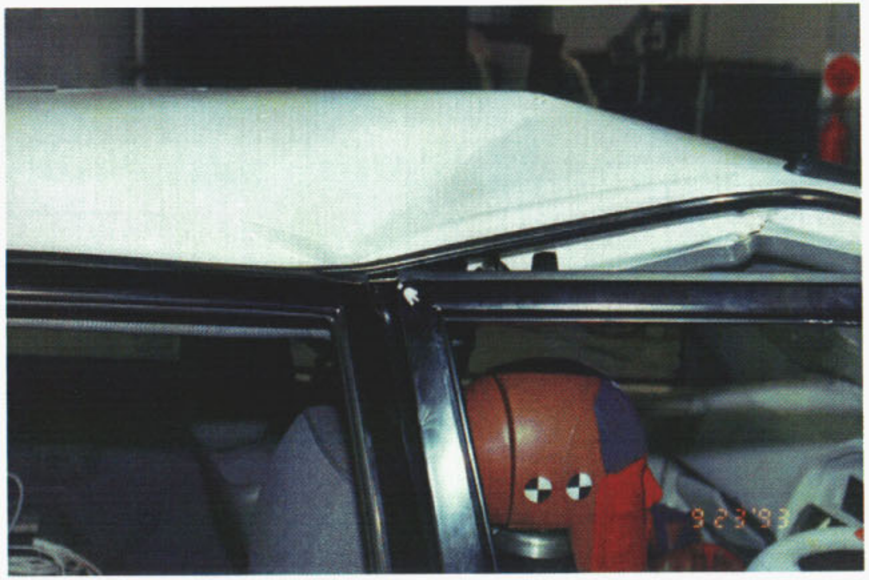
B3015 post test - overhead view



B3015 post test - final position



B3015 post test - underside view



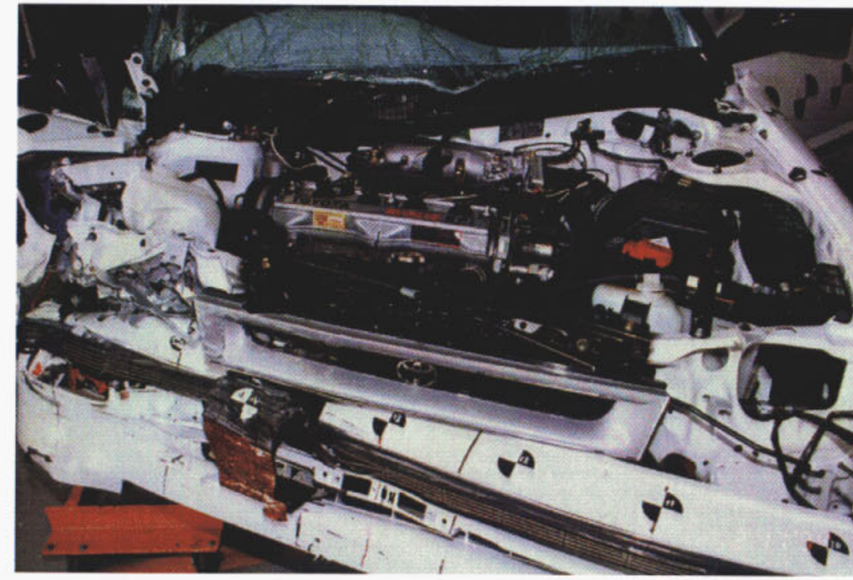
B3015 post test - driver side roof line

B3015 post test - driver footwell

B3015 post test - driver dummy position

B3015 post test - interior view

B4009 post test - overall view

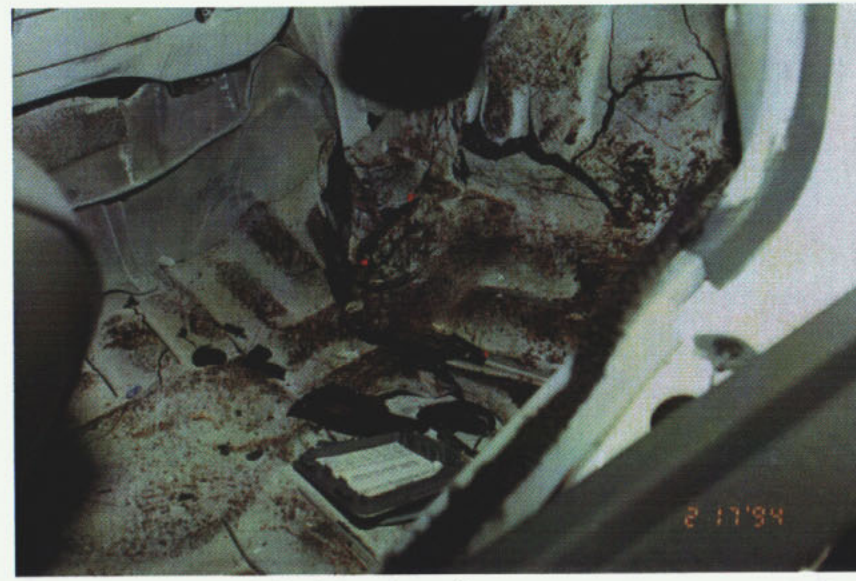


B4009 post test vehicle 1 - engine compartment

B4009 post test vehicle 1 - front right 3/4 view

B4009 post test vehicle 1 - driver dummy position

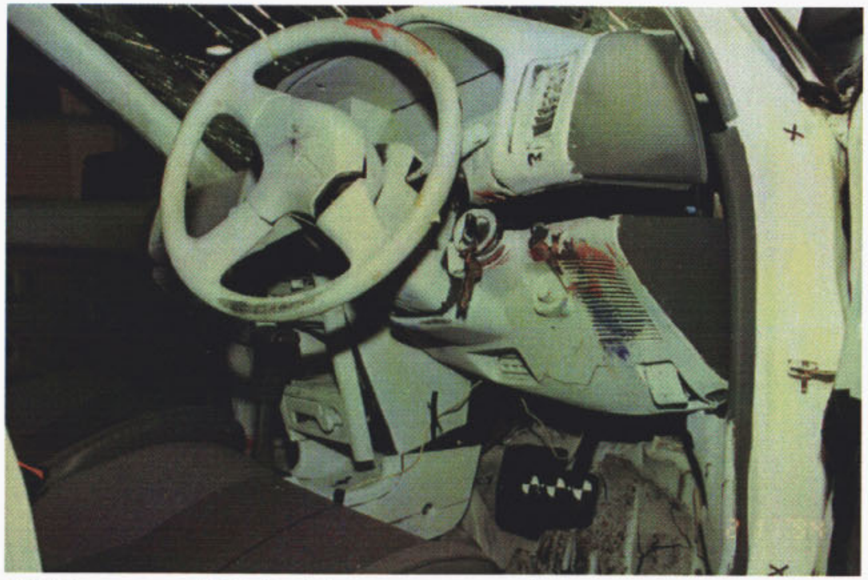
B4009 post test vehicle 1 - driver side roof line



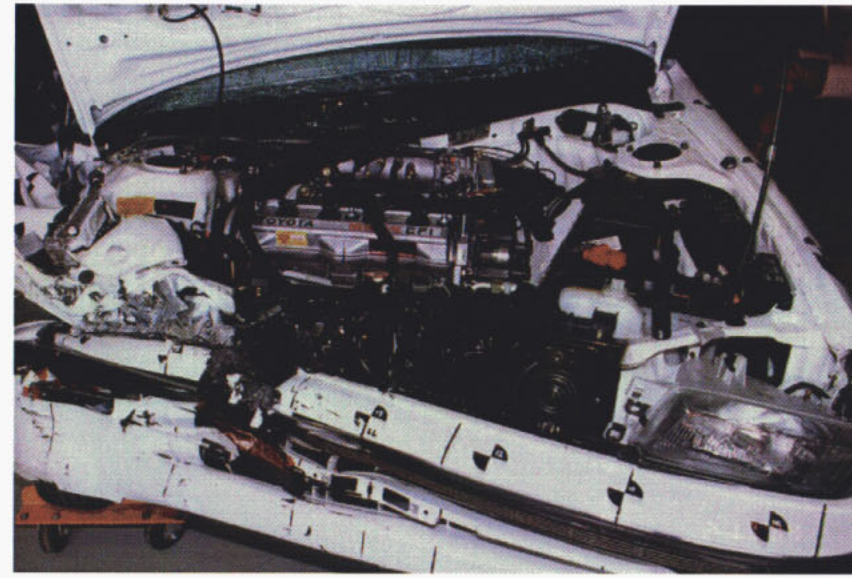
B4009 post test vehicle 1 - driver footwell

B4009 post test vehicle 1 - passenger knee contact marks

B4009 post test vehicle 1 - passenger footwell



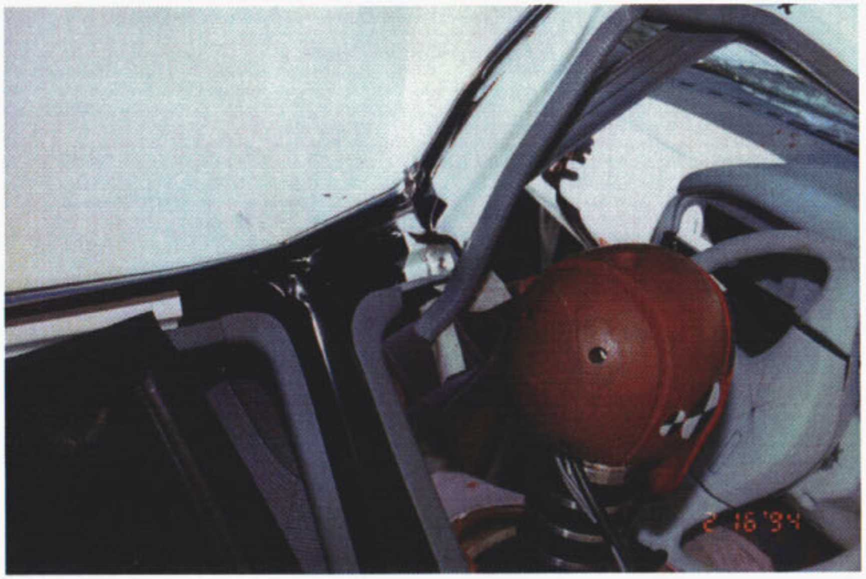
B4009 post test vehicle 1 - driver compartment view



B4009 post test vehicle 2 - engine compartment

B4009 post test vehicle 2 - front right 3/4 view

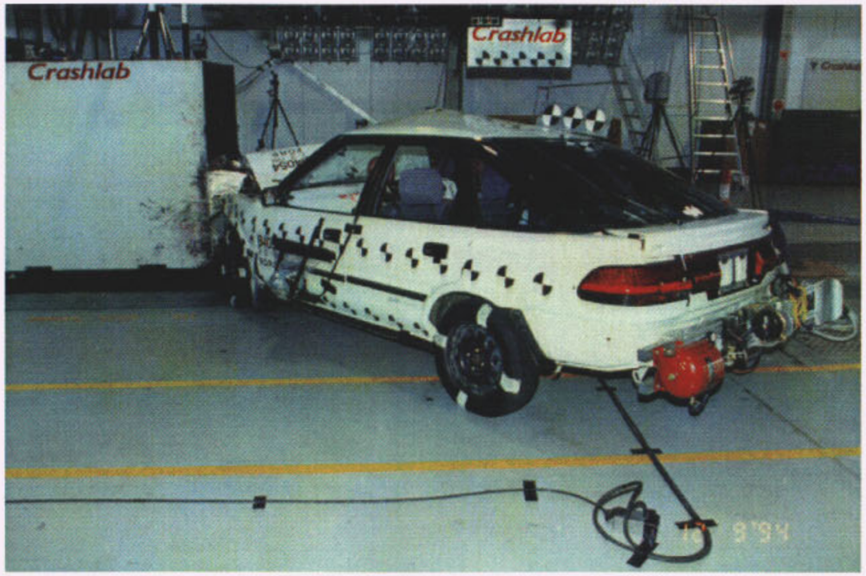
B4009 post test vehicle 2 - driver door



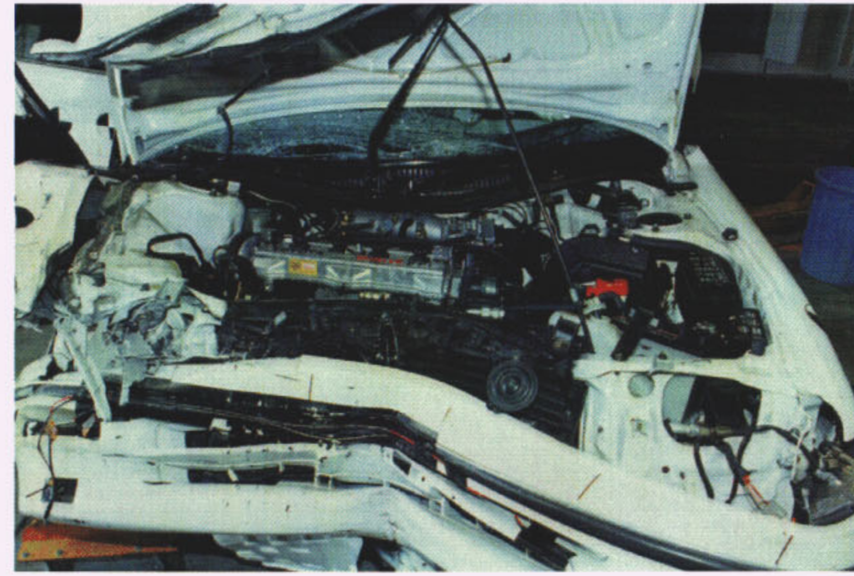
B4009 post test vehicle 2 - driver side roof line

B4009 post test vehicle 2 - passenger footwell

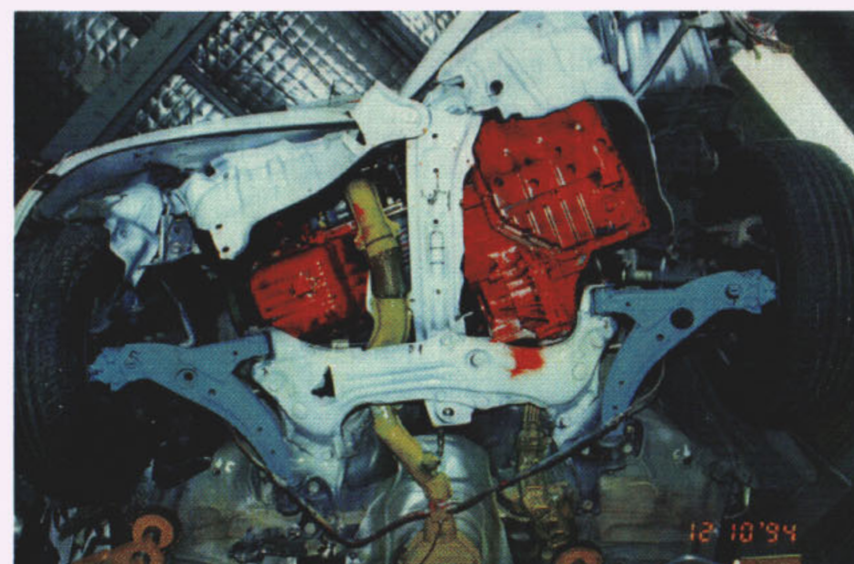
B4009 post test vehicle 2 - driver dummy position



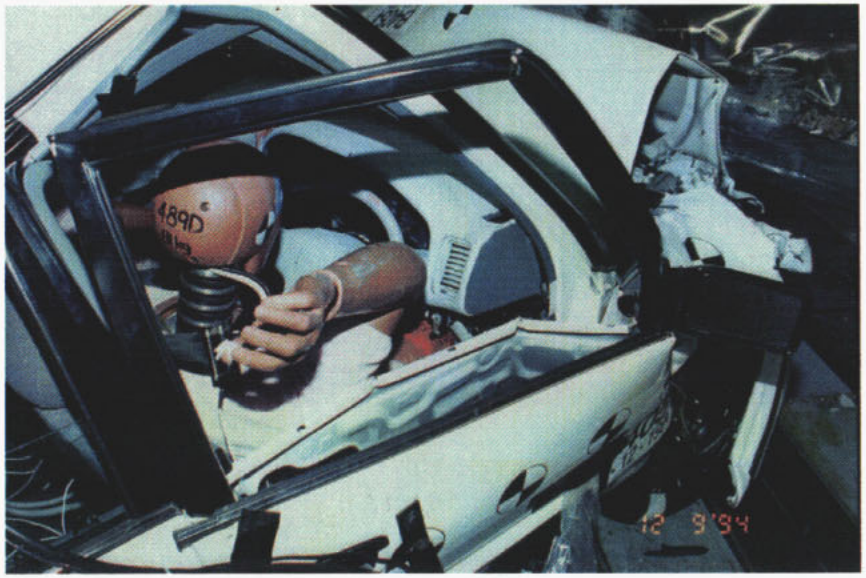
B4054 post test - overall view


B4054 post test - engine compartment

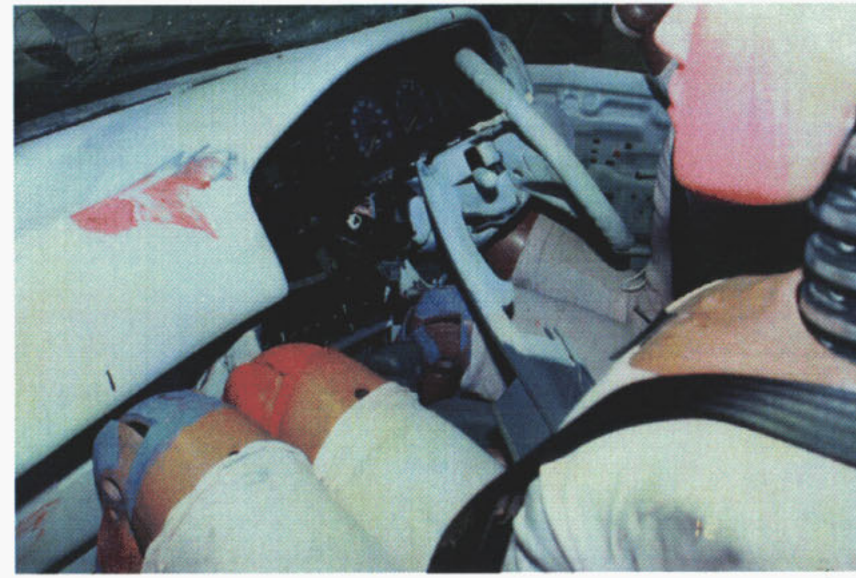
B4054 post test - overhead view



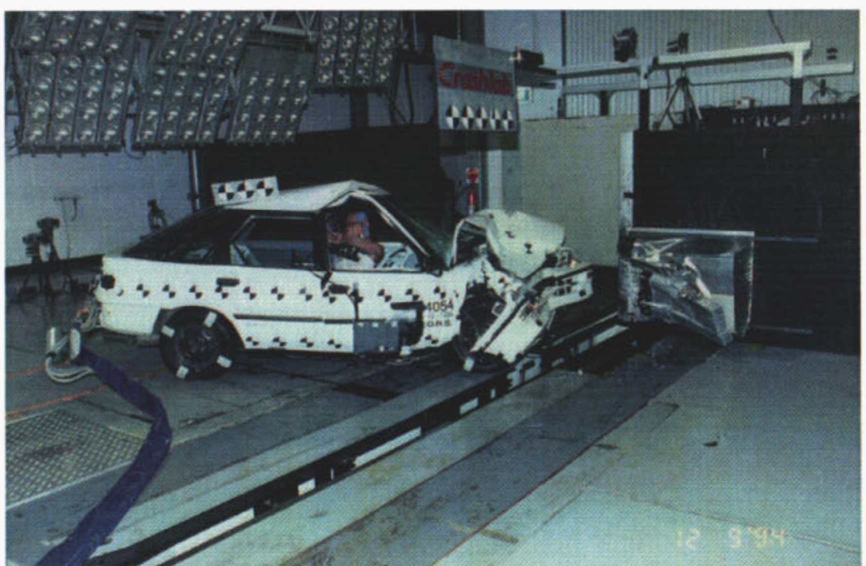
B4054 post test - underside view



B4054 post test - driver door



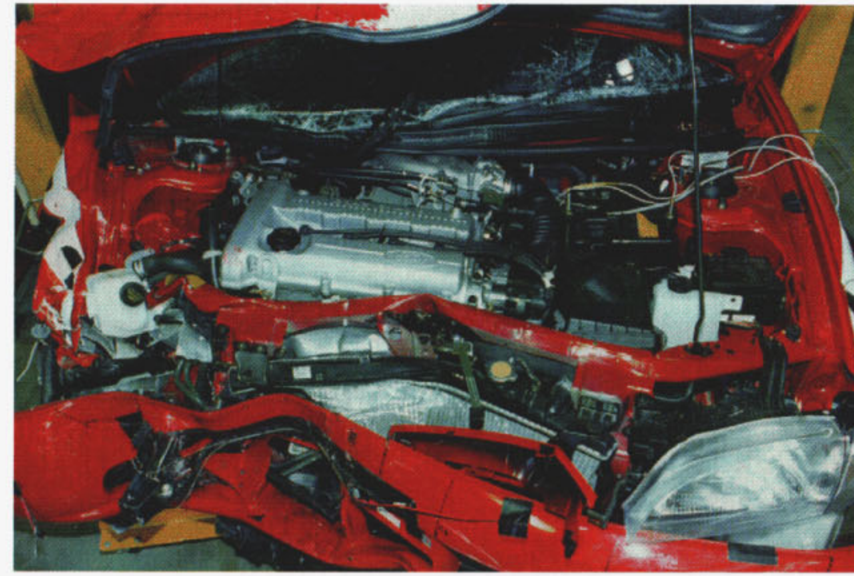
B4054 post test - passenger head contact marks



B4054 post test - final position

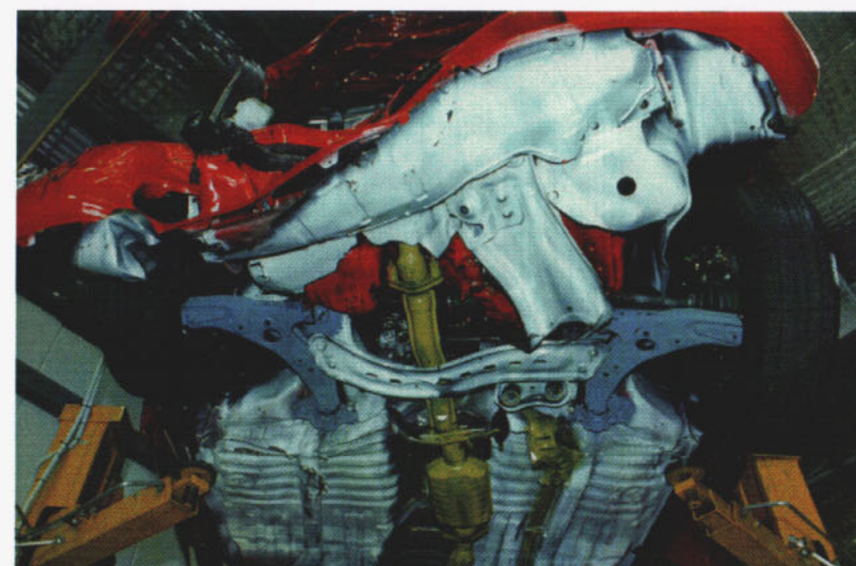
B4054 post test - passenger knee contact marks

B5008 post test - front right 3/4 view



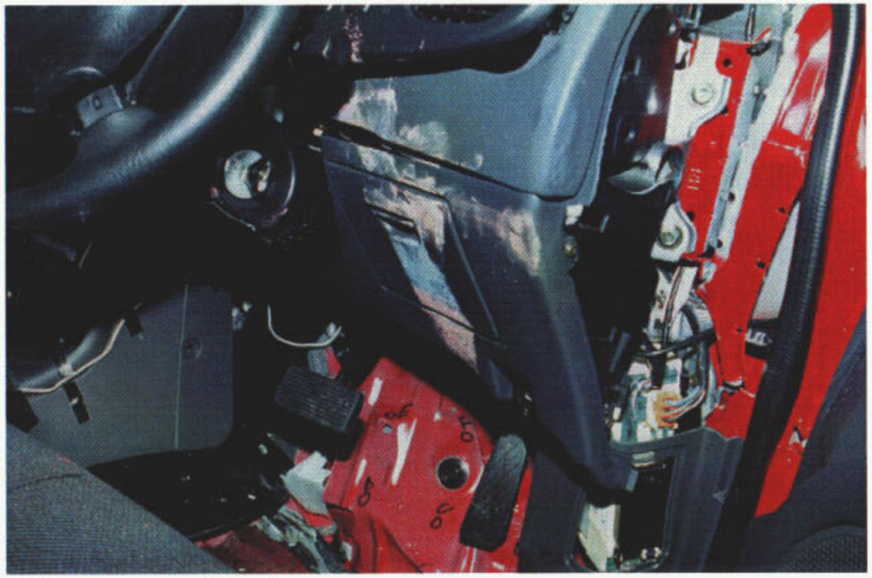
B5008 post test - engine compartment

B5008 post test - overhead view

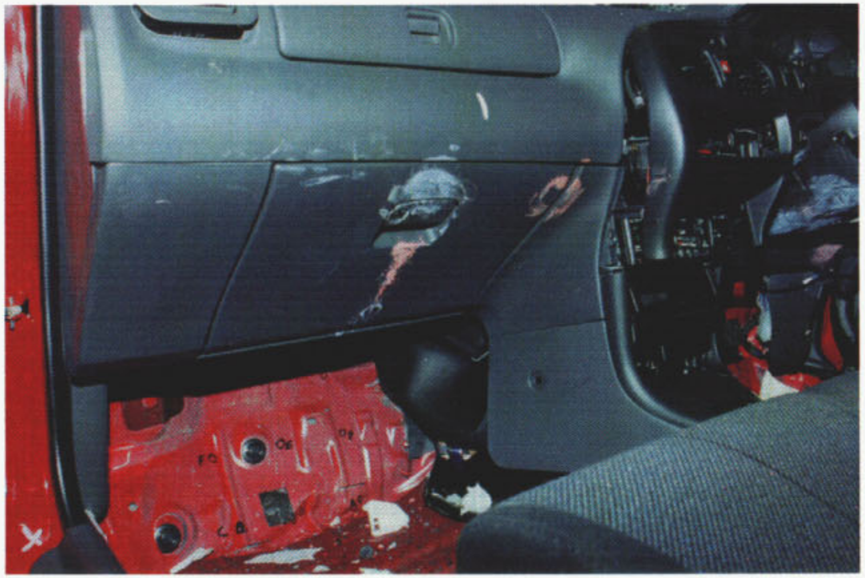


B5008 post test - underside view

B5008 post test - driver side view

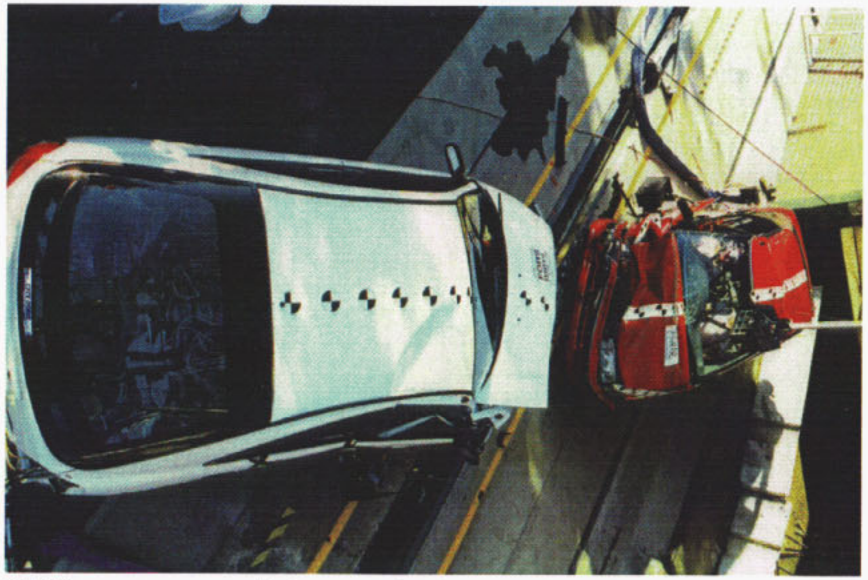


B5008 post test - driver knee contact marks

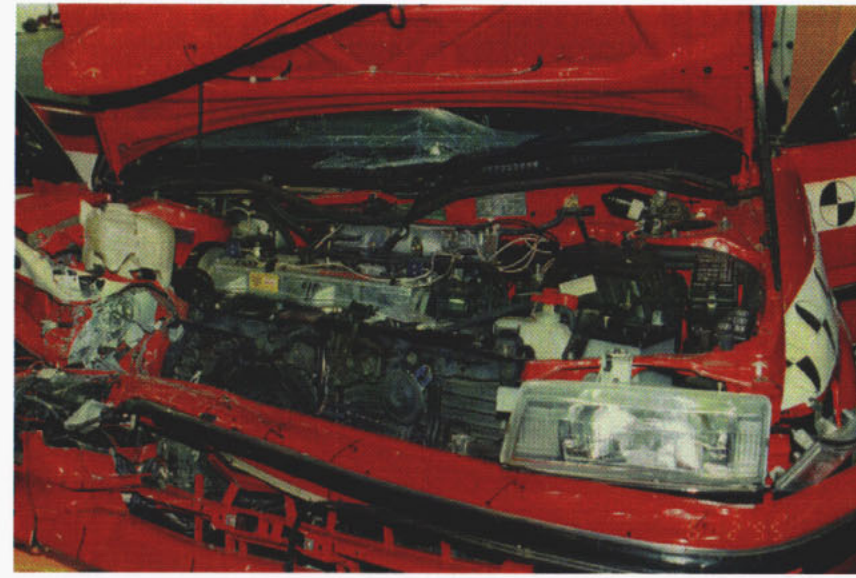


B5008 post test - passenger knee contact marks

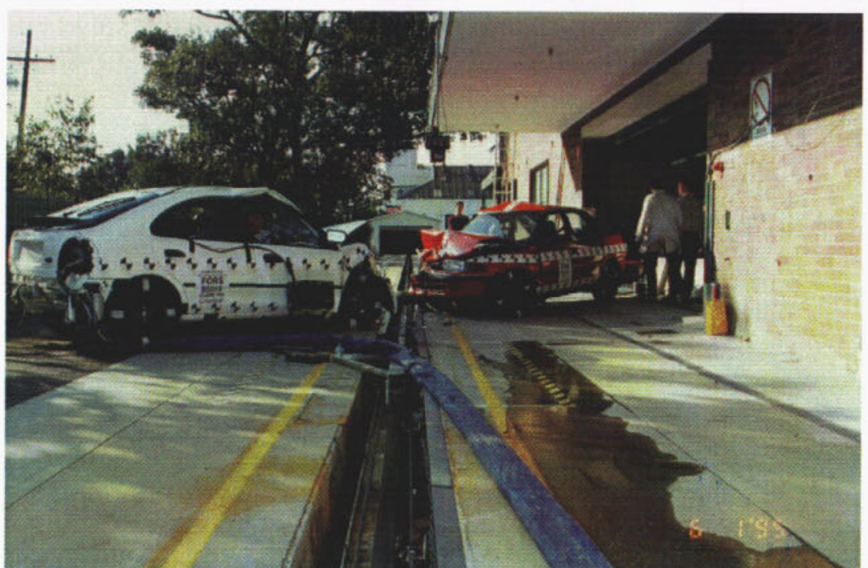
B5008 post test - driver knee contact marks



B5019 post test - overall view (overhead)

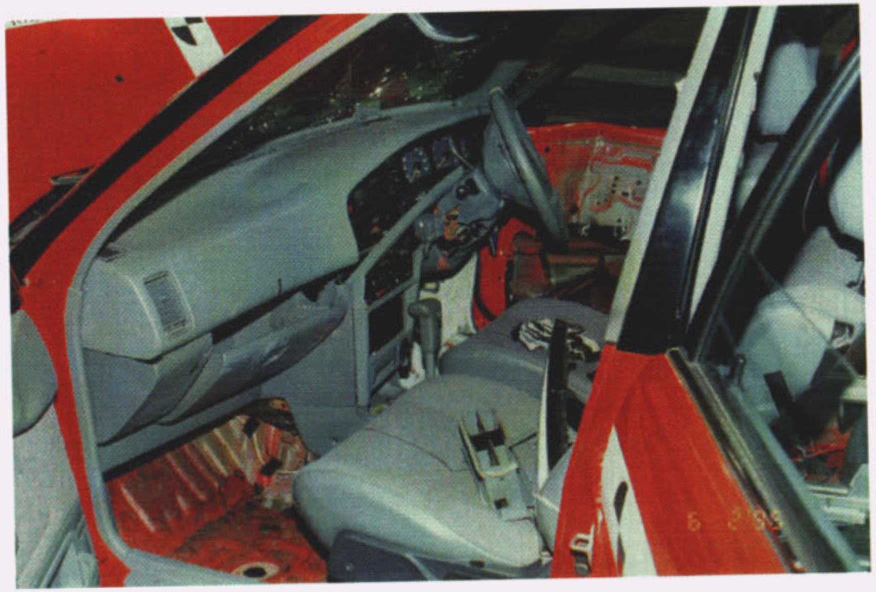


B5019 post test vehicle 1 - engine compartment



B5019 post test - overall view

B5019 post test vehicle 1 - driver door

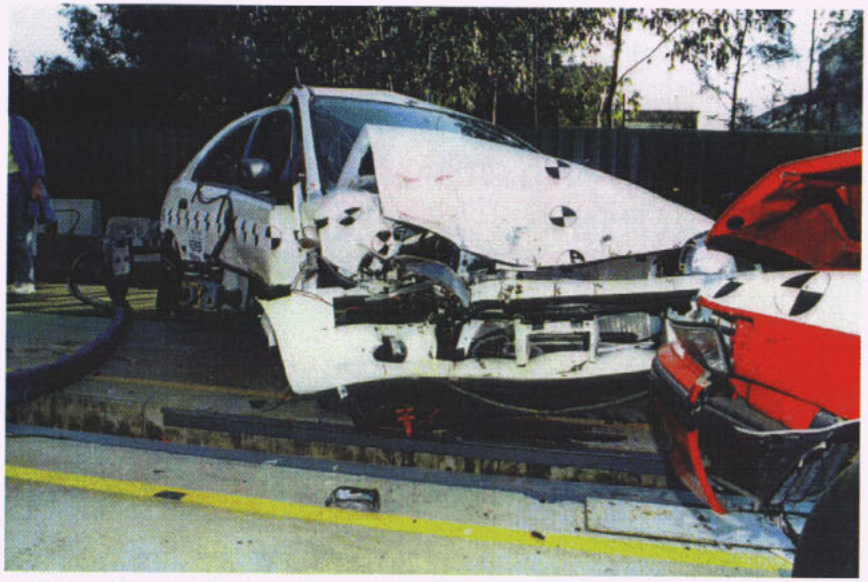


B5019 post test vehicle 1 - interior view

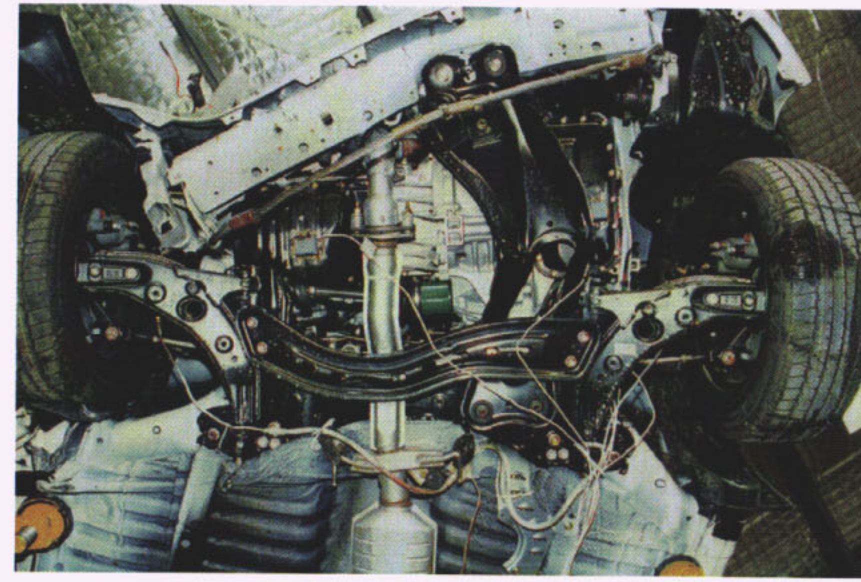
B5019 post test vehicle 1 - driver footwell

B5019 post test vehicle 1 - driver dummy position

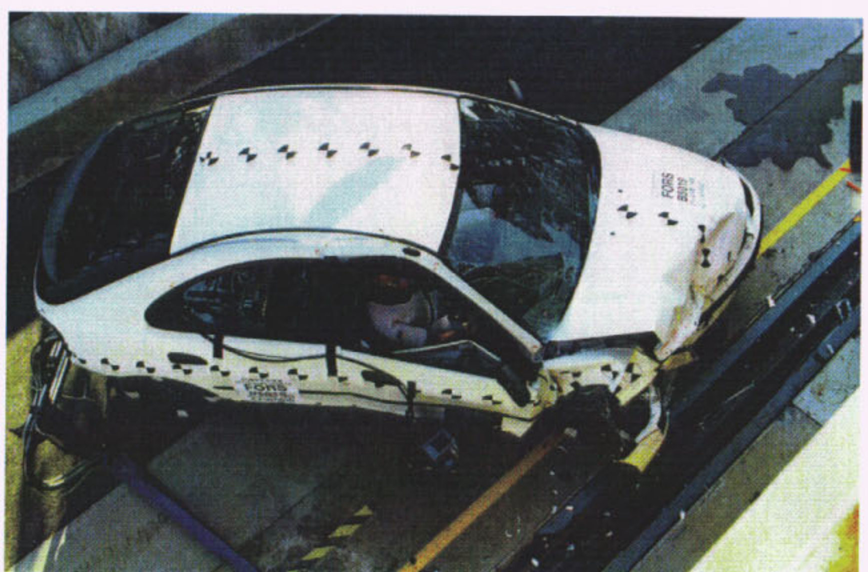
B5019 post test vehicle 2 - front view



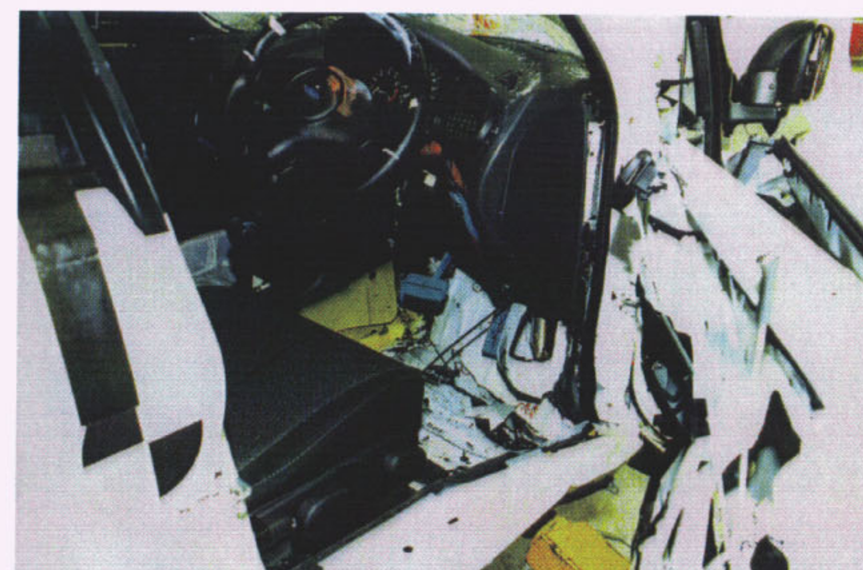
B5019 post test vehicle 2 - front right 3/4 view



B5019 post test vehicle 2 - underside view



B5019 post test vehicle 2 - overhead view



B5019 post test vehicle 2 - driver door view

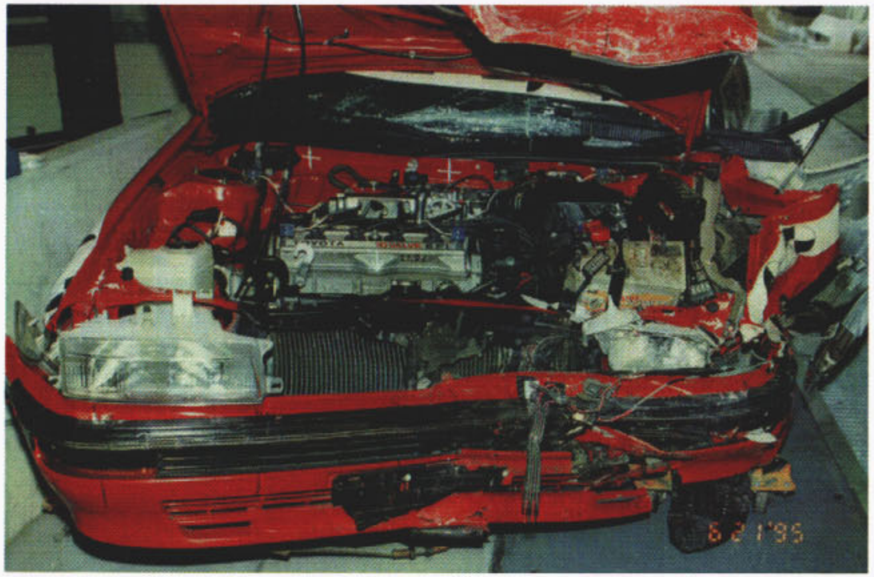
B5019 post test vehicle 2 - passenger dummy position

B5019 post test vehicle 2 - passenger footwell

B5020 post test - overall view

B5020 post test vehicle 1 - overhead view

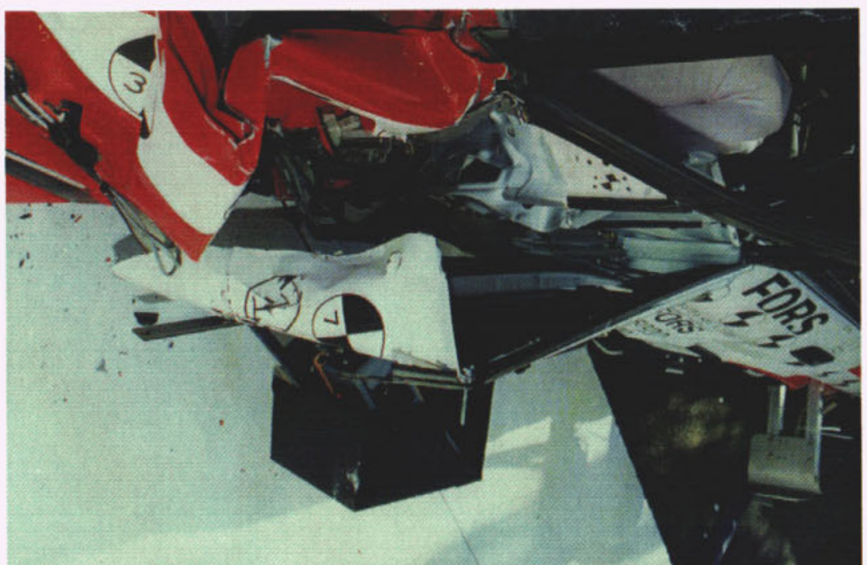
B5020 post test vehicle 1 - driver side view



B5020 post test vehicle 1 - engine compartment

B5020 post test vehicle 1 - underside view

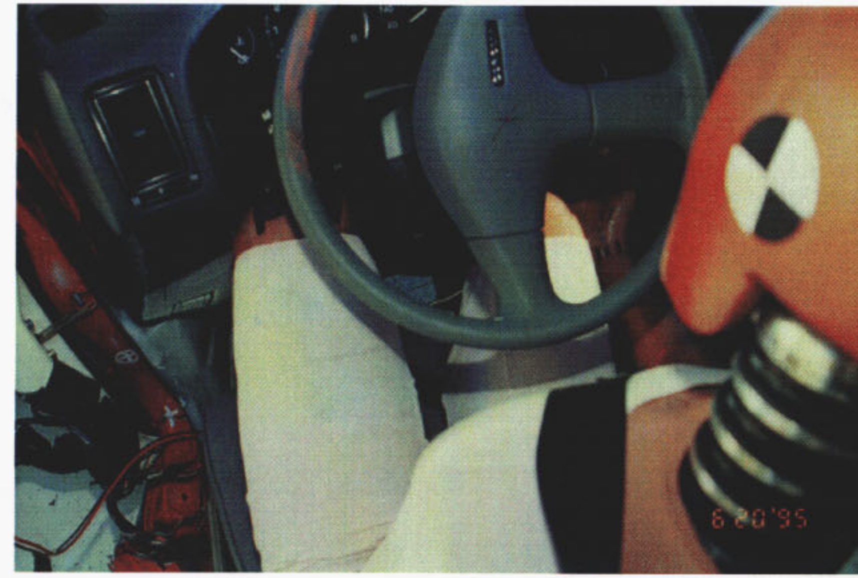
B5020 post test vehicle 1 - driver side roof line



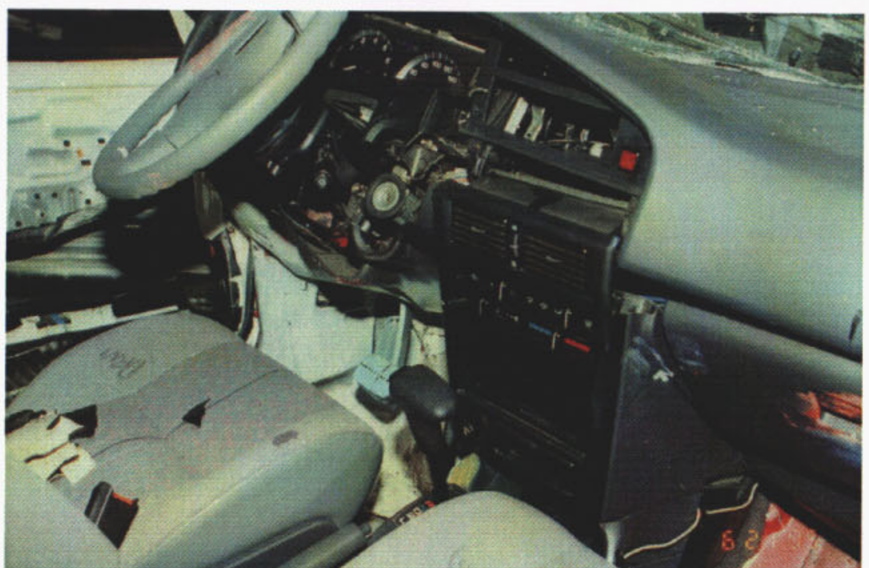
B5020 post test vehicle 1 - driver door

B5020 post test vehicle 1 - driver footwell

B5020 post test vehicle 1 - passenger footwell

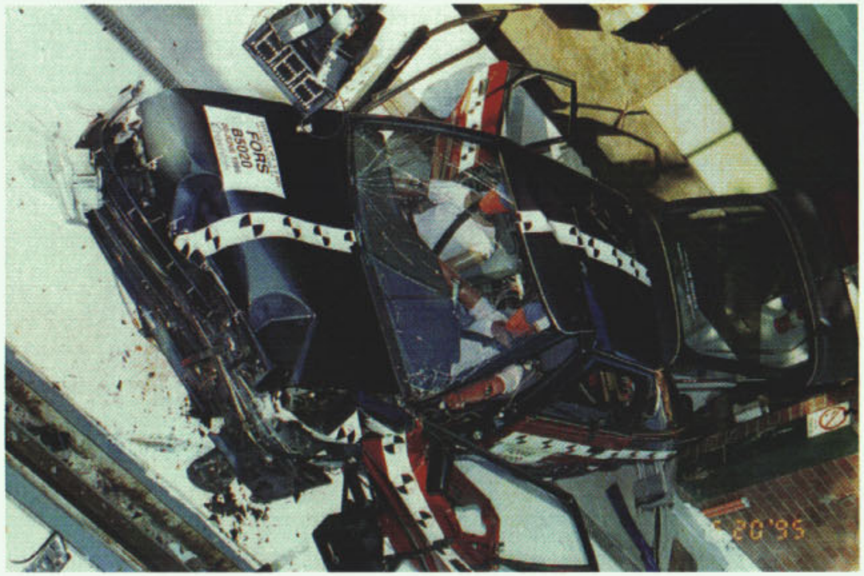


B5020 post test vehicle 1 - steering wheel

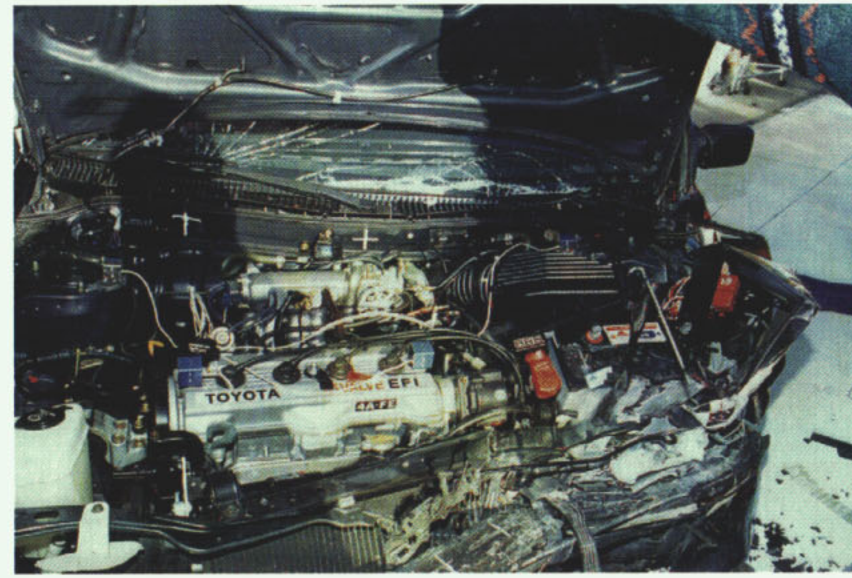


B5020 post test vehicle 1 - interior view

B5020 post test vehicle 2 - front right 3/4 view

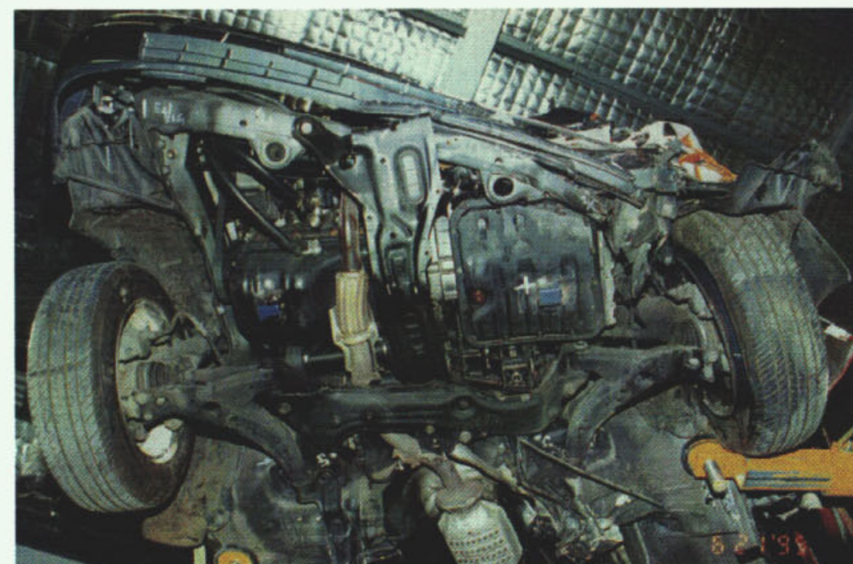


B5020 post test vehicle 2 - overhead view

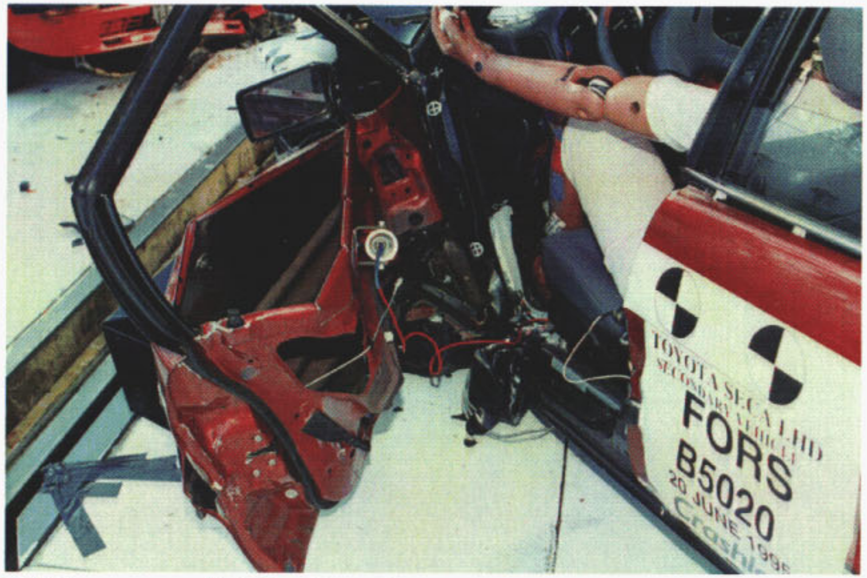


B5020 post test vehicle 2 - engine compartment

B5020 post test vehicle 2 - final position

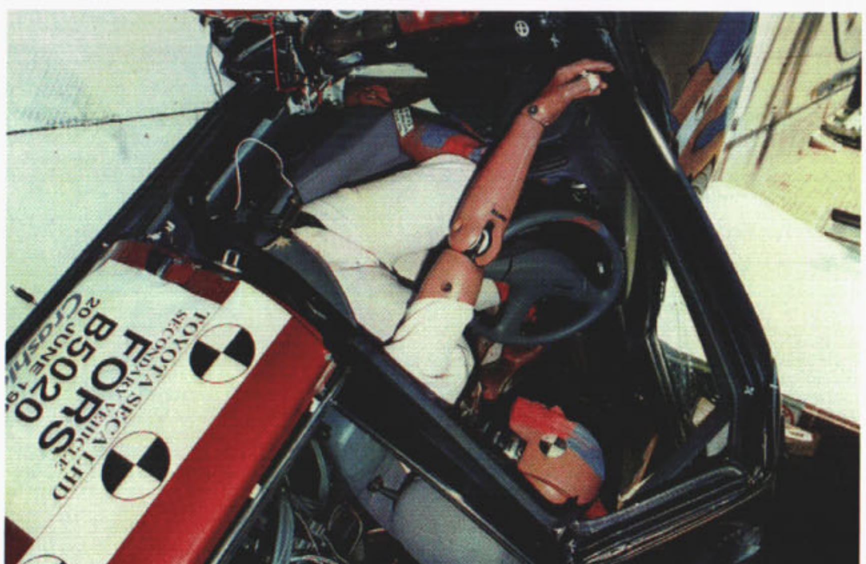


B5020 post test vehicle 2 - underside view

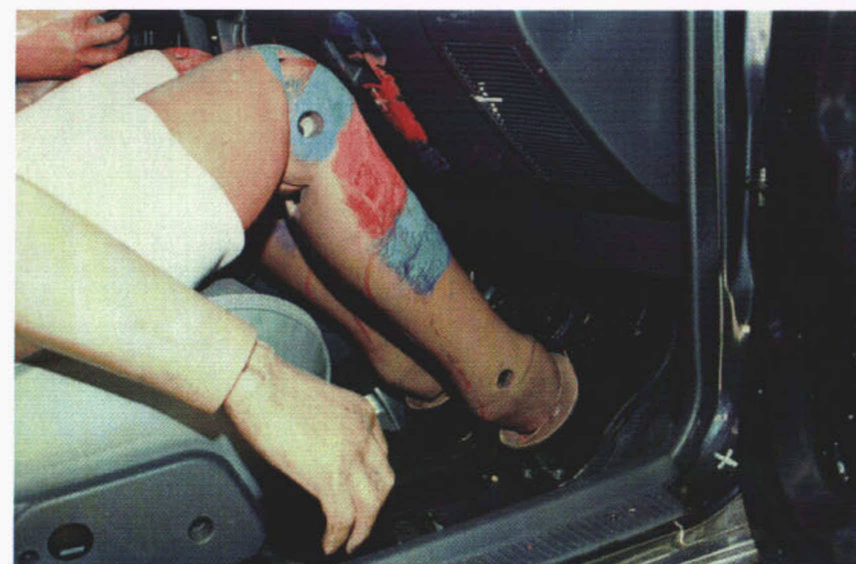


B5020 post test vehicle 2 - driver door

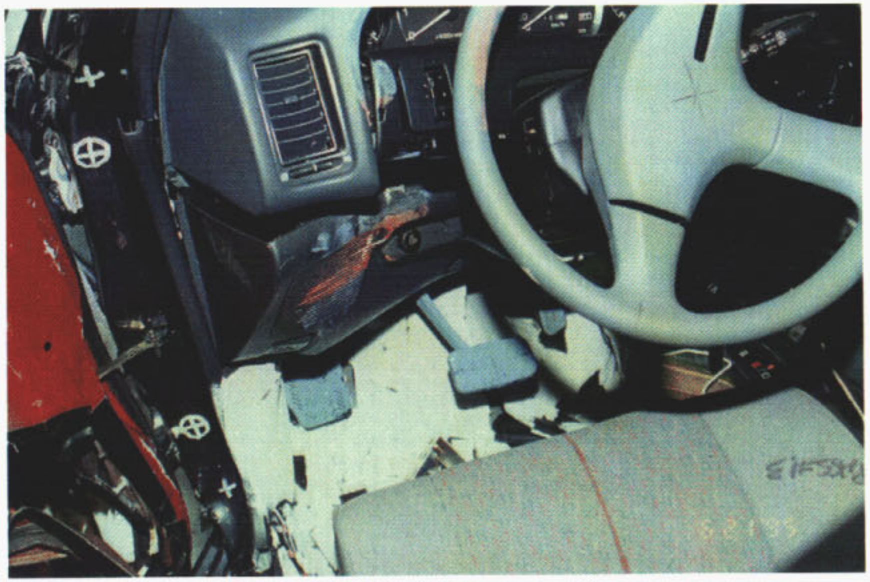
B5020 post test vehicle 2 - driver side view



B5020 post test vehicle 2 - driver dummy position

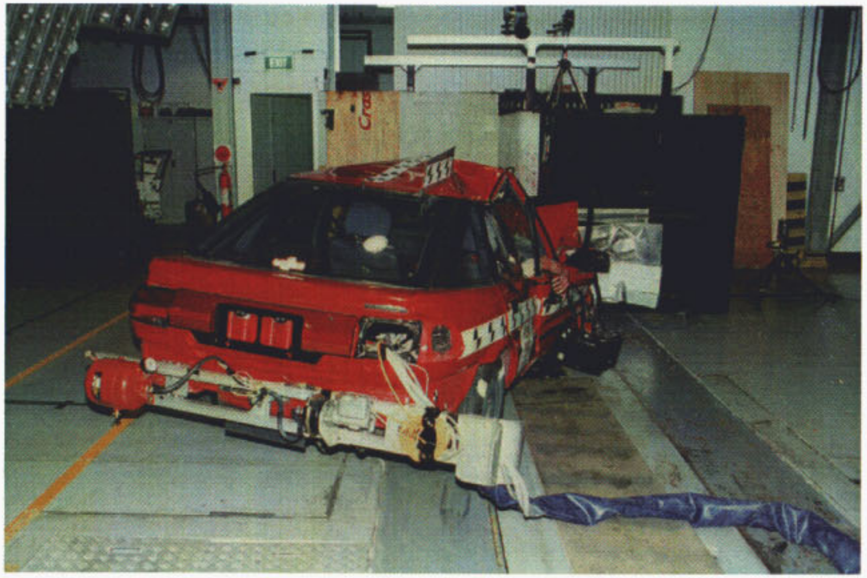


B5020 post test vehicle 2 - passenger dummy contact marks



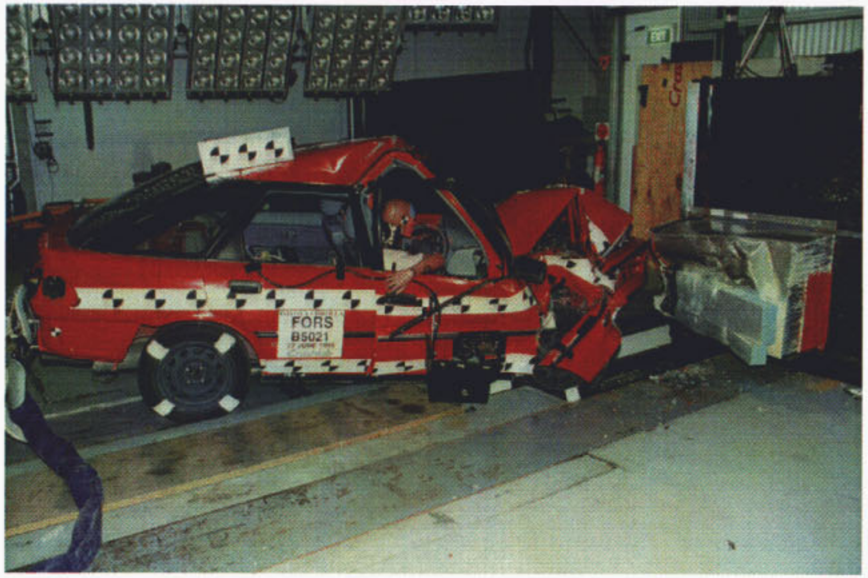
B5020 post test vehicle 2 - driver footwell

B5020 post test vehicle 2 - steering wheel

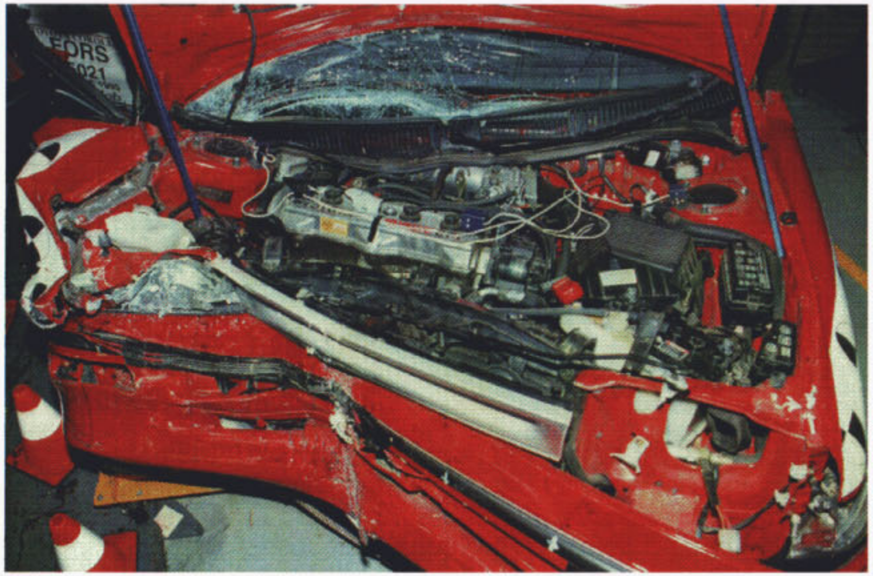


B5021 post test - rear view

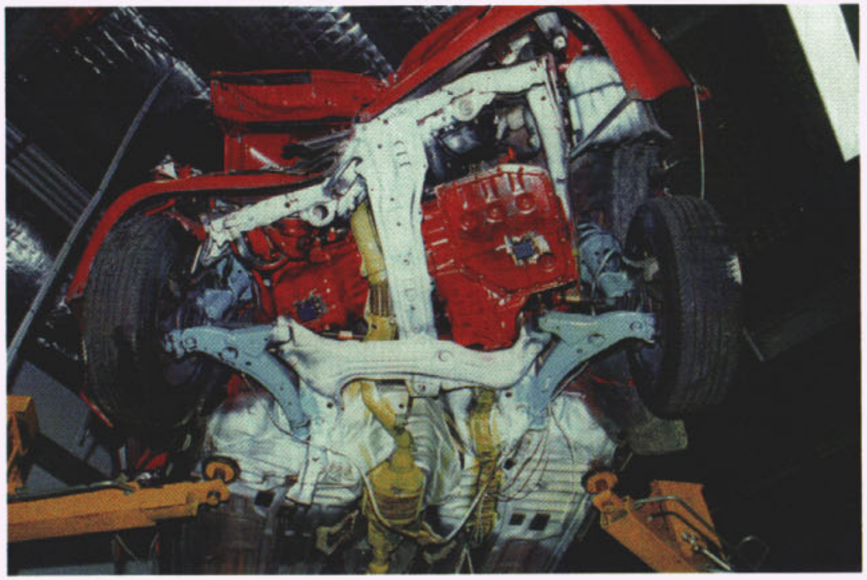
B5021 post test - overhead view



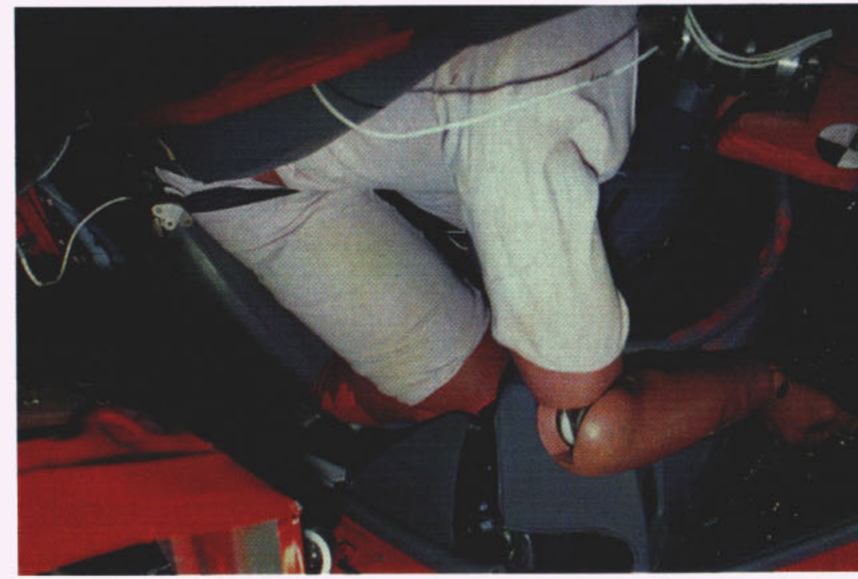
B5021 post test - overall view



B5021 post test - engine compartment



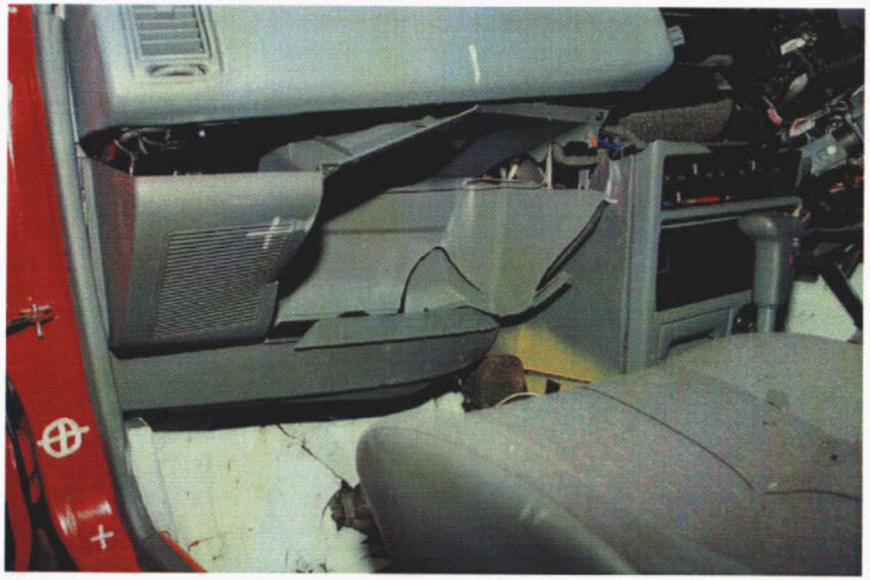
B5021 post test - underside view



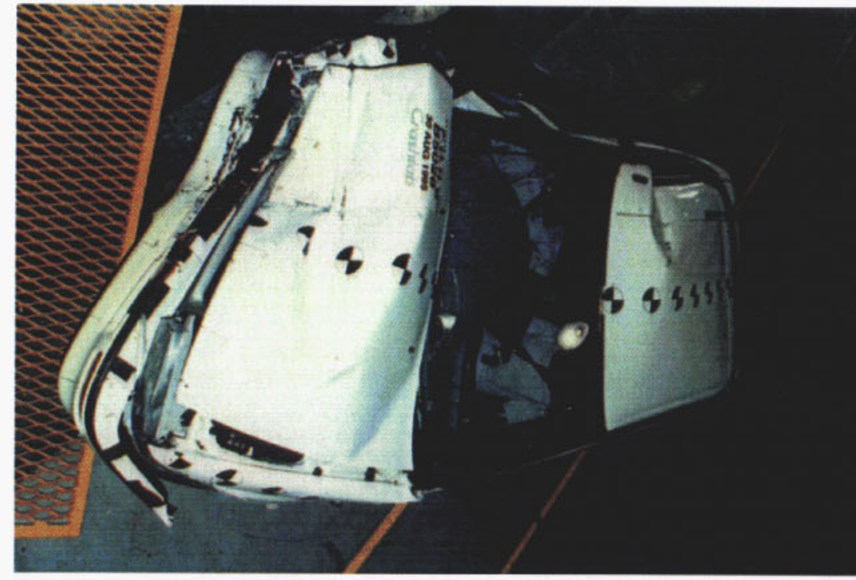
B5021 post test - driver dummy position

B5021 post test - driver side roof line

B5021 post test - driver footwell

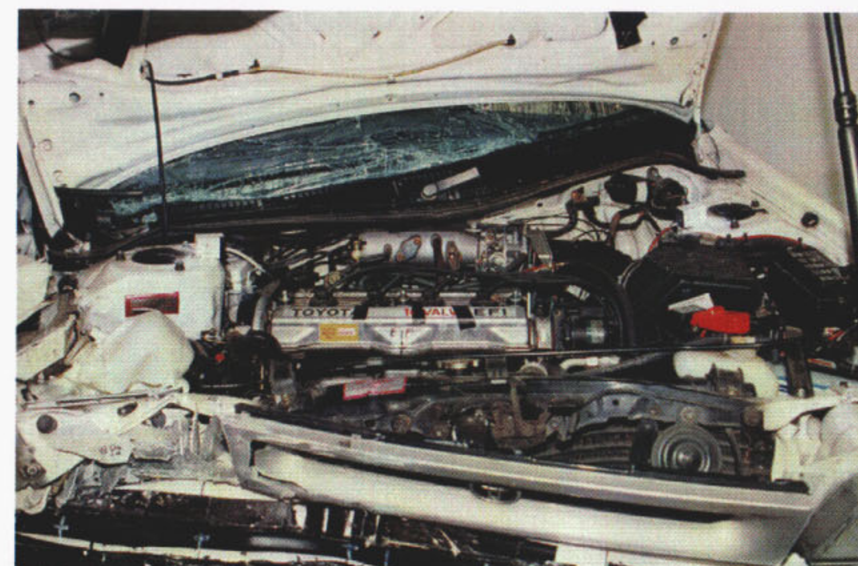


B5021 post test - passenger knee contact marks



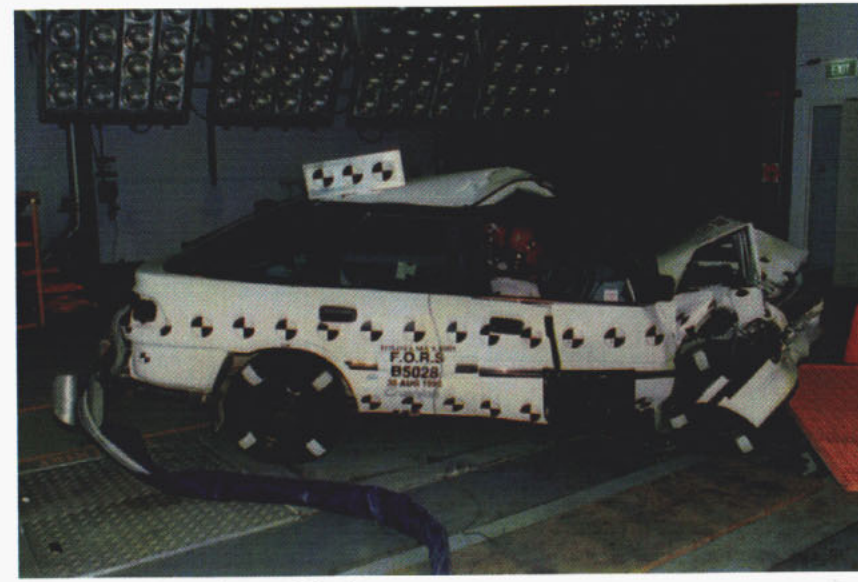
B5028 post test - front overhead view

B5021 post test - barrier



B5028 post test - engine compartment

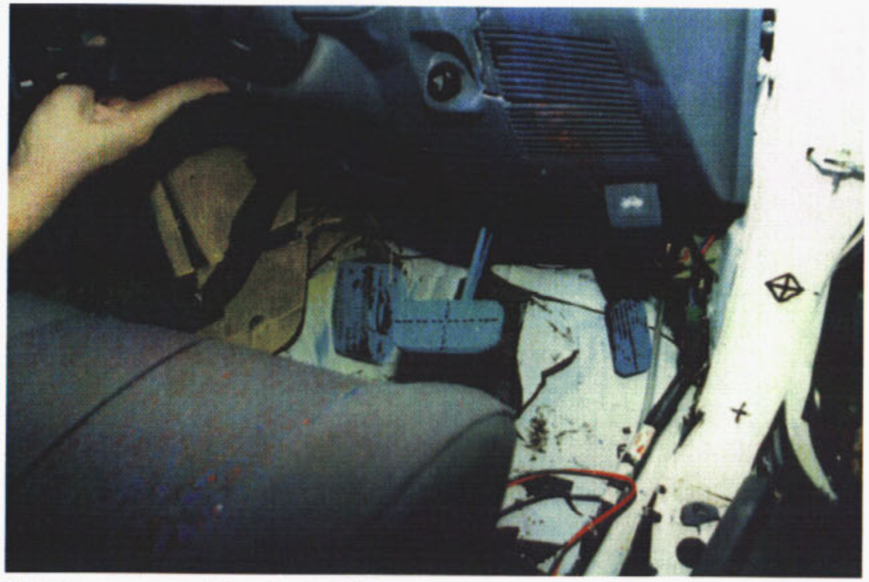
B5028 post test - underside view



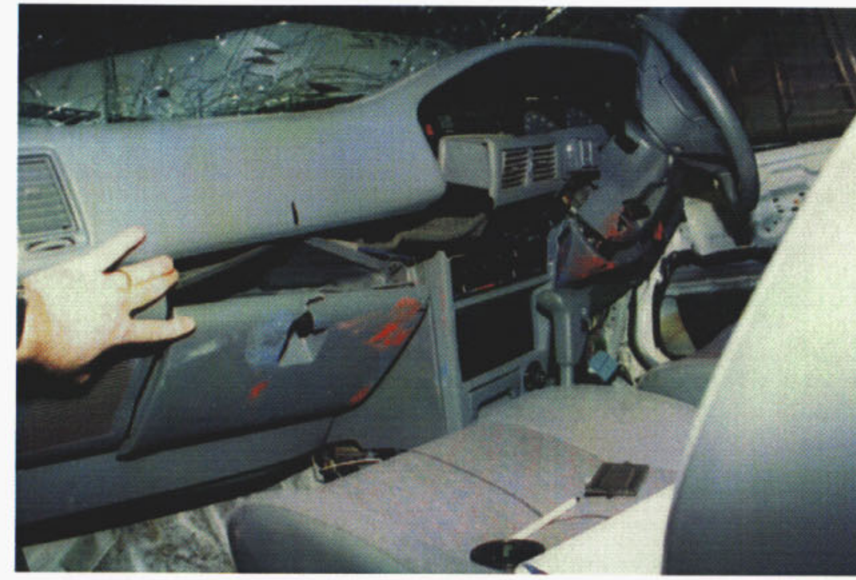
B5028 post test - driver side view

B5028 post test - driver dummy position

B5028 post test - driver dummy position (close up)

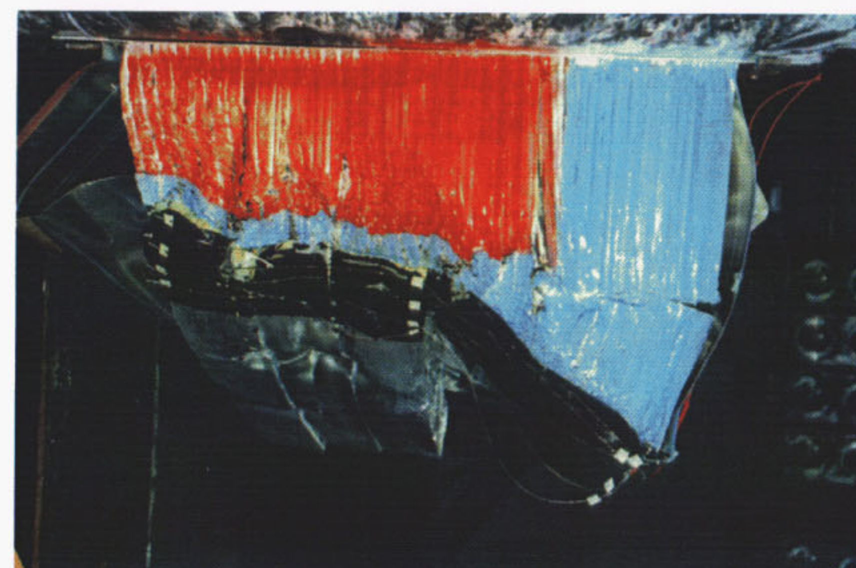


B5028 post test - driver footwell

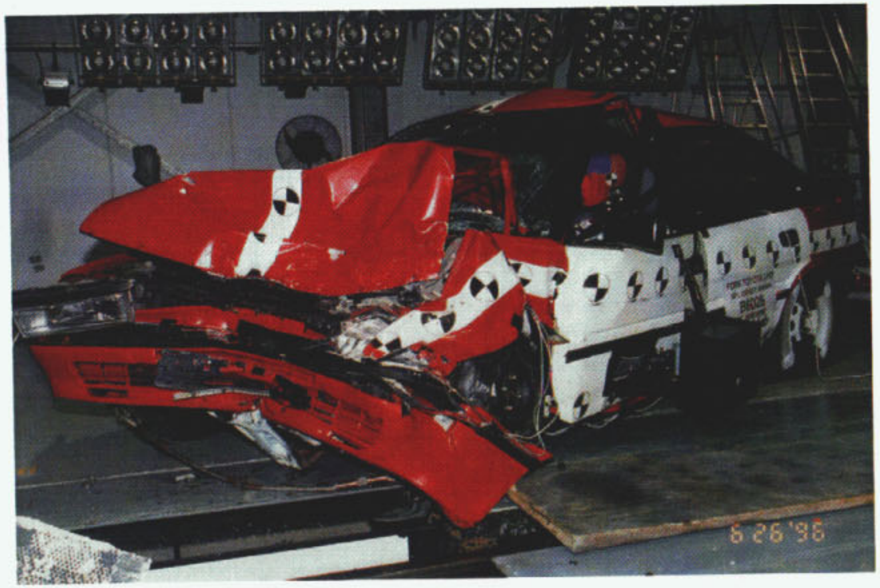


B5028 post test - passenger knee contact marks

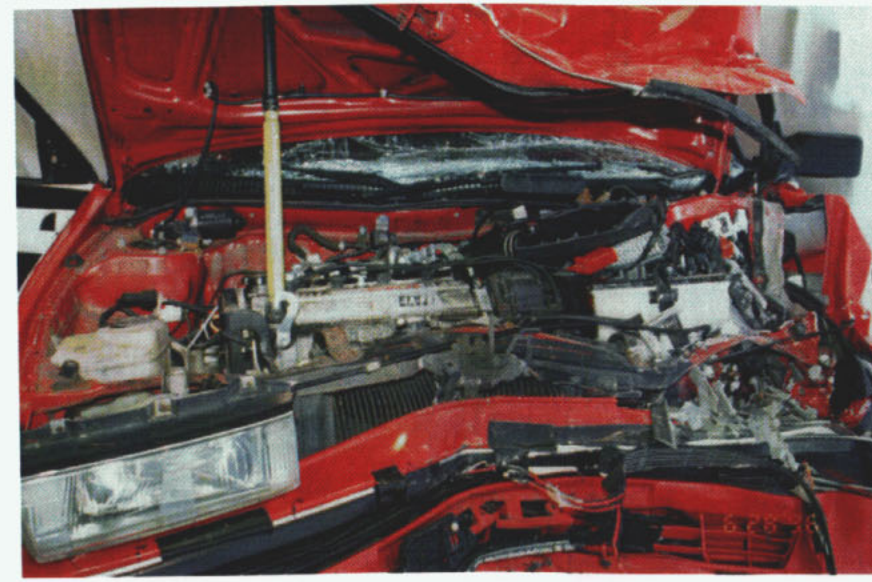
B5028 post test - passenger footwell



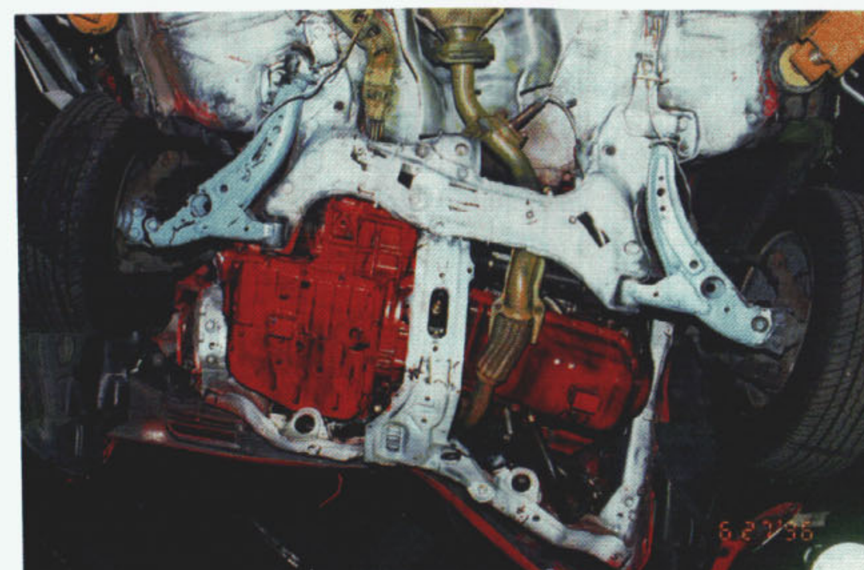
B5028 post test - barrier



B6026 post test - front left 3/4 view


B6026 post test - engine compartment

B6026 post test - front overhead view


B6026 post test - underside view

B6026 post test - driver dummy position

B6026 post test - passenger footwell

B6026 post test - driver footwell

B6026 post test - barrier