



**EUROPEAN NEW CAR ASSESSMENT PROGRAMME  
(Euro NCAP)**

**VULNERABLE ROAD USER  
TESTING PROTOCOL**

Version 9.0.3  
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## Preface

- Where text is contained within square brackets this denotes that the procedure being discussed is currently being trialled in Euro NCAP. Its incorporation in the Test Protocol will be reviewed at a later date.
- During the test preparation, vehicle manufacturers are encouraged to liaise with the laboratory and to check that they are satisfied with the way cars are set up for testing. Where a manufacturer feels that a particular item should be altered, they should ask the laboratory staff to make any necessary changes. Manufacturers are forbidden from making changes to any parameter that will influence the test, such as dummy positioning, vehicle setting, laboratory environment etc.
- It is the responsibility of the test laboratory to ensure that any requested changes satisfy the requirements of Euro NCAP. Where a disagreement exists between the laboratory and manufacturer, the Euro NCAP secretariat should be informed immediately to pass final judgment. Where the laboratory staff suspect that a manufacturer has interfered with any of the set up, the manufacturer's representative should be warned that they are not allowed to do so themselves. They should also be informed that if another incident occurs, they will be asked to leave the test site.
- Where there is a recurrence of the problem, the manufacturer's representative will be told to leave the test site and the Secretary General should be immediately informed. Any such incident may be reported by the Secretary General to the manufacturer and the person concerned may not be allowed to attend further Euro NCAP tests.

DISCLAIMER: Euro NCAP has taken all reasonable care to ensure that the information published in this protocol is accurate and reflects the technical decisions taken by the organisation. In the unlikely event that this protocol contains a typographical error or any other inaccuracy, Euro NCAP reserves the right to make corrections and determine the assessment and subsequent result of the affected requirement(s).

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# **1 VEHICLE PREPARATION**

## **1.1 Unladen Kerb Weight**

- 1.1.1 The capacity of the fuel tank will be specified in the manufacturer's booklet. This volume will be referred to throughout as the 'fuel tank capacity'.
- 1.1.2 Syphon most of the fuel from the tank and then run the car until it has run out of fuel.
- 1.1.3 Refill the fuel tank with fuel (or an equivalent mass of water or other ballast) to its fuel tank capacity.
- 1.1.4 Check the oil level and top up to its maximum level if necessary. Similarly, top up the levels of all other fluids to their maximum levels if necessary.
- 1.1.5 Ensure that the vehicle has its spare wheel on board along with any tools supplied with the vehicle. Nothing else should be in the vehicle.
- 1.1.6 Ensure that all tyres are inflated according to the manufacturer's instructions for half load.
- 1.1.7 Where the vehicle has been supplied directly by the OEM and has a license plate holder attached, this shall not be removed for testing. If the vehicle has been sourced from a dealership, license plate holders that have been added to the vehicle shall be removed.
- 1.1.8 Measure the front and rear axle weights and determine the total weight of the vehicle. The total weight is the 'unladen kerb weight' of the vehicle. Record this weight in the test details.

## **1.2 Additional Weights**

- 1.2.1 Put the fore-aft adjustment of both front seats in their mid-positions. If there is no notch at the mid-position, use the first notch immediately rearward.
- 1.2.2 Place a 75kg mass on the driver's seat and a 75kg mass on the front passenger's seat.
- 1.2.3 Ensure that the front wheels are in the straight ahead position.
- 1.2.4 If the suspension is adjustable in any way, ensure that the vehicle is at the correct attitude for travelling at 40km/h. See Section 1.4.

## **1.3 Suspension Settling**

- 1.3.1 Roll the vehicle forwards by a distance of at least 1 metre
- 1.3.2 Roll the vehicle backwards by a distance of at least 1 metre
- 1.3.3 Repeat steps 1.3.1 and 1.3.2 for three complete cycles. Note: This procedure may be inappropriate for cars which have to be set up as described in Section 1.2.4.
- 1.3.4 Measure and record the ride heights of the vehicle at the point on the wheel arch in the same transverse plane as the wheel centres. Do this for all four wheels.

## **1.4 Normal Ride Attitude**

- 1.4.1 After following the above procedures the vehicle is in its Normal Ride Attitude when the vehicle attitude is in running order positioned on the ground, with the tyres inflated to the recommended pressures, the front wheels in the straight-ahead position, with maximum capacity of all fluids necessary for operation of the vehicle, with all standard equipment as provided by the vehicle manufacturer, with a 75kg mass placed on the driver's seat and with a 75kg mass placed on the front passenger's seat, and with the suspension set for a driving speed of 40km/h in normal running conditions specified by the manufacturer (especially for vehicles with an active suspension or a device for automatic levelling).

- 1.4.2 The manufacturer shall specify the Normal Ride Attitude with reference to the vertical (Z) position of any marks, holes, surfaces and identification signs on the vehicle body, above the ground. These marks shall be selected such as to be able to easily check the vehicle front and rear ride heights and vehicle attitude. If the reference marks are found to be within  $\pm 25\text{mm}$  of the design position in the vertical (Z) axis, then the design position shall be considered to be the normal ride height. If this condition is met, either the vehicle shall be adjusted to the design position, or all further measurements shall be adjusted, and tests performed, to simulate the vehicle being at the design position. Where this is not the case, the normal ride height as determined within Section 1.3 will be used.
- 1.4.3 All ride heights measured are the Normal Ride Attitude ride heights.

## 2 ASSESSMENT OF VEHICLES WITH DEPLOYABLE SYSTEMS

### 2.1 Prerequisites to Assessment

- 2.1.1 Prior to the testing and assessment of a vehicle equipped with a deployable system, the vehicle manufacturer must liaise with the Euro NCAP secretariat and test laboratory. This should begin several weeks before the scheduled test date.
- 2.1.2 In order for systems to be assessed in the deployed position or for the system to be deployed during the tests, it will be necessary for the vehicle manufacturer to provide the Euro NCAP Secretariat with the relevant detailed information highlighted in the following sections before any testing begins.
- 2.1.3 The vehicle manufacturer is responsible for providing all necessary information, detailed in this protocol, to the Euro NCAP Secretariat regarding detection of pedestrians and the deployment of the system. Based on the evidence provided, the Secretariat will decide whether or not the vehicle qualifies for assessment in either the deployed or undeployed position or if dynamic tests are required.
- 2.1.4 General information is also required regarding the functionality of the system along with specific details of the sensing, trigger and deployment systems.
- 2.1.5 The vehicle manufacturer must ensure that the test laboratory is given adequate information regarding the replacement of consumable components, system trigger requirements, details of any health hazards and sufficient spare parts to ensure that testing can be performed on schedule.
- 2.1.6 Where there is no information, a lack of sufficient information or the system does not meet the Euro NCAP requirements; the vehicle will be assessed without triggering of the active pedestrian protection elements.
- 2.1.7 The moveable bonnet top is defined as all structures connected to the bonnet that move with the whole assembly when activated in a pedestrian impact. The rear edge of the bonnet is the most rearward point of the moveable bonnet top when it is closed.

### 2.2 Detection of Pedestrians

- 2.2.1 PDI2 is the default test tool to be used when demonstrating system triggering for the hardest to detect (HTD) pedestrian. Where PDI2 has been used, it will not be necessary for CAE data to be provided justifying the HTD as detailed in 2.2.2. However, head impact times and physical testing will still be required as in 2.2.3 along with the total response time (TRT) of the system.  $TRT = \text{sensing time (ST)} + \text{deployment time (DT)}$ .
- 2.2.2 Where the vehicle manufacturer believes that the PDI2 is not an appropriate test tool for replicating the HTD pedestrian, they must demonstrate with an alternative tool the sensor system's ability to detect a range of pedestrian statures that result in head contacts with the vehicle. The statures should be selected from a 6 year old child, 5th percentile female, 50th percentile male and 95th percentile male. A combination of physical testing and numerical simulations will be required to demonstrate the suitability of the sensing system for the range of pedestrian sizes.
  - 2.2.2.1 The numerical simulations will be required to identify the 'hardest to detect' (HTD) pedestrian and support the use of an alternative test tool. The simulations, which must also include the PDI2 responses, will concern the pedestrian statures that result in head contact with the bonnet, as studied and proven in Section 2.3. Head impact times, according to the definitions from Technical Bulletin TB 024, must be provided for all statures regardless of where they contact the vehicle along with the total response time (TRT) of the system.  $TRT = \text{sensing time (ST)} + \text{deployment time (DT)}$ .



- 2.2.2.2 A minimum of two numerical simulations per appropriate stature (maximum 8 in total) will be required to identify the ‘hardest to detect’ pedestrian and support the choice of test tool. Pedestrian models should be selected from the different statures specified in Section 2.2.2.
- 2.2.2.3 The procedure to certify pedestrian models and the simulation setup is detailed in Technical Bulletin TB 024.
- 2.2.2.4 No changes to the pedestrian model, control cards or control settings are allowed after the certification.
- 2.2.2.5 The pedestrian stance to be used in the model will be facing in a direction perpendicular to the vehicle centreline with the legs apart walking towards the vehicle centreline with the rearward leg being impacted by the bumper first. The same simulation shall be used even if the curvature of the bumper results in the front leg being impacted first.

*Note: Accident analyses performed using the GIDAS database have shown that over 80% of pedestrian impacts are in crossing the road situations. This was used as the basis for modelling the pedestrian in the lateral stance only.*

- 2.2.2.6 The detailed initial posture of the pedestrian is described in Technical Bulletin TB 024. The posture of the pedestrian must not be changed between certification and assessment simulations.
- 2.2.2.7 The contact settings must be consistent with those used in the certification simulations according to TB 024. The frictional value to be applied between the vehicle and pedestrian shall be 0.3.
- 2.2.2.8 The simulations shall be conducted at the system’s lower deployment threshold (LT) impact speed specified by the vehicle manufacturer.
- 2.2.2.9 The simulations will be conducted at two separate locations on the bumper. For each of the appropriate statures simulations will be performed on the vehicle centreline and at the outboard end of the bumper test zone defined in Section 3.9.8. An additional simulation may be required where the bumper test zone is relatively narrow when compared to the width of the moveable bonnet top.
- 2.2.2.10 Outputs from the simulations shall clearly highlight what the critical pedestrian size is for that particular sensing system. Once the hardest to detect pedestrian is established the appropriate test tool that reflects the characteristics of that pedestrian can be identified for use in the physical tests. The minimum output parameters from the numerical simulations will be:
  - Bumper force
  - Effective mass
  - Energy
  - Bumper intrusion
  - Acceleration (when used as trigger)
- 2.2.2.11 Effective mass will be calculated as follows. This calculation assumes that peak force on the vehicle occurs when the leg velocity reaches 0m/s:

$$M_e = \frac{\int_{t_1}^{t_2} F dt}{\Delta v}$$

$M_e$  = Effective mass (kg)  
 $F$  = Force (N)  
 $\Delta v$  = Change in Velocity (m/s)  
 $dt$  = Time increment (s)  
 $t_1$  = Time of first contact (s)  
 $t_2$  = Time of peak force (s)

2.2.2.12 In the event that a system triggers before the peak force is imparted onto the bumper cross member, the following calculation should be used:

$$M_e = \frac{\int_{t_1}^{t_2} F dt}{\int_{t_1}^{t_2} a dt}$$

$M_e$  = Effective mass (kg)  
 $F$  = Force (N)  
 $a$  = Leg acceleration (m/s<sup>2</sup>)  
 $dt$  = Time increment (s)  
 $t_1$  = Time of first contact (s)  
 $t_2$  = Time of system trigger (s)

2.2.2.13 For the calculation of effective mass, only movement in the X direction is considered. The most significant structures that load the leg should be considered, such as the bumper cross member and any upper or lower cross beams. Less significant structures, such as grills and valances may be ignored. Viscous effects should be ignored.

2.2.2.14 Of the outputs specified in Section 2.2.2.10, the most appropriate trigger parameter(s) for the specific type of sensing system will be used to show an appropriate level of correlation between the chosen test tool and the numerical simulations. Trigger parameters must correspond with the system sensing time. The vehicle manufacturer may choose the impact location and vehicle components for inclusion onto the calculation of the output parameters.

2.2.3 Physical testing will be used to assess the capability of the sensing system(s). As a surrogate for a pedestrian that is larger/heavier than a 50th percentile male, the legform detailed in 2.2.3.2 (test 4) for legform to bumper tests shall be used. This is to ensure that the system deploys when impacting larger or ‘upper limit’ pedestrians.

2.2.3.1 To ensure that the pedestrian impact sensor(s) are effective across the full bumper width, a minimum of three tests shall be performed at locations within the bumper test zone.

2.2.3.2 Test matrix:

Test	Impactor	Impact point	Speed	Output
1	PDI2/HTD <sup>1</sup>	<ul style="list-style-type: none"> <li>Directly on localised sensor e.g. accelerometer +/- 50mm. If the sensing system uses a combination of contact strip switches and localised accelerometers, the positions of the accelerometers should be used to define the impact locations.</li> <li>For non-localised sensor systems, such as contact switches, test the vehicle centreline.</li> </ul>	LT <sup>2</sup> +/-2km/h	<ul style="list-style-type: none"> <li>High speed film</li> <li>Actuator trigger time</li> <li>Initiation of deployment</li> </ul>
2	PDI2/HTD	Bumper test zone end, left or right hand side, +/- 50mm.	LT +/-2km/h	<ul style="list-style-type: none"> <li>High speed film</li> <li>Actuator trigger time</li> <li>Initiation of deployment</li> </ul>
3	PDI2/HTD	Farthest from sensor(s) if not tested already, +/- 50mm.	LT +/-2km/h	
4 <sup>3</sup>	FlexPLI or WG17 impactor to account for larger pedestrians	Directly on localised sensor e.g. accelerometer, +/- 50mm. For non-localised sensor systems test directly in line with the front longitudinal member to produce the highest acceleration levels on the impactor. This test may be performed using a representative surrogate with equivalent mass and stiffness to prevent damage to instrumentation.	40km/h +/-2km/h	

Notes:

1. HTD = Other appropriate hardest to detect (as defined by section 2.2.2);

2. LT = Lower deployment Threshold.

3. The impactor for test 4 may be chosen by the vehicle manufacturer.

- 2.2.3.3 At least test #3 shall be witnessed or performed by Euro NCAP to verify deployment of the system at the lower threshold. Alternatively, it may be performed by the manufacturer and witnessed at their facility.
- 2.2.3.4 Where a test is performed below the lower threshold speed but within the velocity tolerance or outside the bumper test zone and the system does not deploy, the test must be repeated at a speed no less than the lower threshold and not outside the bumper test zone.
- 2.2.3.5 The outputs from all physical tests shall include, but is not limited to:
- Good quality high speed film showing an overview of the test.
  - Documentation of the correct test location, e.g. using paint marks and post test photographs.
  - Documentation of test speed (vehicle or impactor as applicable), e.g. using known road markings or speed measurement systems etc.
  - Actuator trigger time (current clamp/ECU).
  - Evidence of system deployment initiation, i.e. film showing the first movement of the bonnet top or frangible break wires/contacts/squibs.
- 2.2.3.6 The first physical test, or tests, must be performed with the pedestrian protection system fully functional from the sensing systems to the bonnet actuators/airbag squibs. At the same time, it is acceptable to include an additional means of highlighting deployment, such as flashes and/or squibs for that first test. Once a valid firing time and system deployment has been confirmed, the remaining tests may then be performed with the flashes/squibs connected in place of the bonnet actuators or airbag; thus negating the need for deployment. The entire system architecture should be present up to the bonnet actuators/airbag for all tests. Flashing hazard warning lights or other indications that are not connected to the actuator wiring system will not be accepted.

### **2.3 Timing of System Deployment**

- 2.3.1 Grid points that are not affected by the active system will be tested statically.
- 2.3.2 Where the manufacturer has demonstrated, by numerical simulations or alternative means (vehicle speed of 45km/h), that a system is fully deployed and remains in the intended position prior to the head impact time of the smallest appropriate stature pedestrian, then all headform tests shall be performed with the bonnet in the fully deployed position. There will be no need to trigger any active elements during the sub system pedestrian tests. This does not apply to airbag systems.
- 2.3.3 However, where the system is not fully deployed before the HIT for any appropriate stature, all grid points forwards of the corresponding wrap around distance will be tested dynamically.
- 2.3.4 For systems that do not remain in a permanently deployed position then dynamic pedestrian testing will be required for all test locations.
- 2.3.5 The simulations shall be performed using the unchanged pedestrian model and simulation setting from Technical Bulletin TB 024. Numerical simulations shall be performed with the bonnet in the undeployed position with all pedestrian statures that result in head contact to the bonnet. Pedestrian models shall be selected from the following statures, a six year old, 5th percentile female, 50th percentile male and 95th percentile male. The pedestrian position and stance to be used in the model is defined in Technical Bulletin TB 024, positioning the pedestrian's head centre of gravity on the vehicle centreline.

- 2.3.6 From the simulation, the vehicle manufacturer must determine the wrap around distance for each test location and establish the relevant head impact time for that stature of pedestrian. A graph shall be plotted with a best fit straight line which also identifies the total response time (TRT) of the system as shown in Figure 1. The plot of wrap around distance vs head impact time shall be provided for the assessed vehicle fitted with a deployable system. The determination of HIT must be consistent with the definition from Technical Bulletin TB 024.
- 2.3.7 Further details on performing dynamic tests are provided in Section 8.5.

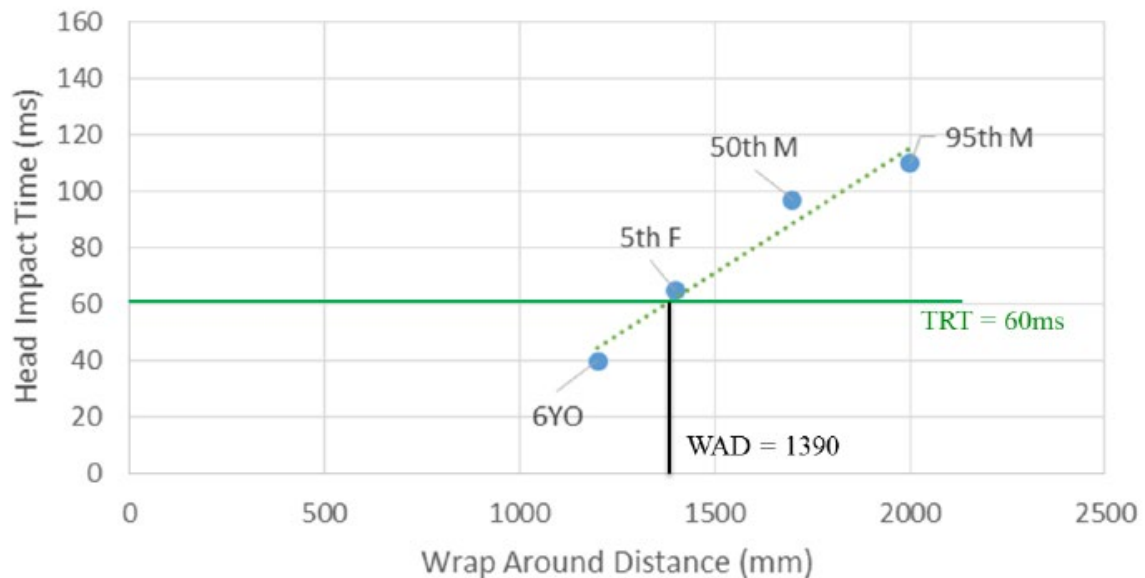


Figure 1: WAD vs HIT

In this example

- Up to WAD 1390 tests are conducted dynamically
- From WAD 1390 tests are performed with bonnet in fully deployed position

## 2.4 Protection at Speeds below the Deployment Threshold

### 2.4.1 Exemption zones

- 2.4.1.1 Euro NCAP maintains that vehicles that offer protection without a deployable device, offer protection at lower speeds and some protection at higher speeds. Therefore, Euro NCAP requires that vehicles equipped with deployable pedestrian protection systems also provide protection at impact speeds below the system deployment threshold on the part of the vehicle affected by the deployable pedestrian protection system.
- 2.4.1.2 The area of the vehicle considered will be all grid points that have a distance measured in the lateral Y axis of 50mm or more inboard from the side reference lines and 50mm or less measured in the lateral Y axis outboard from the movable bonnet shut line. See Figure 2.
- 2.4.1.3 The area will also extend rearward from the 1000mm wrap around distance (WAD) up to the rear of the movable bonnet top defined in 2.1.7. Child/small adult headforms will apply to grid points from wrap around distances 1000mm to 1700mm WAD inclusive and adult headforms will apply to grid points rearward from 1700mm up to the rear of the movable bonnet top. See Figure 2.

- 2.4.1.4 Where parts of the movable bonnet are to be tested in the deployed position e.g. based on head impact time, and others are not, the area of consideration will include all grid points that are located between the rear of the movable bonnet top and 50 mm forward or less from the most forward part of the bonnet that will be tested in the deployed position. See Figure 2.
- 2.4.1.5 The vehicle manufacturer is required to provide the Euro NCAP Secretariat HIC<sub>15</sub> or colour data showing that, at the lower deployment threshold speed, no grid point within the area mentioned above that is predicted green, yellow or orange at 40km/h shall produce HIC values above 1350 at the lower deployment threshold.
- 2.4.1.6 For no less than 2/3rds of the total number of grid points within the prescribed area, HIC values must not exceed 1000.
- 2.4.1.7 Data shall be provided for each grid point according to the following performance criteria:
- $$\begin{aligned} \text{HIC}_{15} < 1000 &= \text{Yellow} \\ 1000 < \text{HIC}_{15} < 1350 &= \text{Orange} \end{aligned}$$
- 2.4.1.8 Up to three physical tests may be performed to verify the CAE data at just below the deployment threshold speed. These tests will be selected at random by the Euro NCAP Secretariat.
- 2.4.1.9 Where any of the criteria in Section 2.4.1.5 to 2.4.1.7 are not met then all pedestrian tests will be performed with the system in the undeployed position.

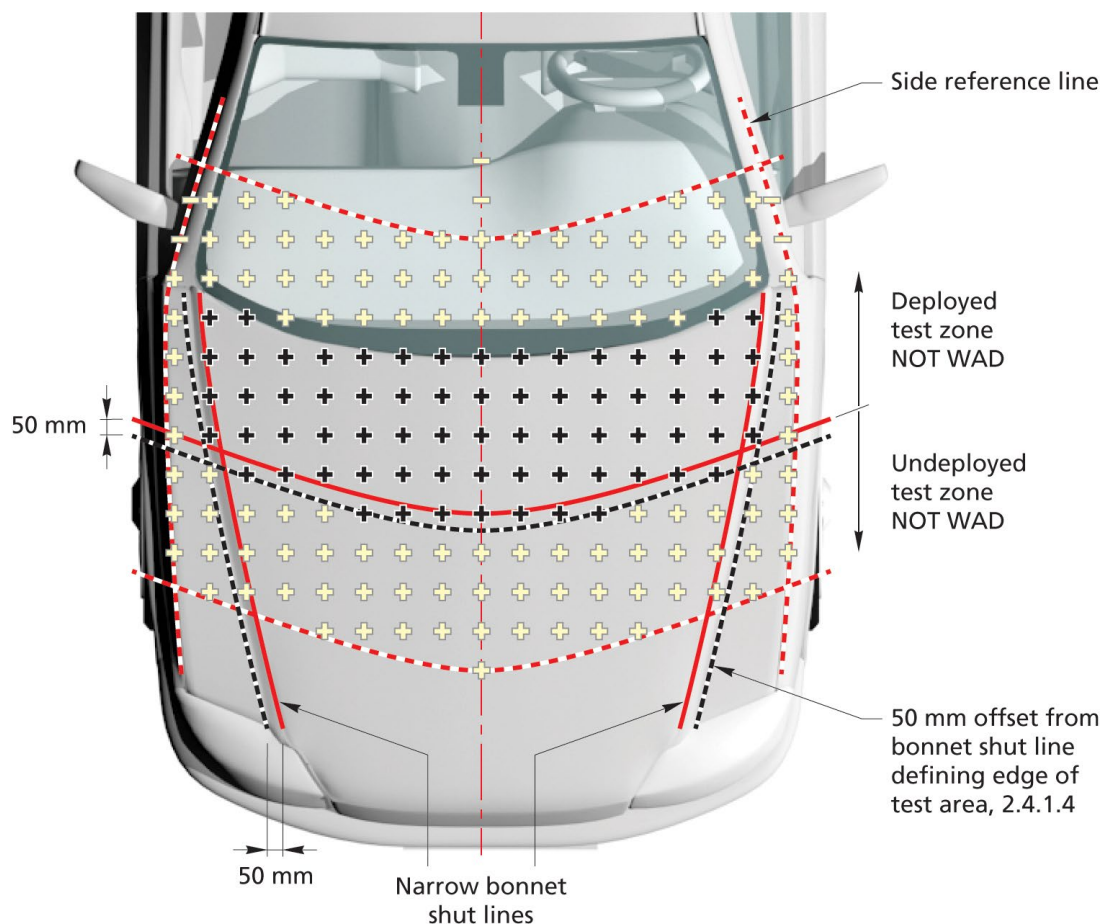


Figure 2: Area to meet low speed requirements

## **2.5 Protection at Higher Impact Speeds**

### **2.5.1 Upper deployment threshold**

- 2.5.1.1 All deployable systems must initiate deployment at speeds of at least 50km/h. It is not necessary for a system to be fully deployed and reach the intended position before head impact at 50km/h, but the vehicle manufacturer must show that deployment has initiated.
- 2.5.1.2 A physical test using the impactor chosen in Section 2.2 is required at 50km/h to show that deployment has initiated. The outputs from the test are as those described in Section 2.2.3.5.
- 2.5.1.3 The test shall be performed at either the vehicle centreline or, if localised sensors used, as far away from the sensor as a possible while remaining within the bumper test zone.

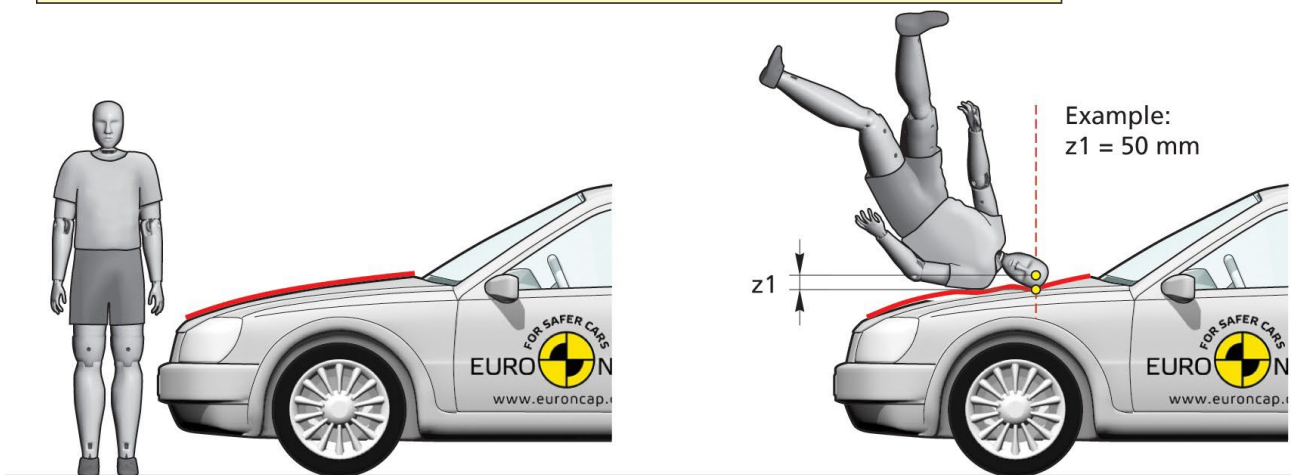
## **2.6 Bonnet Deflection due to Body Loading**

- 2.6.1 Given that deployable bonnets may have reduced support from their peripheral structures compared to passive systems, Euro NCAP requires that head protection is not compromised by bonnet collapse.
  - 2.6.1.1 The evaluation shall be calculated with the use of CAE without the ‘package’ being present. The package meaning engine and ancillaries. All body in white structures and bonnet supports must be present. However, all components that load the legs and pelvis must be included.
  - 2.6.1.2 This is done by measuring and comparing the Z displacement at the position of head contact for both a deployed and undeployed bonnet at the time of first head contact. At the position of head impact the difference between deployed and undeployed bonnet can be no more than 75% of the generated deployment height at that point, see Figure 3.
  - 2.6.1.3 At the point of head impact it is essential that the bonnet deflection in the deployed state does not exceed the total available clearance between deployed bonnet and under bonnet hard point, i.e.  $(h_2 + h_3) - z_2 > 0$ , see Figure 4.
  - 2.6.1.4 This would be established using numerical simulations at 40km/h with the appropriate size pedestrian that loads the least supported part of the bonnet top for that particular size of vehicle. For example, on a small vehicle with a short bonnet it may be that the 50th percentile male contacts the vehicle rearward of the bonnet top. Therefore, a smaller pedestrian stature will be required.
  - 2.6.1.5 The stance described in Technical Bulletin TB 024 shall be used positioning the pedestrian’s head centre of gravity on the vehicle centreline. Unchanged certified pedestrian models and simulation settings must be applied.

*Note: Impacts at the centreline were chosen to simplify to the modelling needed and to avoid the possibility of glancing blows. It is also assumed there will be the least support to the bonnet at the centreline.*

**1. Undeployed simulation:** 40 km/h, centreline, walking posture, 50<sup>th</sup>% (if no bonnet contact 5<sup>th</sup>%)

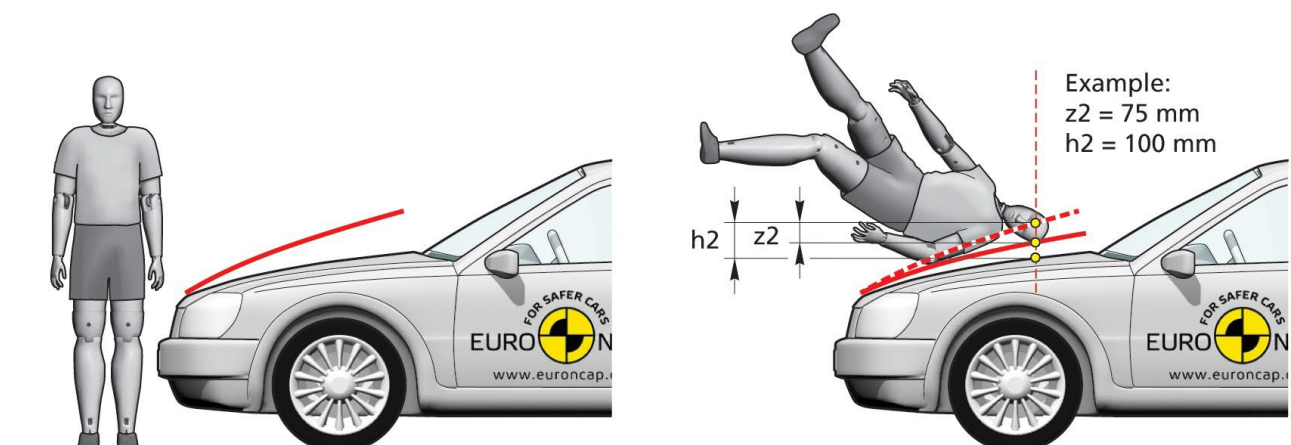
All measures are taken vertically at head impact point at first time of head contact.



Output:

- a. Z displacement at head contact point:  $z_1$   
at first time of head contact

**2. Deployed simulation:** 40 km/h, centreline, walking posture, 50<sup>th</sup>% (if no bonnet contact 5<sup>th</sup>%)



Output:

- b. Z displacement:  $z_2$   
c. Deployment height:  $h_2$

**3. Requirement:**

$$z_2 - z_1 < 75\% \times h_2$$

Example:

$$75 \text{ mm} - 50 \text{ mm} < 75\% \times 100 \text{ mm}$$

$$25 \text{ mm} < 75 \text{ mm} \text{ (= OK)}$$

Bonnet deflection in the deployed state ( $z_2$ ) must not exceed bonnet deflection in the undeployed state ( $z_1$ ) by more than 75% of the deployment height ( $h_2$ ).

Figure 3: Bonnet deflection deployed and undeployed comparison



**Simulation:** 40 km/h, centreline, walking posture, 50<sup>th</sup>% (if no bonnet contact 5<sup>th</sup>%)

All measures are taken vertically at head impact point at first time of head contact.

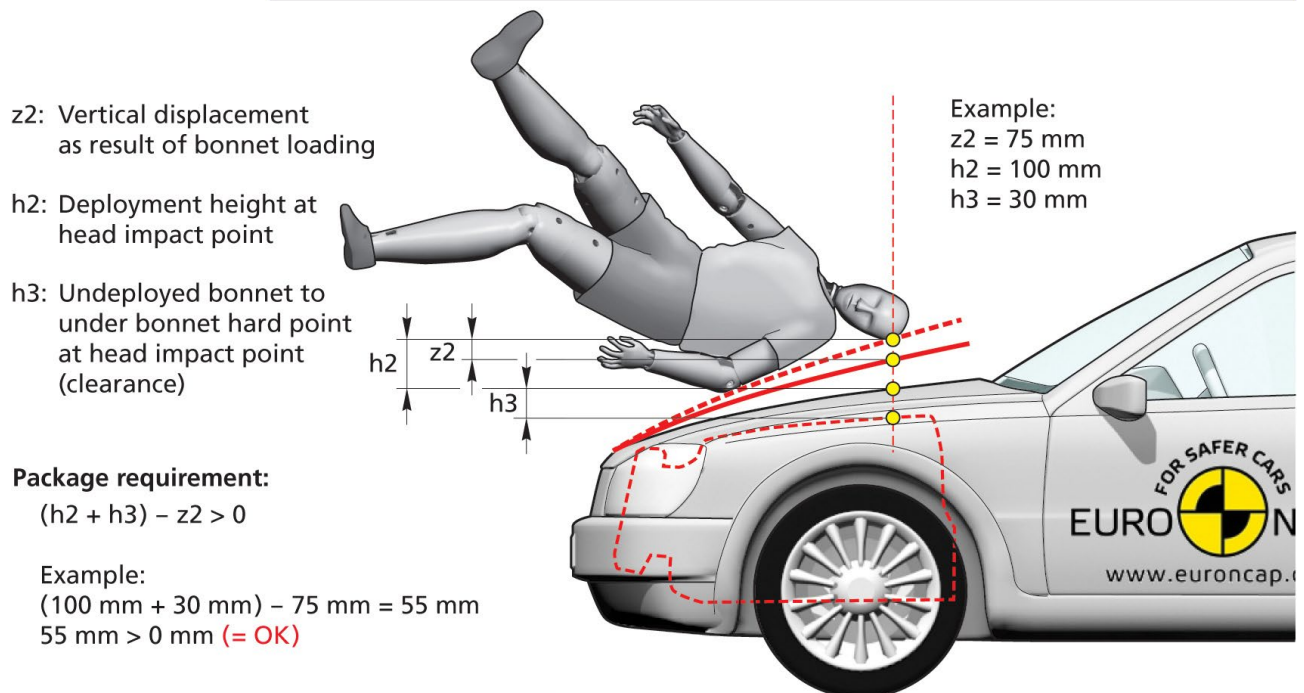


Figure 4: Bonnet deflection total clearance requirement



## 3 VEHICLE MARKING

### 3.1 General

- 3.1.1 The vehicle shall be marked with a grid as described in the following sections. The marking procedures divide the front of the car into zones which are then assessed using appropriate impactors.
- 3.1.2 Where no predicted data is to be provided by the vehicle manufacturer, the testable area shall be marked as described in the Euro NCAP Pedestrian Testing Protocol version 5.3.1, November 2011.
- 3.1.3 All markings and measurements should be made with the vehicle in its Normal Ride Attitude.
- 3.1.4 The vehicle manufacturer must provide Euro NCAP with coordinates of all grid points derived from either CAE data or physical mark out.
- 3.1.5 A comparison of the grid origin C0,0 and two other points on WAD 2100, will be made between the laboratory mark out and the data provided by the vehicle manufacturer. For manufacturer predicted data to be accepted, grid points must be within 10mm of each other.
- 3.1.6 Where the grid points of Euro NCAP and vehicle manufacturer are within 10mm of each other the laboratory mark-out shall be used.
- 3.1.7 Where the two grids differ by more than 10mm the vehicle manufacturer shall be informed and both markings will be examined in greater detail to establish the cause of any differences. The Secretariat will then take a decision as to how to proceed with vehicle marking.
- 3.1.8 The vehicle manufacturer must provide data for all headform grid locations. Testing will be carried out by Euro NCAP to a number of locations to verify the accuracy of data provided by the vehicle manufacturer.
- 3.1.9 For vehicles fitted with deployable systems, the headform impactor marking will be applied to the vehicle with the system in the undeployed state. This will be the case regardless of whether or not the bonnet is locking or non-locking or the vehicle uses an airbag.
- 3.1.10 For vehicles fitted with deployable systems, the WAD 775mm and WAD 930mm will be marked on the vehicle with the system in the un-deployed state. If deployment occurs prior to the pedestrian contact with the WAD 775mm, creating an increased hazard such as increased height, the Euro NCAP secretariat will give consideration to marking out the WAD 775mm and WAD 930mm in the deployed state.  
*Note: Marking in the undeployed state was chosen to avoid the possibility of discontinuities in the test areas leading to anomalies or inconsistencies in the test results.*
- 3.1.11 Where the vehicle manufacturer provides data showing that a deployable system offers protection to the upper leg, the upper legform tests will be carried out by conducting dynamic tests. The WAD 775mm and WAD 930mm will be marked on the vehicle in the deployed position.
- 3.1.12 In case of any gaps in the relevant markup areas of the vehicle front such as WAD 930mm and the internal bumper reference line, e.g. in the grille area, approximate the outer contour of the vehicle using tape to span these gaps. Between the lower bumper reference line and the BLE, create a wrap around up to the BLE. All measurements and markings shall be placed on this tape. In case of any doubt how to place the tape use the WAD marking procedure, i.e. the covering tape is placed like the tape measure during WAD marking.

### 3.2 Bonnet Side Reference Line

The Bonnet Side Reference Line is defined as the geometric trace of the highest points of contact between a straight edge 700mm long and the side of a bonnet, as defined in Section 3.3.1 and A-Pillar, when the straight edge, held parallel to the lateral vertical plane of the car and inclined inwards by 45° is traversed down the side of the bonnet top and A-Pillar, while remaining in contact with the surface of the body shell, any contact with door mirrors is ignored. See Figure 5. Where multiple or continuous contacts occur the most outboard contact shall form the bonnet side reference line.

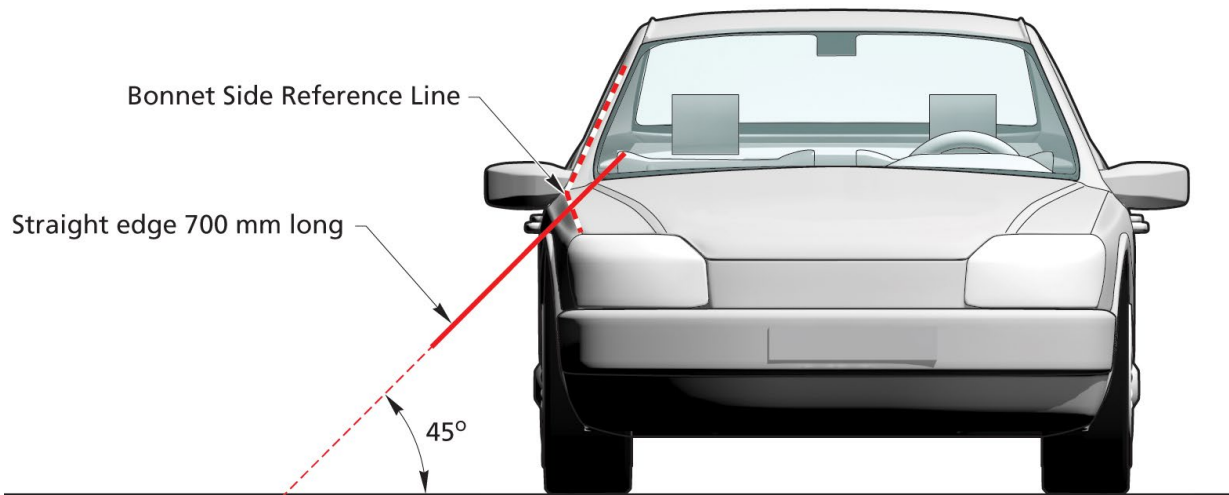


Figure 5: Determination of the bonnet side reference lines

- 3.2.1 Fix a straight edge that is 700mm long at 45° to the vertical. With this edge in a plane parallel to the lateral vertical plane of the car, position the straight edge at the front of the front wing and in contact with, the bonnet.
- 3.2.2 Mark the uppermost point of contact of the straight edge and wing.
- 3.2.3 Pull the straight edge away from the wing, move it towards the other end of the vehicle by not more than 100mm and then back into contact with the wing.
- 3.2.4 Mark the uppermost point of contact of the straight edge and wing.
- 3.2.5 Repeat Sections 3.2.3 to 3.2.4 moving the edge along the length of the wing, A-Pillar and Cant Rail if required (depending on the anticipated position of the 2500 Wrap Around Distance).
- 3.2.6 Using a flexible rule, join the marks on the vehicle to form a line. This line may not be continuous but may 'jump' around the wing/wheel arch.
- 3.2.7 Repeat for the other side of the vehicle.
- 3.2.8 A partial modification of the side reference lines may be necessary subsequent to the determination of the corner reference points according to Section 3.7.2.

### 3.3 Bonnet Leading Edge Reference Line

The Bonnet Leading Edge Reference Line is defined as the geometric trace of the points of contact between a straight edge 1000mm long and the front surface of the bonnet, when the straight edge, held parallel to the vertical longitudinal plane of the car and inclined rearwards by 50° and with the lower end 600mm above the ground, is traversed across and in contact with the bonnet leading edge, see Figure 6. For vehicles having the bonnet top surface inclined at essentially 50°, so that the straight edge makes a continuous contact or multiple contacts rather than a point contact, determine the reference line with the straight edge inclined rearwards at an angle of 40°. For vehicles of such shape that the bottom end of the straight edge makes first contact then that contact is taken to be the bonnet leading edge reference line, at that lateral position. For vehicles of such shape that the top end of the straight edge makes first contact then the geometric trace of 1000mm wrap around distance will be used as the Bonnet Leading Edge reference line at that lateral position. The top edge of the bumper shall also be regarded as the bonnet leading edge, if it is contacted by the straight edge during this procedure.

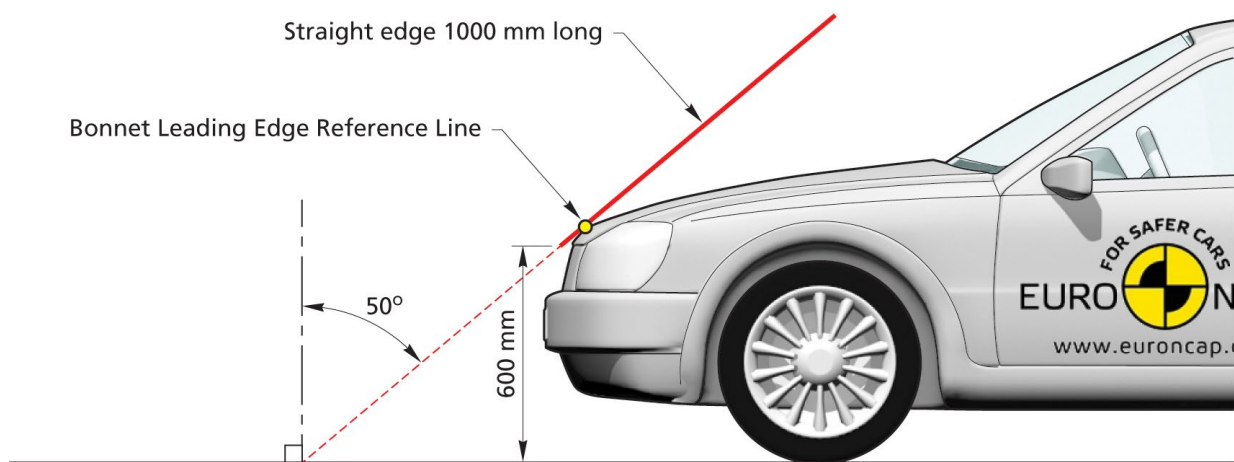


Figure 6: Determination of the Bonnet Leading Edge Reference Line

- 3.3.1 The bonnet leading edge is defined as the front upper outer structure including the bonnet and wings, the upper side members of the headlight surround and any other attachments.
- 3.3.2 Fix a straight edge that is 1000mm long at 50° to the vertical and with its lower end at a height of 600mm. If the top surface of the bonnet is inclined at essentially 50° so that the straight edge makes a continuous contact or multiple contacts rather than a point contact, determine the reference line with the straight edge inclined rearwards at an angle of 40°. With this edge in a plane parallel to the vertical longitudinal plane of the car, position the straight edge at one end of, and in contact with, the bonnet.
- 3.3.3 Mark the point of contact of the straight edge and bonnet.
- 3.3.4 If the bottom end of the straight edge makes first contact then mark this point of contact.
- 3.3.5 If the top end of the straight edge makes first contact behind the 1000mm Wrap Around Distance, then use the geometric trace of the 1000mm Wrap Around Distance at that lateral position.
- 3.3.6 Pull the straight edge away from the bonnet, move it towards the other end of the bonnet by not more than 100mm and then into contact with the bonnet.
- 3.3.7 Mark the point of contact of the straight edge and bonnet.
- 3.3.8 Repeat Sections 3.3.4 to 3.3.7 across the whole width of the bonnet. Using a flexible rule, join the marks on the bonnet to form a line. This line may not be continuous but may 'jump' around the grill and badge area etc. This line is the Bonnet Leading Edge Reference Line.

### 3.4 Bonnet Rear Reference Line

The Bonnet rear reference line is defined as the geometric trace of the most rearward point of contact between a 165mm sphere and the frontal upper surface, when the sphere is traversed across the frontal upper surface, while maintaining contact with the windscreen.

- 3.4.1 Remove the wiper blades and arms.
- 3.4.2 Place a 165mm sphere at the vehicle centreline on the frontal upper surface so that the rearmost point of contact of the sphere is always on the glass.
- 3.4.3 Mark the most forward point of contact between the sphere and the vehicle's frontal upper surface. Repeat this at suitable increments moving outboard until the sphere contacts the side reference line on both sides of the vehicle. See Figure 7.

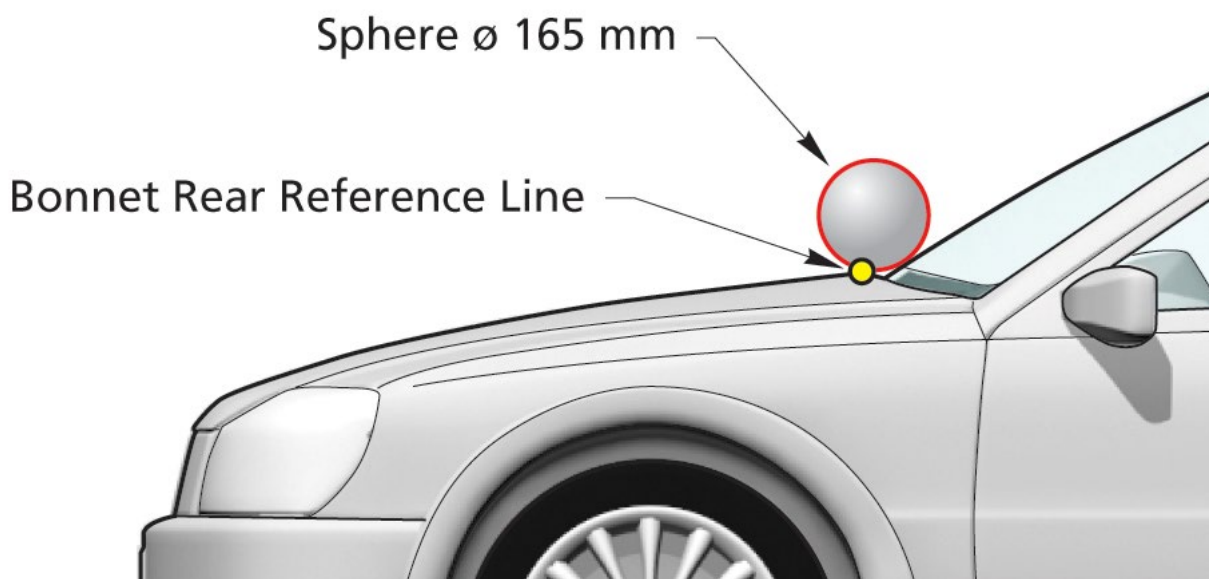


Figure 7: Determination of the bonnet rear reference line

- 3.4.4 If the bonnet rear reference line is located at a wrap around distance of more than 2100mm, the bonnet rear reference line is defined by the geometric trace of the 2100mm wrap around distance.
- 3.4.5 Where the bonnet rear reference line and side reference line do not intersect, the bonnet rear reference line is extended and/or modified using a semi-circular template, of radius 100mm. The template shall be made of a thin flexible sheet material that easily bends to a single curvature in any direction. The template shall, if possible, resist double or complex curvature where this could result in wrinkling. The recommended material is a foam backed thin plastic sheet to allow the template to 'grip' the surface of the vehicle.

- 3.4.6 The template shall be marked up with four points ‘A’ through ‘D’, as shown in Figure 8, while the template is on a flat surface. The template shall be placed on the vehicle with Corners ‘A’ and ‘B’ coincident with the side reference line. Ensuring these two corners remain coincident with the side reference line, the template shall be slid progressively rearwards until the arc of the template makes first contact with the bonnet rear reference line. Throughout the process, the template shall be curved to follow, as closely as possible, the outer contour of the vehicle’s bonnet top, without wrinkling or folding of the template. If the contact between the template and bonnet rear reference line is tangential and the point of tangency lies outside the arc scribed by points ‘C’ and ‘D’, then the bonnet rear reference line is extended and/or modified to follow the circumferential arc of the template to meet the side reference line, as shown in Figure 8.
- 3.4.7 If the template does not make simultaneous contact with the side reference line at points ‘A’ and ‘B’ and tangentially with the bonnet rear reference line, or the point at which the bonnet rear reference line and template touch lies within the arc scribed by points ‘C’ and ‘D’, then additional templates shall be used where the radii are increased progressively in increments of 20mm, until all the above criteria are met.
- 3.4.8 Once defined, the modified bonnet rear reference line is assumed in all subsequent paragraphs and the original ends of the line are no longer used.
- 3.4.9 Replace the wiper arms and blades.

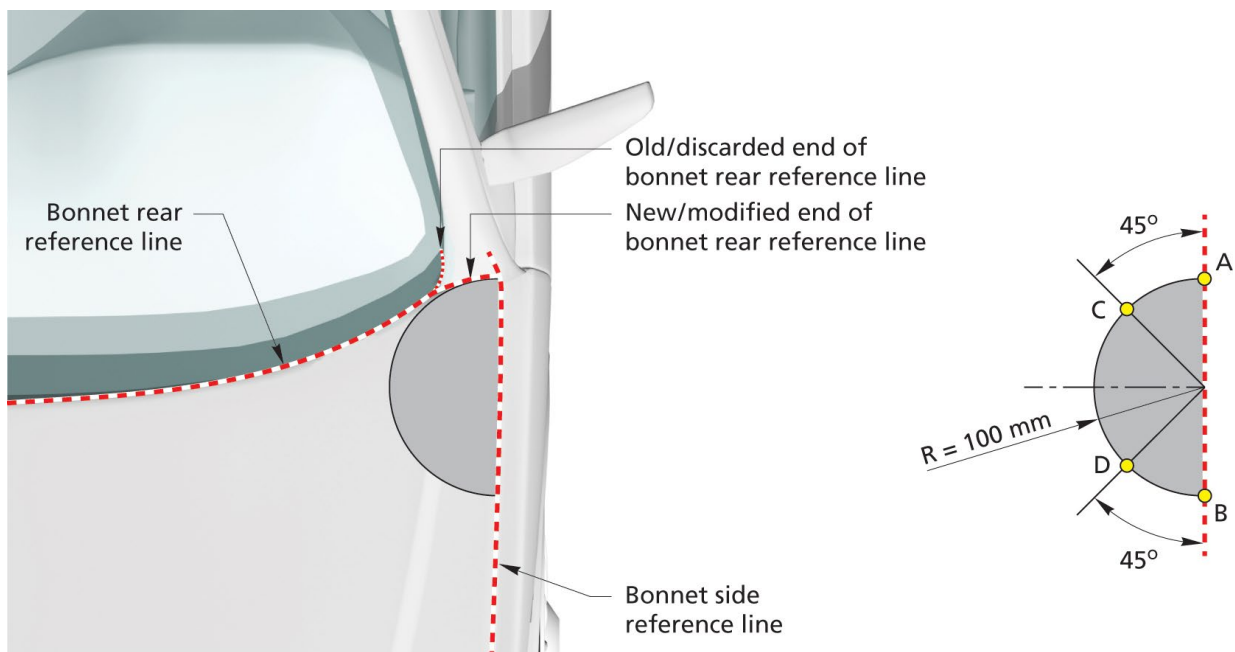


Figure 8: Bonnet rear reference line template and extension

### 3.5 Windscreen Rear Reference Line

The windscreen rear reference line is defined as the physical rearmost edge of the visible windscreen glazing. Glazing at the rear edge of the windscreen that is behind a rubber seals will be counted as the roof. Where there is no discernible boundary for the windscreen rear reference line e.g. the windscreen has formed part of the roof, then the windscreen rear reference line is defined as the geometric trace of the highest points of contact between a straight edge 700mm long and the front surface of the windscreen when the straight edge, held parallel to the longitudinal vertical plane of the car and inclined rearwards by 45°.

- 3.5.1 Beginning at the vehicle centreline draw a line outboard along the intersection of the rearmost glazing edge with the rubber seal up to the outboard edge of the glazing.
- 3.5.2 Using the template defined in Section 3.4.5, place it on the vehicle with corners 'A' and 'B' coincident with the side reference line. Ensuring these two corners remain coincident with the side reference line, the template shall be slid progressively rearwards until the arc of the template makes first contact with the bonnet rear reference line. If the contact between the template and windscreen rear reference line is tangential and the point of tangency lies outside the arc scribed by points 'C' and 'D', then the windscreen rear reference line is extended and/or modified to follow the circumferential arc of the template to meet the side reference line
- 3.5.3 If the template does not make simultaneous contact with the side reference line at points 'A' and 'B' and tangentially with the windscreen rear reference line, or the point at which the windscreen rear reference line and template touch lies within the arc scribed by points 'C' and 'D', then additional templates shall be used where the radii are increased progressively in increments of 20mm, until all the above criteria are met.

### 3.6 Marking Wrap Around Distances

The headform test area is defined as the outer structure that includes the upper surface of all outer structures. It includes, but is not limited to, the bonnet, wings, windscreen scuttle, wiper arms/spindles, windscreen frame, A-pillars and roof. It is bounded by the geometric trace of the 1000mm wrap around line in the front, the Bonnet Side Reference Lines and the 2500mm wrap around distance (WAD).

- 3.6.1 Begin at the vehicle centreline.
- 3.6.2 Place the end of a flexible tape measure or graduated wire on the floor vertically below the front face of the bumper.
- 3.6.3 Wrap the tape or wire over the bumper, bonnet windscreen and roof ensuring that it is maintained in a vertical longitudinal (X, Z) plane and that its end is still in contact with the ground. The tape should be held taut throughout the operation, vertically below the front face of the bumper, see Figure 9.

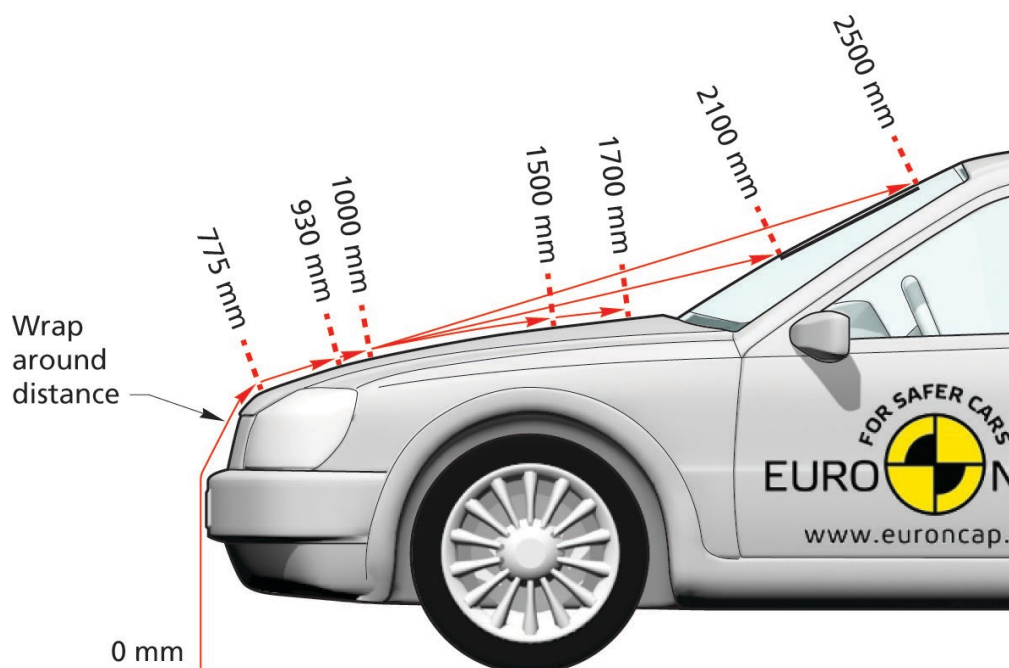


Figure 9: Marking wrap around lines

- 3.6.4 Mark on the bumper/grille, bonnet top, windscreen, A-pillars and/or roof the wrap around distances of 775mm, 930mm, 1000mm, 1500mm, 1700mm, 2100mm and 2500mm. These are the geometric traces described on the outer surface of the vehicle by the end of flexible tape or wire 775mm, 930mm, 1000mm, 1500mm, 1700mm, 2100mm or 2500mm long, when it is held in a vertical fore/aft plane of the car and traversed across the front of the bonnet and bumper.
- 3.6.5 Where any of the WAD's lie below the outer contour of the vehicle, for example in the gap behind the bonnet, using the tape or wire approximate the outer contour of the vehicle horizontally rearward from the last point of contact and project the WAD vertically down onto the underlying structure.
- 3.6.6 Reposition the end of the tape on the ground no further than 100mm laterally outboard starting at the vehicle centreline up to the Corner of Bumper. The tape should be stretched over the A-pillars where necessary.
- 3.6.7 Repeat steps 3.6.2 to 3.6.6 until the width of the vehicle has been marked up to the Side



#### Reference Lines.

- 3.6.8 Join the points marked on the bonnet to form lines at wrap around distances of 775mm, 930mm, 1000mm, 1500mm, 1700mm, 2100mm and 2500mm. Points located on WAD 1000mm up to and including WAD 1500mm will be assessed using the child/small adult headform. Points rearward of WAD 1700mm up to and including WAD 2500mm will be assessed with the adult headform, see Figure 10. The headform to be used in the area rearward of WAD 1500mm up to and including WAD 1700mm depends on the location of the bonnet rear reference line (BRRL).
- 3.6.9 Where the BRRL is rearward of WAD 1500mm up to and including WAD 1700mm, points forward of and directly on the bonnet rear reference line will be assessed using the child/small adult headform, while points rearward of the BRRL will use the adult headform. Where the BRRL is rearward of WAD 1700mm, the child/small adult headform shall be used up to and including WAD 1700mm.
- 3.6.10 Where the BRRL is between and area rearward of WAD 1500mm up to an including WAD 1700mm, the zone is determined by the designated impactor detailed in Section 3.6.9.

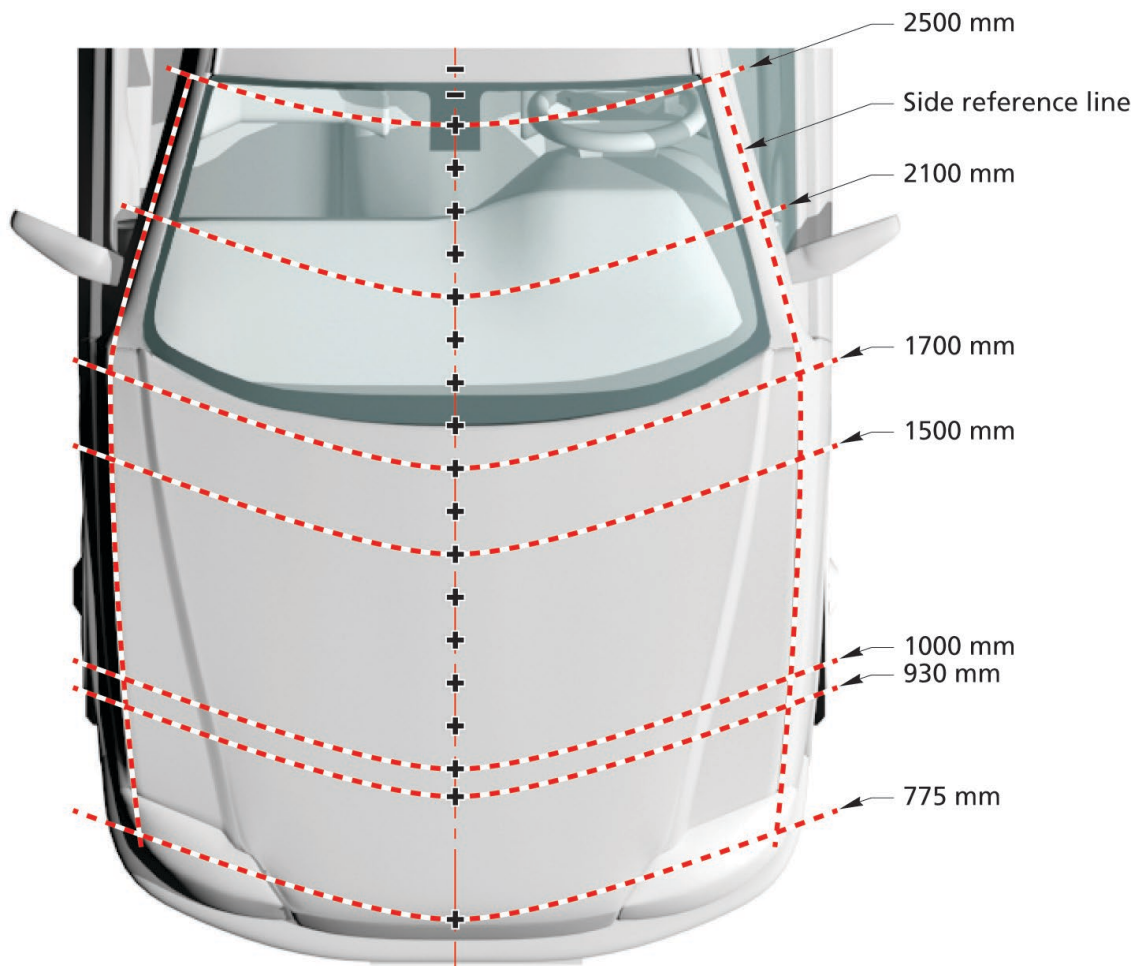


Figure 10: Headform test area



### 3.7 Corner Reference Point

The Corner Reference Point is defined as the intersection of the Bonnet Leading Edge reference line (Section 3.3) and the Bonnet Side reference line (Section 3.2), see Figure 11. Where multiple or continuous contacts occur the most outboard contact shall form the corner reference point.

- 3.7.1 The corner reference point shall be transferred forwards onto the WAD 775mm at the same distance from the vehicle centreline.
- 3.7.2 In case of the corner reference point being located rearwards the WAD 1000mm, a line connecting the corner reference point and its forward projection onto the WAD 1000mm at the same distance from the vehicle centreline shall replace the section of the side reference line which is located forwards the corner reference point.

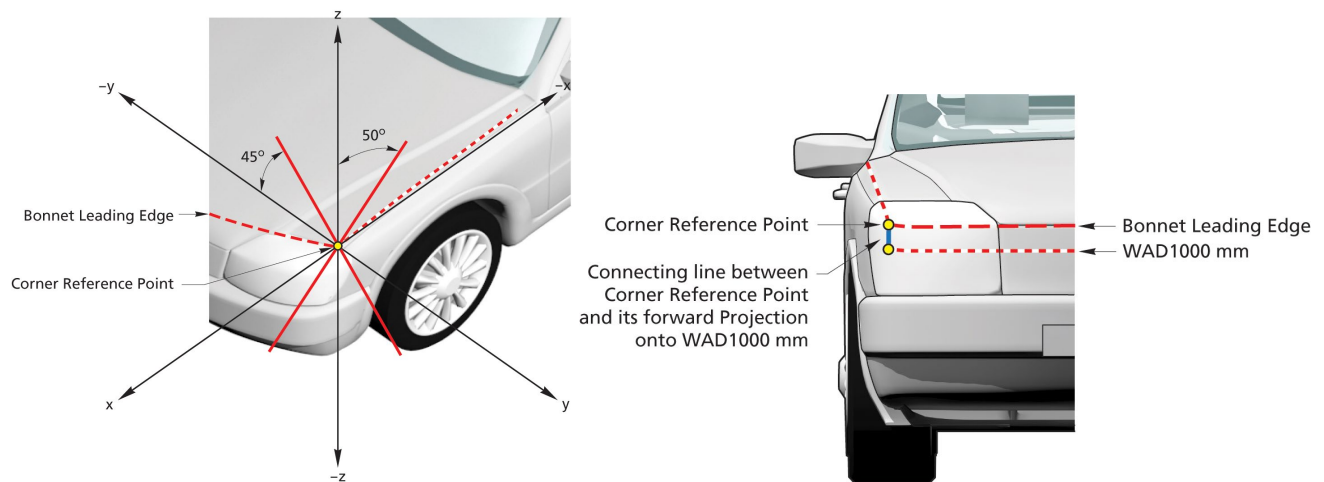


Figure 11: Determination of the corner reference point

### 3.8 Bumper Reference Lines

For vehicles with an identifiable bumper structure the upper Bumper Reference Line is defined as the geometric trace of the upper most points of contact between a straight edge and the bumper, when the straight edge, held parallel to the vertical longitudinal plane of the car and inclined rearwards by 20 degrees, is traversed across the front of the car whilst maintaining contact with the upper edge of the bumper. For a vehicle with no identifiable bumper structure it is defined as the geometric trace of the upper most points of contact between a straight edge 700 mm long and the bumper, when the straight edge, held parallel to the vertical longitudinal plane of the car and inclined rearwards by 20 degrees, is traversed across the front of the car, whilst maintaining contact with the ground and the surface of the bumper. See Figure 12.

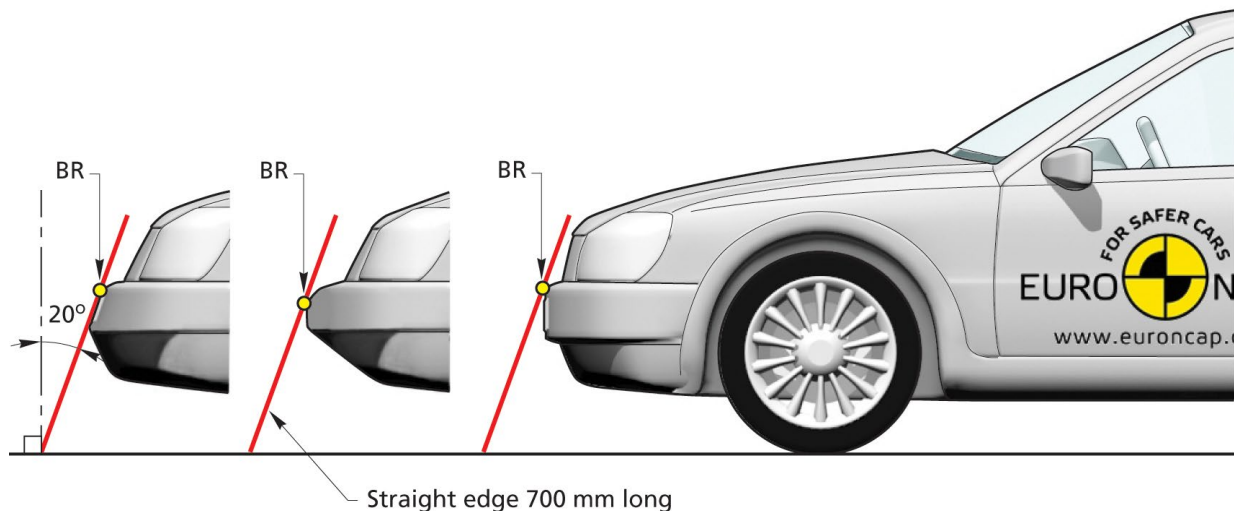


Figure 12: Determination of upper bumper reference line

- 3.8.1 With a 700mm straight edge fixed at 20° to the vertical and in a plane parallel to the vertical longitudinal plane of the car, position the straight edge at one end of, and in contact with, the bumper and the ground. The straight edge may be shortened to avoid contact with structures above the bumper, the straight edge may also be lengthened to reach the bumper.
- 3.8.2 Mark the uppermost point of contact of the straight edge and bumper.
- 3.8.3 Pull the straight edge away from the bumper, move it towards the other end of the bumper by not more than 100mm and then into contact with the bumper.
- 3.8.4 Mark the uppermost point of contact of the straight edge and bumper.
- 3.8.5 Repeat Sections 3.8.3 and 3.8.4 along the whole of the length of the bumper.
- 3.8.6 Using a flexible rule, join the marks on the bumper to form a line. This line may not be continuous but may 'jump' around the licence plate area etc. This line is the Upper Bumper Reference Line (UBRL).

- 3.8.7 The Lower Bumper Reference Line (LBRL) also needs to be marked on the vehicle. This line identifies the lower limit to significant points of pedestrian contact with the bumper. It is defined as the geometric trace of the lower most points of contact between a straight edge 700mm long and the bumper, when the straight edge, held parallel to the vertical longitudinal plane of the car and inclined forwards by 25°. It is traversed across the front of the car, while maintaining contact with the ground and with the surface of the bumper; see Figure 13.
- 3.8.8 Proceed as per Sections 3.8.2 to 3.8.6 this line is the Lower Bumper Reference Line.

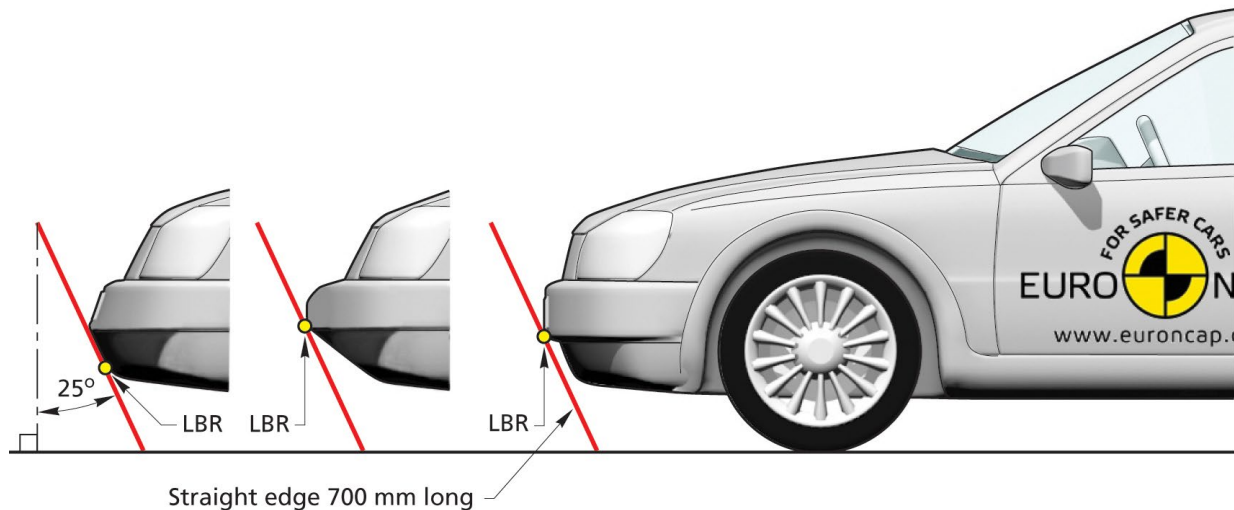


Figure 13: Determination of the Lower Bumper Reference Line

### 3.9 Bumper Corners, Bumper Test Zone and Internal Bumper Reference Line

The Corner of Bumper is the point of contact of the vehicle with a vertical plane which makes an angle of 60° with the vertical longitudinal plane of the car and is tangential to the outer surface of the bumper, see Figure 14. Where multiple or continuous contacts occur the most outboard contact shall form the bumper corner.

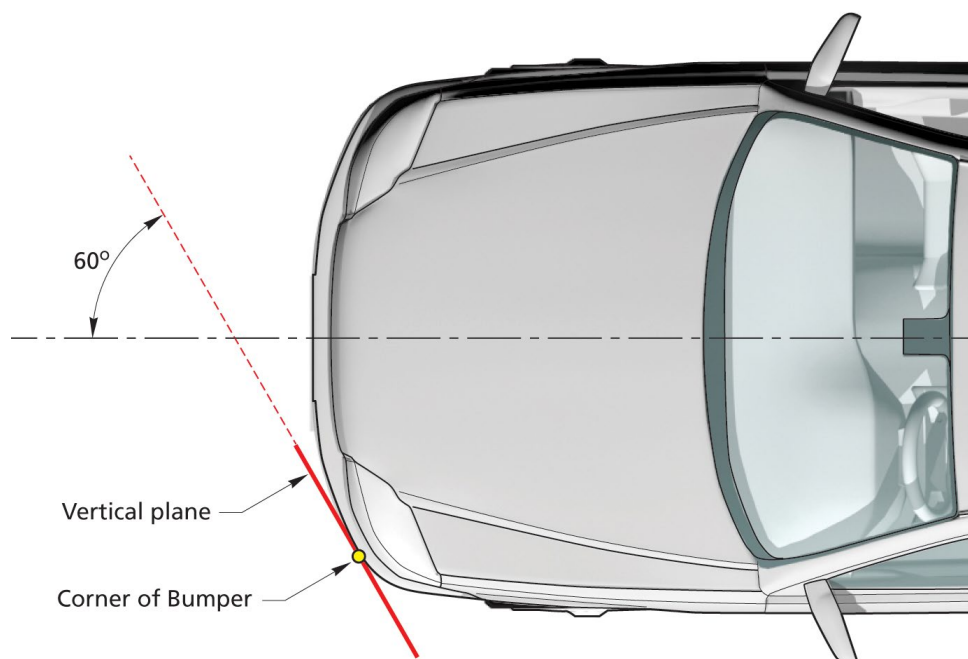


Figure 14: Determination of bumper corner

- 3.9.1 Fix a 700mm straight edge at 60° to the longitudinal direction of the car. With this edge horizontal move it into contact with the most forward part of the bumper.
- 3.9.2 Mark the point of contact between the straight edge and the bumper. This is the Bumper Corner.
- 3.9.3 If the bumper is angled at essentially 60°, so that the straight edge makes a continuous contact or multiple contacts rather than a point contact, the outermost point of contact shall be the Bumper Corner.
- 3.9.4 Repeat for the other side of the vehicle.
- 3.9.5 Mark a line across the bumper face at a vertical height of 520mm above ground reference level.
- 3.9.6 Remove the plastic bumper cover and any associated components such as padding and energy absorbers.
- 3.9.7 Identify the outermost ends of the bumper beam/lower rails/cross beam structures.
- 3.9.8 The bumper test zone is defined as either the area limited by the bumper corners or the outermost ends of the bumper beam/lower rails/cross beam structures, whichever is larger.
- 3.9.9 Record the distance from the vehicle centreline to the end of the bumper test zone.
- 3.9.10 To mark the internal bumper reference line (IBRL):
- 3.9.11 Measure the height of the bumper from a vertical plane contacting the beam up to 10mm into the profile to get the internal bumper reference line height at 100mm intervals outboard of the vehicle centreline. See Figure 15: Marking IBRL height.

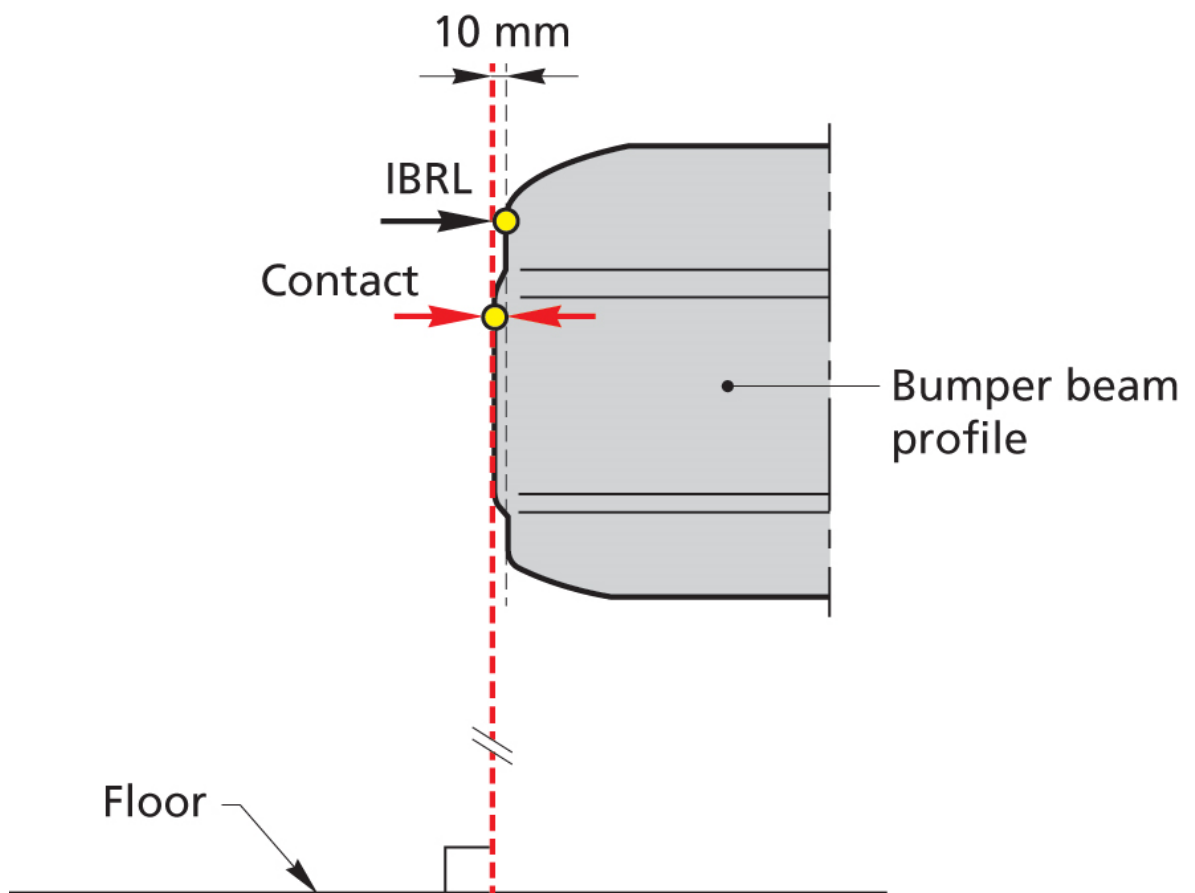
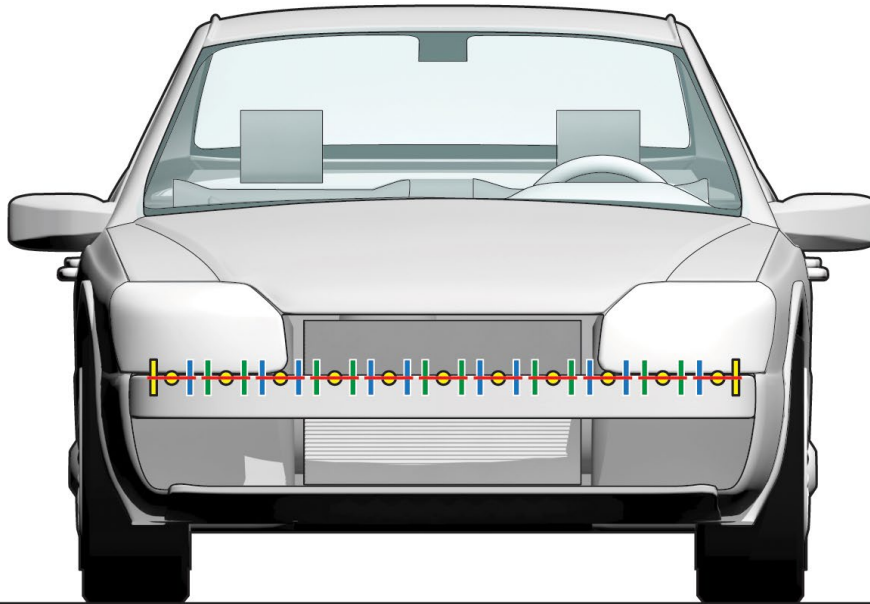


Figure 15: Marking IBRL height

- 3.9.12 A bumper beam will be deemed structural for determination of the IBRL where the minimum thickness is  $\geq 1\text{mm}$  for steel and  $\geq 2\text{mm}$  for aluminium.

- 3.9.13 For every upper legform grid point outboard of the bumper beam, use the average bumper beam height allocated to the outermost grid point on the bumper beam as defined in 3.9.14.
- 3.9.14 Divide the area between each 100mm mark into three areas of equal width. If the bumper beam extends by 33.3mm or more outboard of the outermost 100mm grid point, mark the distance of 33.3mm on the bumper beam. Take the average height of each 100mm mark and the adjacent two marks. The height at each 100mm interval is the average height of the 100mm mark and adjacent divisions, see Figure 16. If the end of the bumper beam is less than 33.3mm outboard of the outermost grid point, the average height is taken from the height of the grid point and the inboard adjacent mark only.



- |                   |                          |
|-------------------|--------------------------|
| ● Grid point      | — Average IBRL height    |
| Adjacent markings | Edge of bumper test zone |

Figure 16: IBRL height at 100mm intervals

- 3.9.15 Replace the bumper components and mark both outermost ends of the bumper beam/lower rails/cross beam structures.
- 3.9.16 Transfer the averaged height of the beam calculated at each 100mm interval on the bumper beam onto the external bumper face.
- 3.9.17 The internal bumper reference line is then constructed using the heights marked on the bumper face in 3.9.16 up to a maximum height above ground reference level of 520mm. Where there are locations above 520mm, the internal reference line will be limited to no more than 520mm above ground reference level for those locations.

### 3.10 Marking Headform Impact Area Grid Points

- 3.10.1 Mark the longitudinal centreline of the vehicle on the bumper/grille, bonnet top, windscreen and roof.
- 3.10.2 Mark Wrap Around Distances (not lines) on the centreline only at 100mm intervals. Start from Wrap Around Distance 1000mm and end at Wrap Around Distance 2500mm. For vehicles with a V-shaped front end it may also be necessary to mark additional Wrap Around Distances of 2600mm, 2700mm, etc. See Figure 17.
- 3.10.3 Starting at one of the wrap around distance marks at the centreline, mark grid points every 100mm in both lateral directions up to the side reference lines. The 100mm distances are measured horizontally in a lateral vertical plane through the respective centreline mark and projected vertically onto the vehicle surface. Where a vehicle has the WAD 1000 mark on the vehicle centreline forward of the Bonnet Leading Edge Reference Line and having the forward angle being more than  $60^\circ$  to the ground reference level the distances are projected horizontally onto the vehicle surface. The forward angle is defined as the angle to the ground reference level, of a straight line connecting the WAD 1000 mark on the centreline with the intersection point of the Bonnet Leading Edge Reference Line and the centreline. The angle designated by the manufacturer may be deemed as the forward angle if it deviates within  $\pm 2^\circ$  from the actual measurement. If due to the horizontal projection two grid points have a distance of less than 50 mm to each other, the horizontal projected grid point will be deleted. The distance shall be measured with a tautly held flexible tape.
- 3.10.4 Repeat step 3.10.3 for every wrap around distance on the vehicle centreline until the entire headform impact area is marked with grid points. Depending on the shape of the vehicle, (e.g. V-shaped vehicle front end) it may be necessary to also use the wrap around distance points at 2600mm, 2700mm, etc. See Figure 17.
- 3.10.5 For A-pillars only, mark an additional grid point at the intersection of the lateral vertical plane and the side reference line for each wrap around distance.

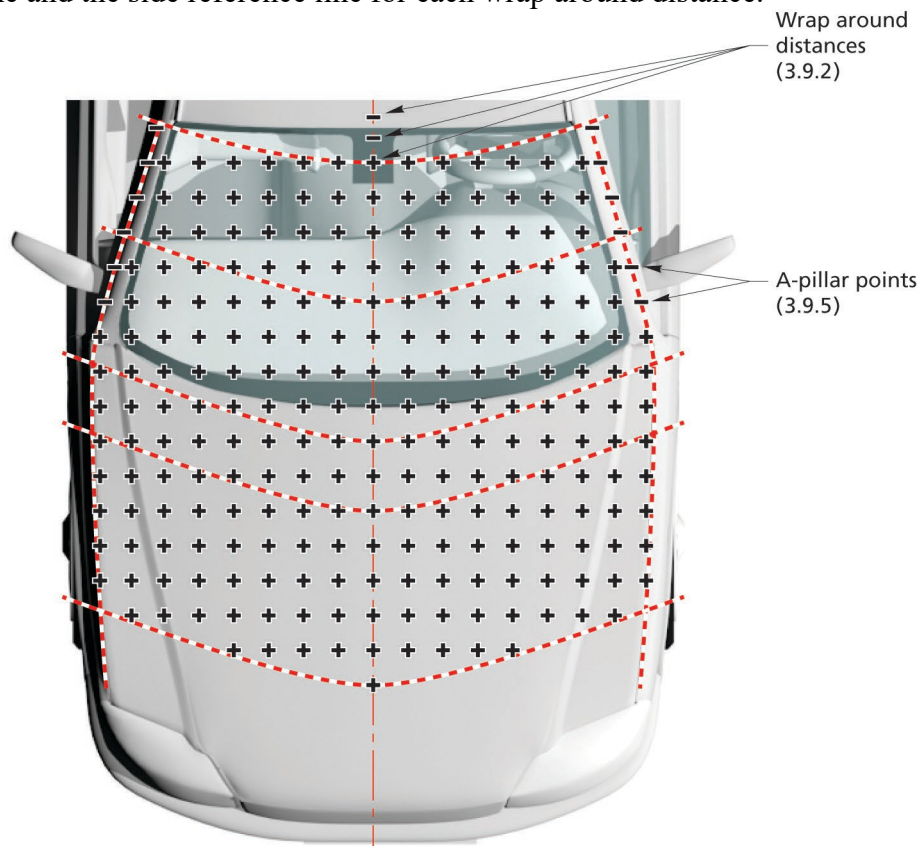


Figure 17: Grid points



- 3.10.6 Where any of the grid points lie underneath the outer contour of the vehicle, for example in the gap behind the bonnet, approximate the outer contour of the vehicle horizontally rearward from the last point of contact by using an adhesive tape. Mark the grid point on the tape to replace the underlying grid point. See Figure 18.
- 3.10.7 Where a wiper obstructs the placement of the tape, the wiper shall be ignored during tape placement unless the grid point falls on the wiper itself.

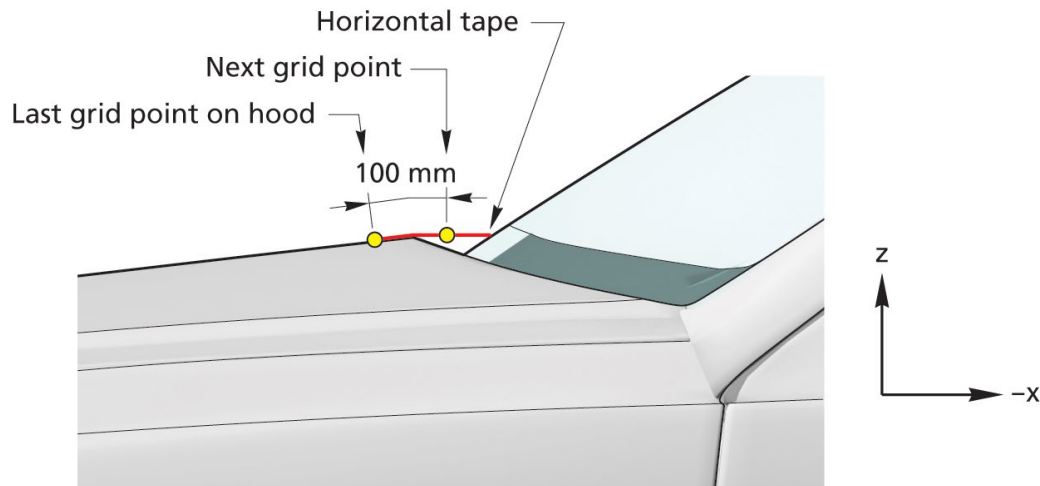


Figure 18: Grid points beneath outer contour (example at vehicle centreline)

- 3.10.8 Remove those grid points that have a distance, measured in the lateral Y axis, of less than 50mm to the side reference lines, excluding those points which are on A-pillar side reference line. See Figure 19.
- 3.10.9 The remaining grid points are used for the assessment of the vehicle. For impact testing, these grid points are the aiming points.
- 3.10.10 Where the vehicle is equipped with an active system, the aiming points will always be considered in the undeployed state.

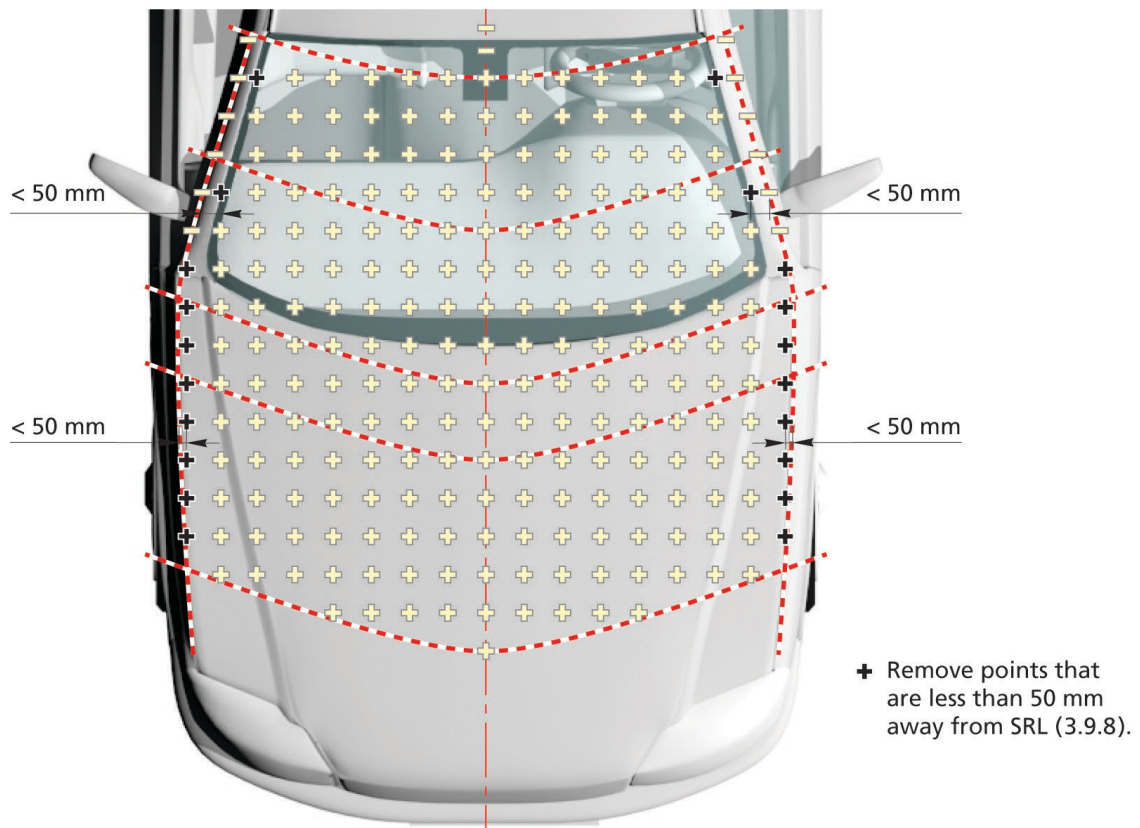


Figure 19: Deleting grid points



### 3.11 Identification of the Headform Grid Points

- 3.11.1 All child/small adult grid points will contain the prefix 'C'. All adult grid points will contain the prefix 'A'. All (bi)cyclist grid points will contain the prefix 'B'.
- 3.11.2 The child/small adult zone is defined as all grid points on WAD 1000mm up to and including WAD 1500mm.
- 3.11.3 The adult zone is defined as all grid points rearward of WAD 1700mm up to and including WAD 2100mm.
- 3.11.4 The cyclist zone is defined as all grid points rearward of WAD 2100mm up to and including WAD 2500mm. See Figure 20.

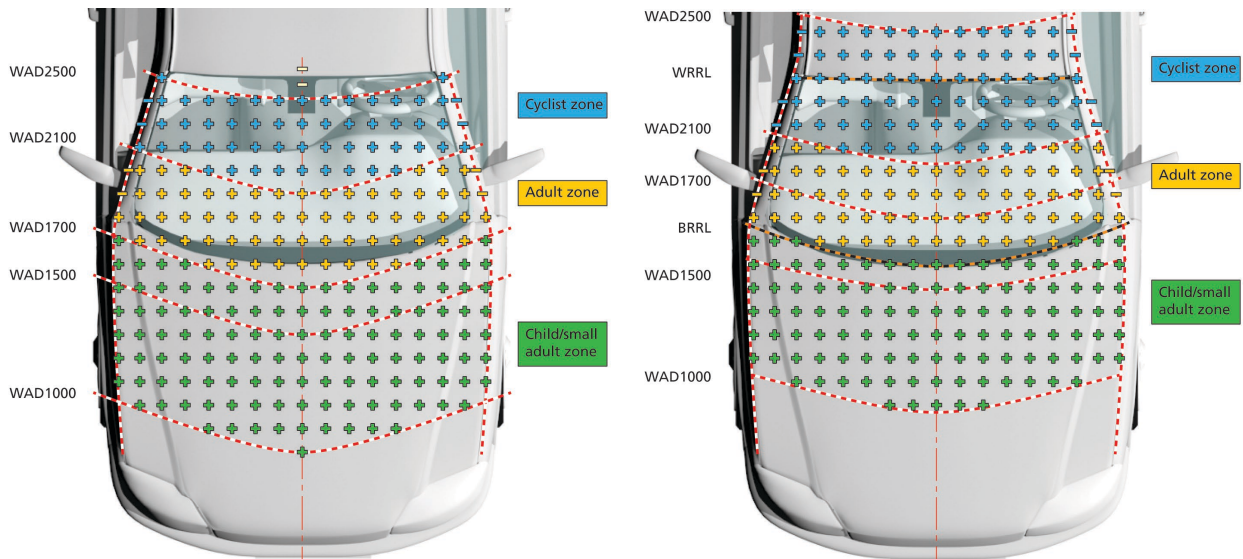


Figure 20 Identification of VRU headform zones

- 3.11.5 The grid point will be identified by means of a row and column system. The origin will be at the grid point on the vehicle centreline and the 1000mm WAD. This point is C0,0.
- 3.11.6 The rows at the origin will be row 0, the subsequent rows will be marked in increasing increments of 1 up to the rearmost row.
- 3.11.7 The column on the centreline will be column 0, the adjacent column on the right of the vehicle, as shown below, will be column +1, with the other columns increasing by 1 toward the SRL, i.e. +2, +3, ....+8. The column on the left of the vehicle will be column -1 with the other columns decreasing by 1 toward the SRL, i.e. -2, -3, ....-8.
- 3.11.8 Every point will be identified firstly by the relevant headform impactor (A or C), then by the row, then by the column. See Figure 21.

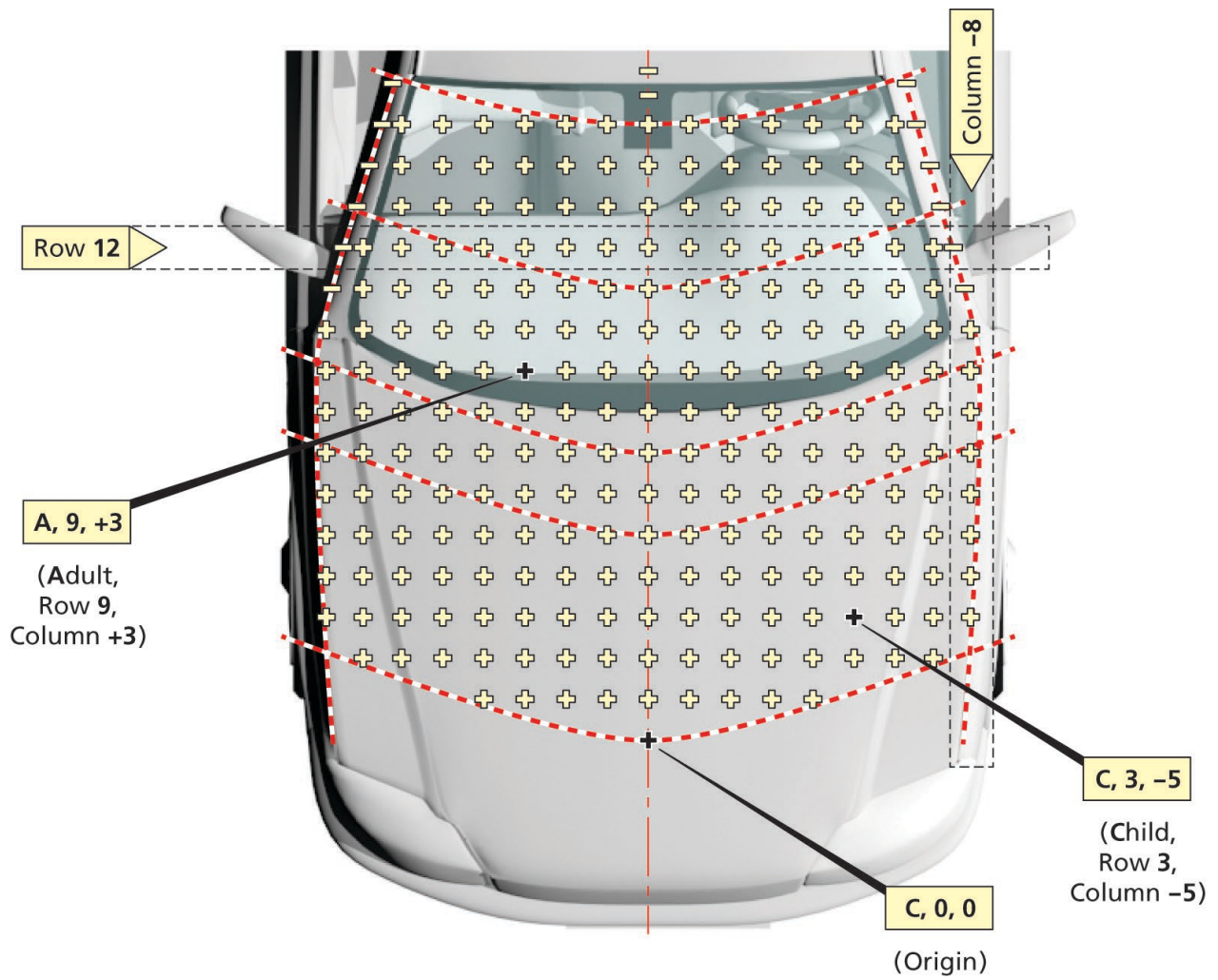


Figure 21 Labelling of the headform grid points

### 3.12 Marking Upper Legform to WAD775mm Grid Points

- 3.12.1 Starting at the intersection of the vehicle centreline and WAD775mm, mark grid points every 100mm in both lateral directions along the WAD775 up to the corner reference points, which have been projected fore/aft onto the WAD775mm. The 100mm distances are measured horizontally in a lateral vertical plane and projected onto the WAD775mm. See Figure 22.
- 3.12.2 Grid points less than 50mm from the corner reference point shall be deleted.

### 3.13 Marking Legform Grid Points

- 3.13.1 Starting at the intersection of the vehicle centreline and upper bumper reference line, mark grid points every 100mm in both lateral directions up to the edge of the bumper test zone. The 100mm distances are measured horizontally in a lateral vertical plane and projected onto the upper bumper reference line. See Figure 22.
- 3.13.2 Where the edge of the bumper test zone is more than 50mm outboard of the outermost grid point, an additional point will be added 50mm outboard of the last grid point. The distances are measured horizontally in a lateral vertical plane.

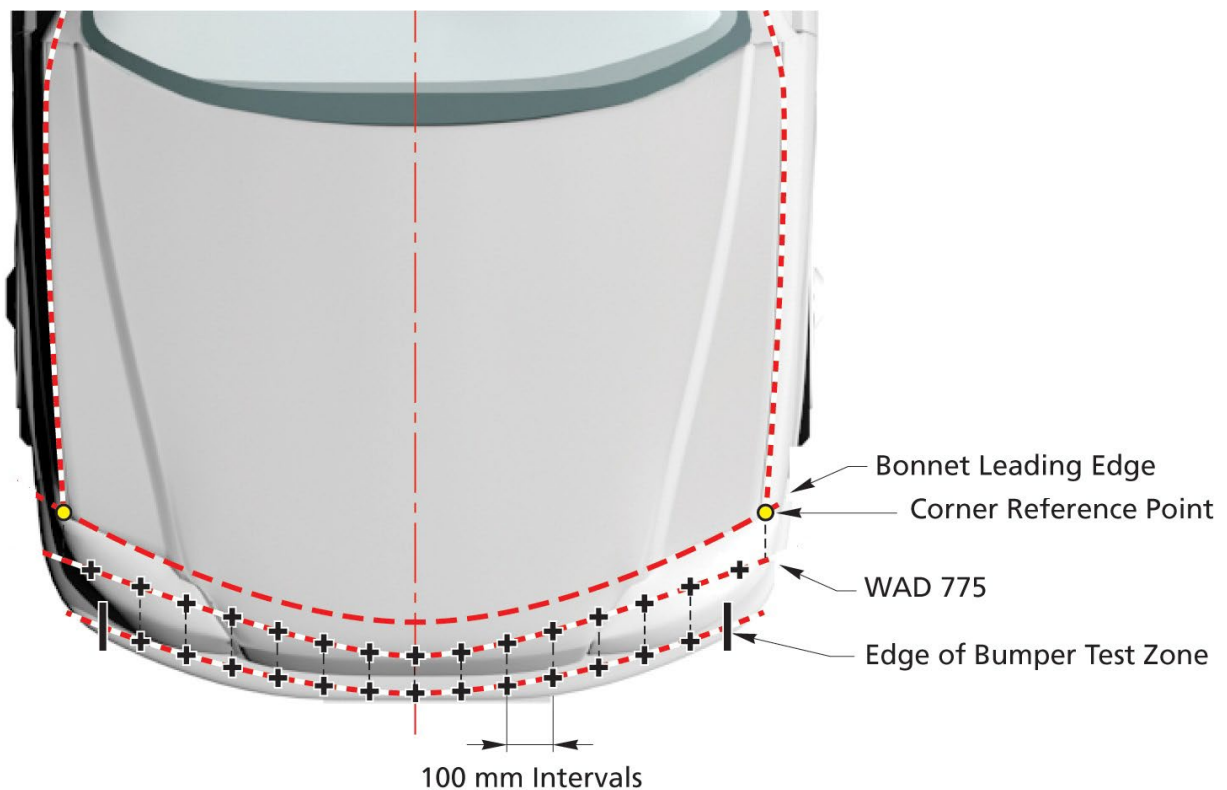


Figure 22: Division of the WAD775 and upper bumper reference lines

### 3.14 Labelling the Upper Legform and Legform Grid Points

- 3.14.1 All upper legform grid points will contain the prefix 'U'. All legform points will contain the prefix 'L'.
- 3.14.2 The grid points will be marked sequentially from the origin at the grid points on the vehicle centreline. For the upper legform, the origin will be marked U0. For the legform the origin will be marked L0.
- 3.14.3 The adjacent points on the right of the vehicle will be +1, with the other points increasing by 1 with outboard movement, i.e. +2, +3 etc. The points on the left of the vehicle -1 with the other columns decreasing by 1 i.e. -2, -3 etc.
- 3.14.4 Every point will be labelled firstly by the relevant impactor (U or L), then by the individual number. See Figure 23.

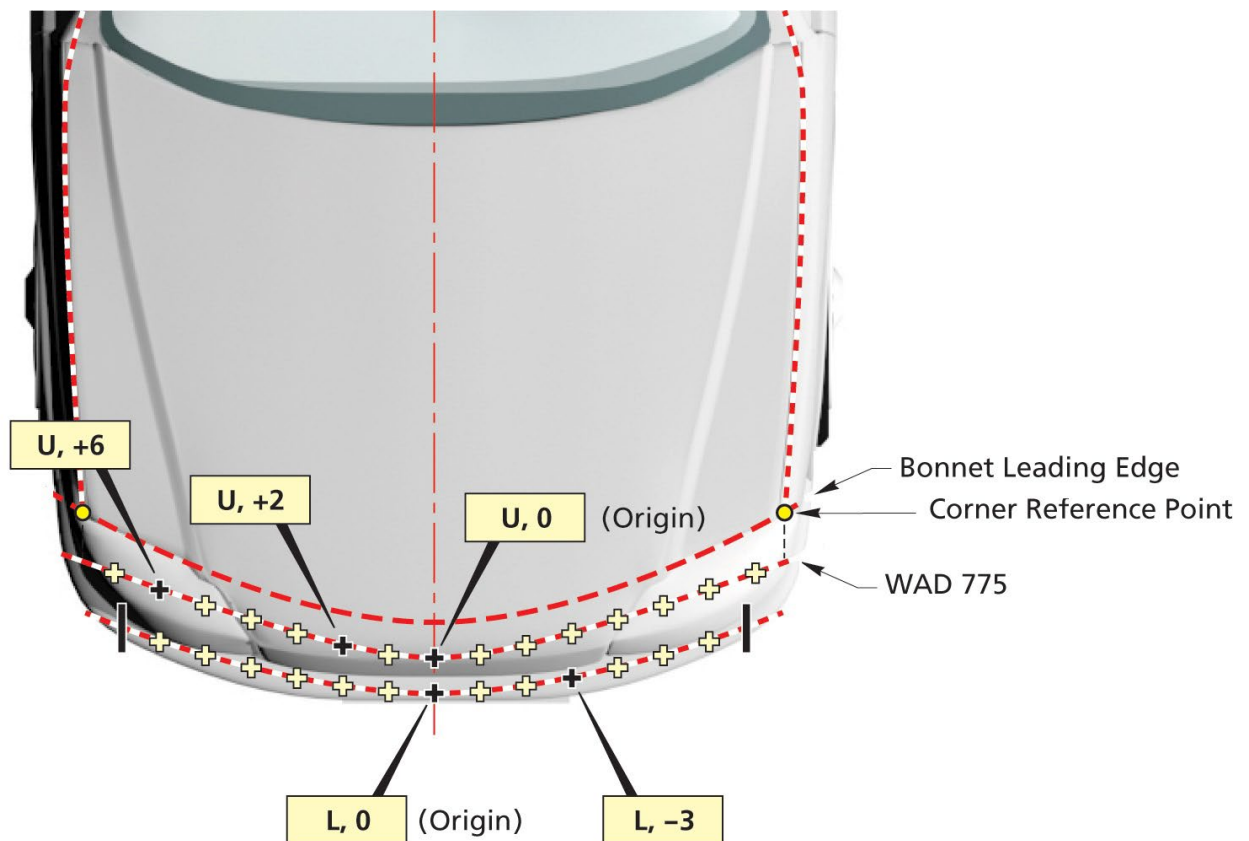


Figure 23: Labelling the Upper Legform and Legform grid points

## 4 Headform DATA

### 4.1 Manufacturer Supplied Data

- 4.1.1 The vehicle manufacturer is required to provide the Euro NCAP Secretariat with HIC<sub>15</sub> or colour data detailing the protection offered by the vehicle at all headform grid locations.
- 4.1.2 All data must be supplied by the manufacturer before any vehicle marking or testing begins, preferably with delivery of the test vehicle(s).
- 4.1.3 For the headform area, data shall be provided for each grid point according to the following performance criteria:

$HIC_{15} < 650$	= Green
$650 \leq HIC_{15} < 1000$	= Yellow
$1000 \leq HIC_{15} < 1350$	= Orange
$1350 \leq HIC_{15} < 1700$	= Brown
$1700 \leq HIC_{15}$	= Red

- 4.1.4 Some grid points shall have a default red rating awarded to them. These shall be clearly identified as defaulted in the predicted data. The only areas to be defaulted red are as follows:
- A-pillars
  - Roof
- 4.1.5 Where the vehicle manufacturer can provide evidence that shows either an A-pillar or the roof is not red, those grid points will be considered in the same way as other points.
- 4.1.6 Grid points on the side reference line that are rearward of the bonnet rear reference line will be deemed as grid points on the A-pillars.
- 4.1.7 Grid points on the windscreen glazing that are predicted green will be excluded from point selection providing that:
- The green grid point is completely surrounded by predicted green grid points.
  - The green grid point is more than 165mm from the solid strip around the periphery of the windscreen mounting frame. The 165mm shall be measured along the outer contour of the windscreen, see Figure 24.
  - There are no underlying structures.
- 4.1.8 Where there are any structures mounted directly behind the windscreen, such as cameras and/or sensor systems, the overlying grid points shall be included for point selection.
- 4.1.9 Grid points on the windscreen that are within 100mm of ANY underlying structures in the windscreen base area, measured from the grid point in the impact direction of the relevant headform shall also be included for point selection.
- 4.1.10 Defaulted locations are not included in the random selection of verification tests, see Section 5, and the correction factor calculation.
- 4.1.11 Before test points are selected, default red locations and excluded green points will be confirmed by the laboratory.

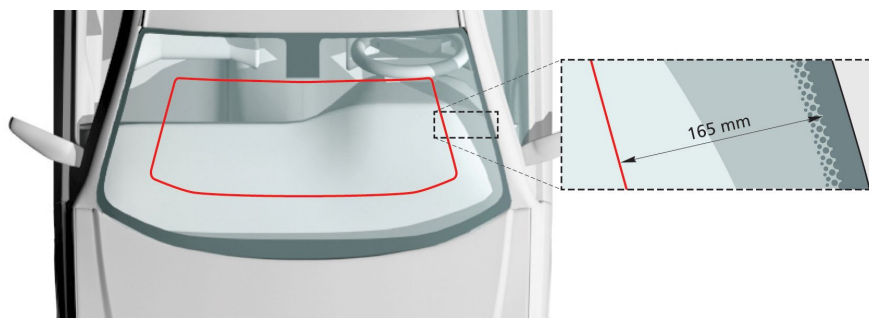


Figure 24: Windscreen periphery measurement

## **4.2 Unpredictable Grid Locations**

- 4.2.1 Where certain structures are such that the protection offered by particular grid points is unpredictable, those grid points may be coloured blue in the predicted data.
- 4.2.2 Those areas of the vehicle that may contain blue grid points are limited to the following structures:
- Plastic scuttle
  - Windscreen wiper arms and windscreen base
  - Headlamp glazing
  - Break-away structures
- 4.2.3 Where blue points are identified, the vehicle manufacturer must provide test results and/or CAE modelling as justification to show the unpredictable performance of the location(s).
- 4.2.4 Blue points, either singly or grouped together in pairs, will form a blue zone.
- 4.2.5 Where there are two grid points in a zone they must be adjacent (longitudinally, laterally and diagonally) to each other. A maximum of eight zones may be blue over the entire headform impact area.
- 4.2.6 The laboratory will choose one blue point to assess each zone. Symmetry may be applied.
- 4.2.7 The test results of blue points will be applied to the grid point(s) in each zone. The colour of each tested blue point will be changed from blue to the colour corresponding to the HIC15 measured.
- 4.2.8 Blue point tests will not be used in the random selection of verification tests, see Section 5, and the correction factor calculation.

## **4.3 Absence of Manufacturer Data**

- 4.3.1 Where predicted data is NOT provided by the vehicle manufacturer, the vehicle sponsor may choose for ALL grid points to be tested by the Euro NCAP laboratory.
- 4.3.2 Alternatively, test points will be selected on a worst case performance basis.
- 4.3.3 The bonnet marking and point selection for all impactors will follow that outlined in the Euro NCAP Pedestrian Testing Protocol version 5.3.1, November 2011.
- 4.3.4 The latest impactors will be used which are specified in Section 11.
- 4.3.5 The latest performance criteria (HIC650-1700) will be applied; details of the criteria are contained in the assessment protocol.



## 5 HEADFORM VERIFICATION TESTS

### 5.1 Verification Tests

- 5.1.1 The vehicle sponsor will fund 10 verification tests in the headform area.
- 5.1.2 The vehicle manufacturer has the option of sponsoring up to 10 additional headform verification tests. These are in addition to any blue points and those funded by the sponsor. Where this is the case, the vehicle manufacturer must inform Euro NCAP of the number of tests when predicted data is provided.
- 5.1.3 The location of all verification tests will be selected at the same time and at random by the Euro NCAP Secretariat regardless of the test sponsor.
- 5.1.4 At least one of the verification tests shall always be a green point on the excluded glazed area that is in accordance with Section 4.1.7.
- 5.1.5 Only those grid points on defaulted red, excluded green (noting the exception above) positions or those coloured blue will be excluded from the randomly selected points. All other grid points are eligible for selection.
- 5.1.6 There is no restriction as to the location of the randomly selected tests. Tests to adjacent impact locations are acceptable provided that permanent vehicle damage would not influence other test results.
- 5.1.7 Where damage from already tested grid points affects other verification tests, the Secretariat will be informed and will take a decision on how to proceed.
- 5.1.8 The results of all verification tests will be used in the calculation of a correction factor.

### 5.2 Headform Tests

- 5.2.1 The selected grid point shall be treated as the aiming point for the headform impactor, with deployable system in the undeployed position.
- 5.2.2 The centreline of the headform impactor shall be directly in the line of flight toward the aiming point. See Figure 25.

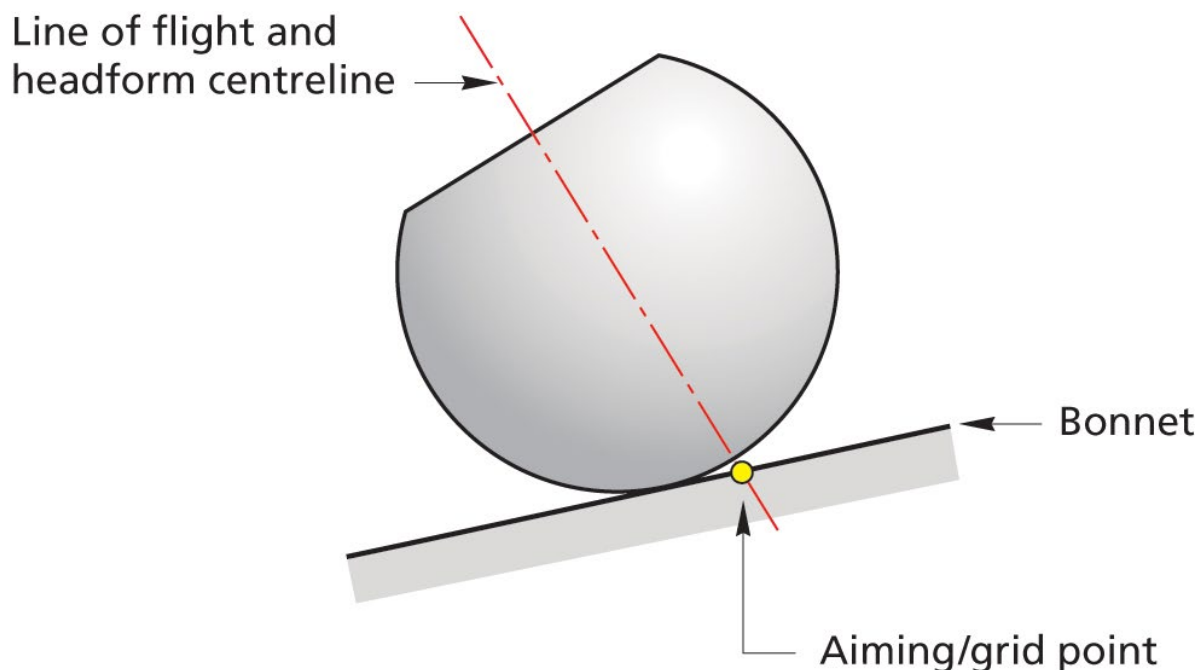


Figure 25: Aiming point

- 5.2.3 The effect of gravity shall be considered when positioning the propulsion system for test. Under the influence of gravity the headform will deviate from the trajectory it has initially when leaving the propulsion system.
- 5.2.4 Gravity must be taken into account in order to establish the correct trajectory for the headform. The determination of where to position the firing mechanism will require the following information:
- Headform diameter
  - Distance that the headform must travel after leaving the propulsion system
  - Required angle of impact to horizontal
  - Angle of the bonnet top at the point of impact
  - Required impact velocity
- 5.2.5 Using the above information calculate the distance from the aiming point to ensure that the required correct trajectory is established. The angle to which the propulsion system should be set and the velocity that the propulsion system must give to achieve the required velocity at impact and the required angle of incidence at impact must also be calculated.

### **5.3 Testing Glazed Points**

- 5.3.1 Where a test point to a glazed area results in a colour change of three or more boundaries, the Secretariat will allow the vehicle manufacturer to sponsor two retests in that location (assessment years 2023 & 2024 only).
- 5.3.2 Results to glazed points that were not predicted green may not be retested.
- 5.3.3 The results of the re-tests will only be accepted where atypical performance has been demonstrated and is supported by all of the following data:
- Physical and/or CAE test data, from at least three impacts to the same test location
  - All acceleration traces (x, y, z, resultant) must be provided
  - Details of headform instrumentation used
  - High speed film for physical test or animation for CAE data
- 5.3.4 Where the three results are all a different colour the original test result shall be applied to that grid location. Where any two results are of the same colour, that colour shall be applied to the grid location.
- 5.3.5 Euro NCAP will consider adoption of an improved definition for atypical behaviour on glazing tests should one become available.



## **6 DETERMINATION OF UPPER LEGFORM AND LEGFORM IMPACT POINTS**

### **6.1 Legform to Bumper Tests**

- 6.1.1 The legform to bumper tests will be conducted to selected grid locations within the test zone defined in Section 3.9.
- 6.1.2 The vehicle manufacturer must identify any asymmetrical grid points before the start location is selected and any nominations are made.
- 6.1.3 The Euro NCAP Secretariat will select one of the locations L0 or L1 for testing; additional tests will then be performed to every second grid point outboard of this point.
- 6.1.4 Symmetry is applied across the vehicle. Tests can be made on both sides of the vehicle. For each pair of symmetrical grid points the laboratory chooses the point to be physically tested.
- 6.1.5 Grid points that have not been tested will be awarded the worst result from one of the adjacent points.
- 6.1.6 Where the vehicle manufacturer believes that the performance of an unselected point will not be reflected correctly or symmetry does not apply, they may choose to sponsor additional tests to any of these points. Nominations must be made for both possible starting points and before the first point to test is chosen as detailed in Section 6.1.3.

### **6.2 Upper Legform to WAD775mm Tests**

- 6.2.1 A test is not required if the calculated impact energy would be less than 160J.
- 6.2.2 The vehicle manufacturer must identify any asymmetrical grid points before the start location is selected and any nominations are made.
- 6.2.3 The Euro NCAP Secretariat will select one of the locations U0 or U1 for testing; additional tests will then be performed to every second grid point outboard of this point.
- 6.2.4 Symmetry is applied across the vehicle. Tests can be made on both sides of the vehicle. For each pair of symmetrical grid points the laboratory chooses the point to be actually tested.
- 6.2.5 Grid points that have not been tested will be awarded the worst result from one of the adjacent points.
- 6.2.6 Where a point is to be awarded a symmetrical or adjacent result, there must be no more than a 10% difference in the calculated impact energy between the two points. Where the energy differs by more than 10%, a test is required.
- 6.2.7 Where the vehicle manufacturer believes that the performance of a non selected point will not be reflected correctly or symmetry does not apply, they may choose to sponsor additional tests to any of these points. Nominations must be made for both possible starting points and before the first point to test is chosen as detailed in Section 6.1.2.

## **7 RECORDING THE IMPACT POINT LOCATIONS**

### **7.1 General**

- 7.1.1 A three dimensional measuring system with an accuracy of  $\pm 0.5\text{mm}$  shall be used to record the grid origin and the points chosen for test. For all impact locations, record the position of the selected impact points.
- 7.1.2 Care should be taken at all times not to move the vehicle while the impact points are being recorded or transferred.

### **7.2 Measuring Impact Points**

- 7.2.1 Ensure that the vehicle is at its test weight and fully test prepared as defined in Section 1.
- 7.2.2 Measure the ride heights at all four wheels using the marks defined in Section 1.3.4. Record the ride heights in the test details.
- 7.2.3 During digitising, care should be taken not to move the vehicle by, for example, leaning on it.
- 7.2.4 The co-ordinates of all impact locations should be digitised with the 3D arm.
- 7.2.5 A hard copy of the impact points co-ordinates should be obtained for reference.
- 7.2.6 After digitisation, the bonnet top and bumper featuring all the impact points shall be removed and replacements fitted. See Section 8.3 for fitting procedures.
- 7.2.7 The original bonnet and bumper shall be kept for reference and will be replaced on the vehicle once testing is complete.

### **7.3 Transferring Impact Points to Replacement Vehicle Parts**

- 7.3.1 Replacement parts will need to be fitted to the vehicle for the series of tests. It is not practical to have to mark out each of the parts completely for a single test. Therefore, the original marked-out bonnet will be retained as a reference and individual impact locations transferred to replacement components.
- 7.3.2 With the new component(s) fitted, measure the ride heights at all four wheels.
- 7.3.3 These ride heights must be altered until they match the original recorded ride heights measured in Section 1.3. If the ride heights are too high then they can be reduced by adding weights. If the ride heights are too low then they can be increased by removing weight from the vehicle and/or inserting blocks under the body of the vehicle. The additional weights and/or blocks shall be removed before testing.
- 7.3.4 Set up the 3D measuring system.
- 7.3.5 Using the co-ordinates recorded in Section 7.2 for the original impact points, locate and mark the desired impact point on the new component.

## 8 PERFORMING OF PEDESTRIAN IMPACT TESTS

### 8.1 General

- 8.1.1 Safety to personnel shall be a priority at all times
- 8.1.2 Ensure that all equipment used is in full working order, has been checked for safety and is in calibration where appropriate

### 8.2 Propulsion System

- 8.2.1 An air, spring, electric or hydraulic gun may be used to propel the various body form impactors.
- 8.2.2 For the legform and the headform tests the impactors are required to be in free flight at the time of impact.

### 8.3 Fitting Replacement Parts to Vehicles

- 8.3.1 Careful note shall be taken before any testing is performed as to how any parts liable to need replacement are fitted to the vehicle structure.
- 8.3.2 Fitting of parts shall not increase or decrease the strength of the structure of the vehicle.
- 8.3.3 If significant repair work is required, this will be done at a manufacturer-approved dealer.

### 8.4 Photographic Record

- 8.4.1 A photographic record shall be kept of each test.
- 8.4.2 Before any testing has been conducted but after the vehicle is fully test prepared including all markings, the vehicle shall be photographed according to the following schedule. Note that these shall be the only pre-test photographs taken.

- 8.4.3 List of still photographs

<u>Amount of vehicle visible</u>	<u>View Point</u>
Full vehicle	Left side
Full vehicle	Right side
Front third vehicle	Left side
Front third vehicle	Right side
Full vehicle	Front
Left half vehicle	Front
Right half vehicle	Front
Front third of vehicle	Top
Front third, right half of vehicle	Top
Front third, left half of vehicle	Top
Legform test points	Front
Upper legform test points	Front
Child head zone test points	Top
Adult head zone test points	Top

- 8.4.4 Post-test photographs are detailed for each test type in the individual test procedures.

## 8.5 Testing Active Systems

### 8.5.1 Static pedestrian tests

8.5.1.1 Static pedestrian tests will be performed in the normal way and according to the usual tolerances.

### 8.5.2 Dynamic pedestrian tests

8.5.2.1 Where dynamic tests are required, only a lateral impact tolerance of  $\pm 10\text{mm}$  will be required. The headform shall be aimed at the grid point, the subsequent impact location on the vehicle will then be determined by the timing of the system deployment relative to the propulsion of the headform.

8.5.2.2 The vehicle manufacturer will be required to provide Euro NCAP with data from numerical simulations performed with the bonnet in the undeployed position. Simulations are to be conducted with a vehicle speed of  $40\text{km/h}$  with all pedestrian statures that result in head contact to bonnet. Pedestrian models should be selected from the following statures, a 6 year old, 5th percentile female, 50th percentile male and 95th percentile male. The pedestrian position and stance to be used in the model is defined in Technical Bulletin TB 024.

8.5.2.3 From the simulations both head impact time (HIT as defined in TB 024) and the wrap around distance should be recorded.

8.5.2.4 A graph shall be plotted with a best fit straight line as shown in Figure 26. When a test point is selected, as the wrap distance will be known, the equivalent head impact time can be obtained from the graph that will be used in the dynamic test set up.

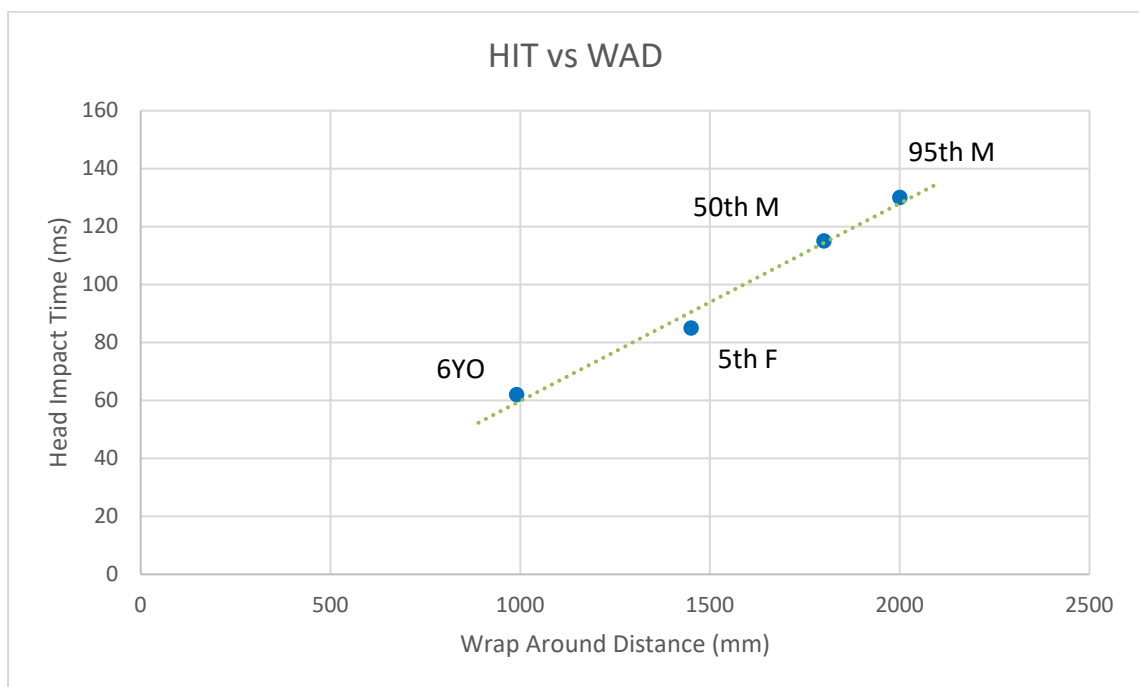


Figure 26: WAD vs HIT

8.5.2.5 The vehicle manufacturer must provide the test laboratory with all the necessary details of how to trigger the system, monitor trigger signals and replace spare parts.

### 8.5.3 Upper leg testing

8.5.3.1 If deployment occurs prior to pedestrian contact with the WAD775mm, creating an increased hazard such as increased height, the Euro NCAP secretariat will give consideration to marking out the WAD775mm in the deployed state.

- 8.5.3.2 Unless there is concern about additional hazards being created by the system deploying prior or during pedestrian contact with the WAD775mm, all upper legform testing will be carried out with the system in the un-deployed state.
- 8.5.3.3 Where the vehicle manufacturer provides data showing that a deployable system offers protection to the upper leg, the upper legform tests will be carried out by conducting dynamic tests.

## 9 LEGFORM TESTS

### 9.1 Description of Legform and its Instrumentation

- 9.1.1 The legform impactor used shall conform to that specified in the aPLI user manual for SBL-B, with background information available in IRCOBI paper IRC-20-76, Konosu et al. (2020)<sup>1</sup>.
- 9.1.2 Modified bumper covers, left and right, shall be fitted as detailed in the specification of July 2022.
- 9.1.3 Modified overload cables for the femur and tibia shall be fitted as detailed in the specification of July 2022.
- 9.1.4 Instrumentation:

Location	Measurement	CFC (Hz)	CAC	No of channels
Upper mass	Acceleration	180	500g	3
Femur Bending	Femur-3 Femur-2 Femur-1	180	600Nm	3
Knee Elongation	Medial collateral ligament Anterior cruciate ligament Posterior cruciate ligament	180	40mm	3
Tibia Bending	Tibia-1 Tibia-2 Tibia-3 Tibia-4	180	400Nm	4

### 9.2 Certification

- 9.2.1 The certification procedures are based on the FlexPLI inverse certification test<sup>2</sup> and are detailed in the aPLI user manual.
- 9.2.2 The dynamic certification corridors are detailed in Euro NCAP Technical Bulletin TB 032.
- 9.2.3 The legform shall be re-certified after a maximum of 20 impacts and at least once every 12 months.
- 9.2.4 If the legform exceeds any of its lower performance limits then it shall be re-certified.
- 9.2.5 The legform shall be re-certified according to the procedures prescribed in ISO TS 20458.

### 9.3 Test Procedure - Pre Test

- 9.3.1 Ensure that the vehicle is fully test prepared as described in Section 1.
- 9.3.2 Ensure that the legform, the vehicle, the propulsion system and the data acquisition equipment has soaked in a temperature in the range of 16°C to 24°C for at least 4 hours prior to testing.
- 9.3.3 Align the vehicle so that the propulsion system can aim at the impact position and the

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<sup>1</sup> Konosu et al. (2020): "Biofidelity Improvement of Advanced Pedestrian Legform Impactor in Rebound Phase". Available at <http://www.ircobi.org/wordpress/downloads/irc20/pdf-files/76.pdf>.

<sup>2</sup> Un regulation No. 127, revision 2. Available at <https://unece.org/transport/vehicle-regulations-wp29/standards/addenda-1958-agreement-regulations-121-140>

- propulsion system can fire the legform in a direction that is parallel to the vehicle centre line.
- 9.3.4 Roll the vehicle forwards to give the desired free flight distance.
- 9.3.5 At the time of first contact the bottom of the legform shall be 25mm above Ground Reference Level  $\pm 10\text{mm}$ . The measurement must be taken from the bottom of the legform without any protective covers.
- 9.3.6 Insert blocks under the wheels of the vehicle such that vehicle height is raised as required by the gravity correction method used to ensure the above tolerance; and the tolerance for direction of impact are both satisfied. Alternatively, ensure that the vehicle is positioned above a trench in the floor. See Figure 27.

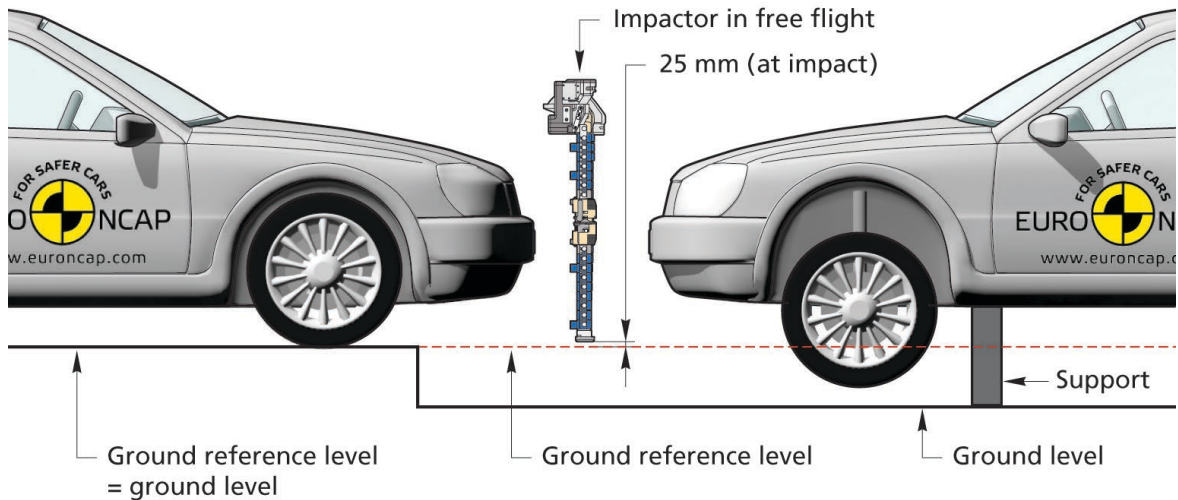


Figure 27: Legform to Bumper tests

- 9.3.7 If required, ensure the vehicle is at the same ride heights as those recorded during marking up of the vehicle, friction in the vehicle's suspension system may be a source of variance.
- 9.3.8 To ensure that the legform impacts with its bottom at the correct height above the ground a correction to take into account the action of gravity when the legform is in free flight is required. This can take the form of raising the legform a distance  $h$ , and firing it horizontally so that the action due to gravity results in the bottom of the impactor being at 25mm above ground level at the point of first contact with the vehicle. This can be achieved using the method in Section 9.4. However, this method will only remain within the tolerance specified in 9.5.9 if its free flight distance is about 400mm or less. For test houses that use a free flight distance of more than 400mm then the legform shall be fired using a ballistic correction procedure as described in Section 9.5.

#### 9.4 Compensation for Gravity (horizontal firing)

- 9.4.1 Measure the distance  $d$  (in metres) between the point of first contact and the point from where the legform will leave the propulsion system and begin free flight (release point).
- 9.4.2 The distance that the legform will fall due to gravity can be calculated from the formula:

$$\text{Fall due to Gravity } h = \frac{gd^2}{2v^2}$$

Assuming values for  $g$ , acceleration due to gravity  $= 9.81\text{ms}^{-2}$  and  $v$ , exit velocity of the legform from the propulsion system (at the release point)  $= 11.1\text{ms}^{-1}$  gives:

$$\text{Fall due to Gravity } h = 0.03981 d^2$$

- 9.4.3 Raise the propulsion system by this calculated amount,  $h$ . The angle  $\theta$  must remain within the tolerance specified in Section 9.5.9. See Figure 28.
- 9.4.4 Proceed to Section 9.5.8.

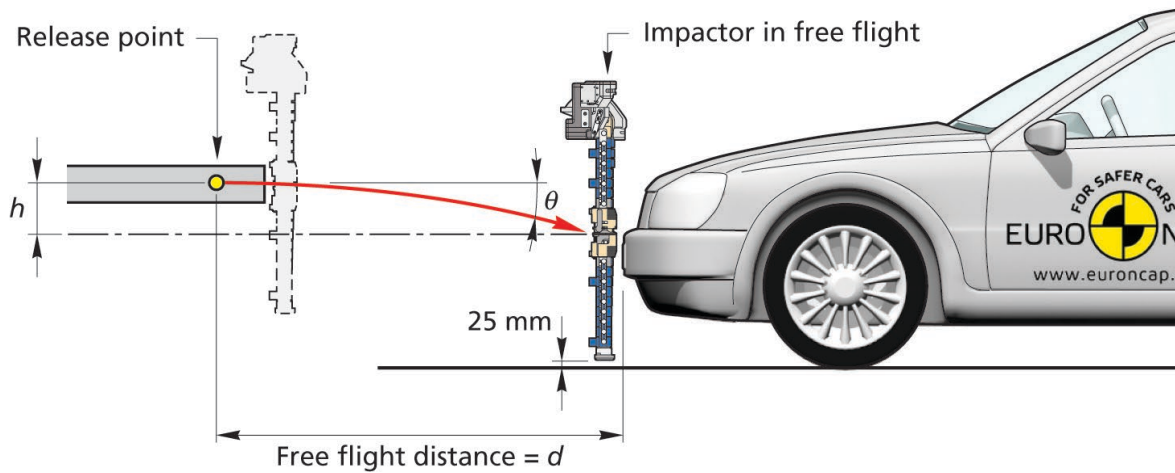


Figure 28: Droop Compensation

### 9.5 Ballistic Compensation

There are two procedures which can be used for ballistic compensation, it is at the discretion of the test house as to the most appropriate method, see Figure 29. The terms used for the calculations are:

At the release point:

$u$  = initial velocity

$\phi$  = firing angle

At the point of first contact:

$v$  = impactor velocity (11.1m/s)

$\theta$  = direction of impact ( $0^\circ$ )

$d$  = free flight distance

$h$  = height increase

- 9.5.1 The first case is where  $\phi$  is fixed, and  $\theta = 0^\circ$ ,  $v = 11.1\text{m/s}$ . The vehicle must be positioned in relation to the fixed propulsion system, therefore  $u$ ,  $d$ , and  $h$  are the subjects.
- 9.5.2 Using the following equations find  $u$ ,  $d$ , and  $h$ :

$$u = \frac{v}{\cos(\phi)}$$

$$d = \frac{v^2}{g} \tan(\phi)$$

$$h = \frac{v^2}{2g} \tan^2(\phi)$$

- 9.5.3 Position the vehicle to be the correct distance away from, and height above the release point. Proceed to Section 9.5.8.
- 9.5.4 The second case is where  $d$  is fixed, and  $\theta = 0^\circ$ ,  $v = 11.1\text{m/s}$ . The propulsion system is positioned and aimed in relation to the vehicle, therefore  $u$ ,  $h$  and  $\phi$  are the subjects.



9.5.5 Using the following equations find  $u$ ,  $h$  and  $\phi$ :

$$u = v \left( 1 + \frac{g^2 d^2}{v^4} \right)^{\frac{1}{2}}$$

$$h = \frac{gd^2}{2v^2}$$

$$\phi = \tan^{-1} \left( \frac{gd}{v^2} \right)$$

9.5.6 Position the propulsion system to be the correct distance away from, height above and correctly aimed at the vehicle.

9.5.7 The angle  $\phi$  shall be set so that the impactor is at the top of the ballistic at the point of first contact.

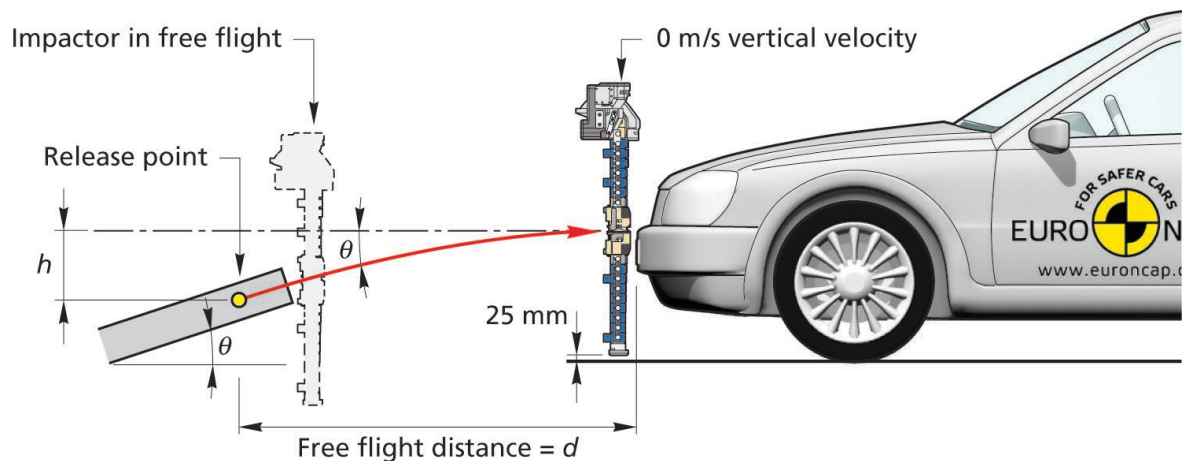


Figure 29 Ballistic compensation

9.5.8 Set the speed control on the propulsion system to give  $11.1\text{m/s} \pm 0.2\text{m/s}$  at the point of first contact. The velocity measuring device should be able to measure to an accuracy of at least  $\pm 0.02\text{ m/s}$ . The effect of gravity shall be taken into account when the impact velocity is obtained from measurements taken before the point of first contact.

9.5.9 The direction of impact at the point of first contact shall be in the horizontal plane and parallel to the longitudinal vertical plane of the vehicle. The axis of the legform shall be vertical at the time of first contact. The tolerance to these directions is  $\pm 2^\circ$ .

9.5.10 At the time of first contact the impactor shall have the intended orientation about its vertical axis, for correct operation of the knee joint, with a tolerance of  $\pm 2^\circ$ .

9.5.11 The bending moments shall be  $\pm 10.0\text{Nm}$  within the 30ms immediately prior to impact.

9.5.12 At the time of first contact the centre line of the legform impactor shall be within  $\pm 10\text{mm}$  of the selected impact point.

9.5.13 It is recommended that the above tolerances are halved for the purposes of Euro NCAP testing.

9.5.14 During contact between the legform impactor and the vehicle, the impactor shall not contact the ground or any object not part of the vehicle.

9.5.15 Fire the propulsion system.

## **9.6 Test Procedure - Post Test**

- 9.6.1 Take at least two still photographs of the resultant dent, one from the side and one from the front. Each photograph shall have some means of identifying the vehicle and test location. The preferred method shall be to use unique run numbers for each test.
- 9.6.2 Additional photographs may be required for an individual test at the Project Managers discretion.
- 9.6.3 Check that no CAC has been exceeded before conducting the next test, if this has occurred then the impactor must be re-certified before the next test.
- 9.6.4 Replace any damaged part of the vehicle that will affect the results of the next test with new parts according to Section 8.3.
- 9.6.5 Repeat procedure for the next impact location.

## 10 UPPER LEGFORM TO WAD775mm TESTS

### 10.1 Description of Upper Legform and its Instrumentation

10.1.1 The upper legform used shall conform to that specified in UN Regulation No. 127 Revision 2, Annex 4.

10.1.2 Instrumentation:

Location	Measurement	CFC (Hz)	CAC	No of channels
Upper femur	Force	180	10kN	1
Lower femur	Force	180	10kN	1
Centre of femur	Bending moment	180	1000Nm	1
50mm above centre of femur	Bending moment	180	1000Nm	1
50mm below centre of femur	Bending moment	180	1000Nm	1

### 10.2 Certification

10.2.1 The certification procedures are detailed in Regulation UN Regulation No. 127 Revision 2 Annex 6, Chapter 2.

10.2.2 The foam sheet<sup>3</sup> from which the pieces of foam shall be taken shall be certified before the test programme.

10.2.3 The upper legform shall be re-certified after a maximum of 20 impacts and at least once every 12 months.

10.2.4 If the upper legform exceeds any of its lower performance limits then it shall be re-certified.

### 10.3 Determination of Impact Angle, Impact Energy and Impact Velocity

10.3.1 The impact angle  $\alpha$  in relation to the ground at each grid point is perpendicular to a straight line passing through the internal bumper reference line and WAD930mm at the same lateral position from the vehicle centreline. Measure and record the angle  $\alpha$  at each grid point to be tested.

10.3.2 The nominal impactor energy to be used in the test shall be calculated using the following formula:

$$En = 0.5 \times m_n \times v_c^2$$

Where:

$$\begin{aligned} m_n &= 7.4kg \\ v_c &= v_o \cos(1.2\alpha) \\ v_o &= 11.11 \frac{m}{s} \end{aligned}$$

10.3.3 The test velocity  $v_t$  shall then be adjusted to meet the nominal energy by using the following

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<sup>3</sup> The foam shall be 25mm thick ConforTM foam type CF-45 or equivalent

formula:

$$vt = \sqrt{\frac{2En}{10.5kg}}$$

#### **10.4 Test procedure - Pre-test**

- 10.4.1 Ensure that the vehicle is fully test prepared as described in Section 1.
- 10.4.2 Ensure the vehicle is at the same ride heights as those recorded during marking up of the vehicle.
- 10.4.3 Ensure that the upper legform, the vehicle, the propulsion system and the data acquisition equipment has soaked in a temperature in the range of 16°C to 24°C for at least 2 hours prior to testing.
- 10.4.4 Fit a new piece of foam to the upper legform impactor from the certified sheet of foam.
- 10.4.5 Apply weights to the back of the upper legform impactor to bring the total mass to 10.5kg. Larger weights should first be applied and various smaller weights should then be added to achieve the correct weight. The upper legform impactor mass should be measured to an accuracy of better than  $\pm 1\%$ .
- 10.4.6 Where  $\alpha < 0^\circ$ , then  $\alpha = 0^\circ$ . The impact will be in the same Y-Z plane as each grid point. The tolerances to these directions are  $\pm 2^\circ$ .
- 10.4.7 The upper legform impactor shall be aligned such that the centre line of the propulsion system and the longitudinal axis of the upper legform impactor are in the fore and aft vertical plane of the section of the vehicle to be tested. The tolerances to these directions are  $\pm 2^\circ$ . At the time of first contact the impactor centre line shall be coincident with the WAD775mm with a  $\pm 10\text{mm}$  tolerance, and laterally with the selected impact location with a tolerance of  $\pm 10\text{mm}$ .
- 10.4.8 Adjust the propulsion system to give the correct velocity and angle of incidence at the point of impact with the tolerance on the impact velocity being  $\pm 2\%$ . The effect of gravity shall be taken into account when the impact velocity is obtained from measurements taken before the first point of contact. The velocity measuring device should be able to measure to an accuracy of at least  $\pm 0.02\text{m/s}$ . The effect of gravity shall be taken into account when the impact velocity is obtained from measurements taken before the point of first contact. The tolerance on impact direction  $\pm 2^\circ$ .
- 10.4.9 Roll the vehicle forwards to give the desired distance, so that the impactor strikes the vehicle after it has been accelerated to the test speed and so that any end stops on the guidance system do not interfere with its interaction with the vehicle. See Figure 30.
- 10.4.10 Fire the propulsion system.

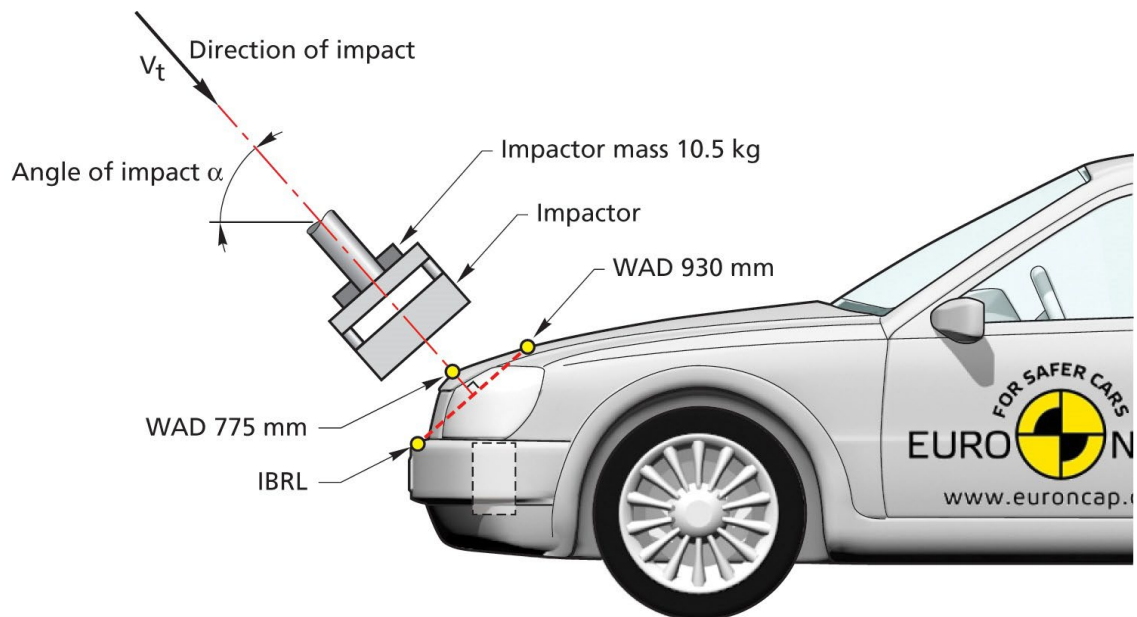


Figure 30: Upper Legform to WAD775mm Test

## 10.5 Test Procedure - Post Test

- 10.5.1 Take at least two still photographs of the resultant dent, one from the side and one from the front. Each photograph shall have some means of identifying the vehicle and test location. The preferred method shall be to use unique run numbers for each test.
- 10.5.2 Additional photographs may be required for an individual test at the Project Managers discretion.
- 10.5.3 Check that no CAC has been exceeded before conducting the next test, if this has occurred then the impactor must be re-certified before the next test.
- 10.5.4 Replace any damaged part of the vehicle which would affect the results of the next test with new parts according to Section 8.3.
- 10.5.5 Repeat procedure for the next impact location.

## 11 HEADFORM TESTING

### 11.1 Description of Headforms and Their Instrumentation

- 11.1.1 The headforms used shall conform to that specified in UN Regulation No. 127 Revision 2, Annex 4.
- 11.1.2 The child/small adult impactor to be used is defined in UN Regulation No. 127 Revision 2, Annex 4, Chapters 5.1 and 5.2. The adult impactor to be used is defined in UN Regulation No. 127 Revision 2, Annex 4, Chapters 5.3 and 5.4.
- 11.1.3 Instrumentation:

Location	Measurement	CFC	CAC	No of channels
Centre of gravity of headform	Fore/Aft acceleration <sup>4</sup>	1000	500g	1
Centre of gravity of headform	Vertical acceleration	1000	500g	1
Centre of gravity of headform	Lateral acceleration	1000	500g	1

### 11.2 Certification - Dynamic

- 11.2.1 The certification procedures are detailed in Regulation UN Regulation No. 127 Revision 2, Annex 6, Chapter 3.
- 11.2.2 The headforms<sup>5</sup> shall be certified after a maximum of 20 impacts and at least once every 12 months.
- 11.2.3 If the headforms<sup>5</sup> exceed any of their lower performance limits then they shall be re-certified.

### 11.3 Test Procedure - Pre Test

- 11.3.1 Ensure that the vehicle is fully test prepared as described in Section 1.
- 11.3.2 Ensure the vehicle is at the same ride heights as those recorded during marking up of the vehicle.
- 11.3.3 Ensure that the headforms, the vehicle, the propulsion system and the data acquisition equipment have soaked in a temperature in the range of 16°C to 24°C for at least 2 hours prior to testing.
- 11.3.4 Fit the required headform to the propulsion system. A child/small adult headform impactor shall be used for tests to the forward section of the bonnet top, A-pillars, windscreen, roof (labelled C in Section 3.11), with the test locations lying between boundaries described by wrap around distances of 1000mm and 1500mm. An adult headform impactor shall be used for tests to the rearward section of the bonnet top (labelled A in Section 3.11), with the test locations lying between boundaries described by wrap around distances of 1700 mm and 2500 mm. Where test locations lie between 1500 mm and 1700 mm the structure being tested will determine the headform to be used, see Section 3.6.9.
- 11.3.5 The position of the 'test location' describes the location of the grid point and will always determine which impactor shall be used; this will also be the case where the grid point is not coincidental with the point of first contact. For example, between 1500 mm and 1700 mm a grid point on the windscreen base will be impacted by the adult headform even if the point

<sup>4</sup> Relative to the direction of motion of the headform

<sup>5</sup> Headforms consist of headskins, aluminium sphere and instrumentation

of first contact is with the rear edge of the bonnet.

- 11.3.6 Roll the vehicle forwards to give the desired free flight distance.
- 11.3.7 Adjust the propulsion system so that it can fire the headform at the grid point with the correct angle of incidence and is aimed at the impact point.
- 11.3.8 The direction of impact shall be in the fore and aft vertical plane of the section of the vehicle to be tested. The tolerance for this direction is  $\pm 2^\circ$ . The direction of impact of tests to the bonnet top shall be downward and rearward, as if the vehicle were on the ground.
- 11.3.9 The angle of impact for tests with the child/small adult headform impactor to the bonnet and windscreen shall be  $50^\circ \pm 2^\circ$  to the Ground Reference Level. For all headform grid points on or forward of the bonnet leading edge reference line, defined in Section 3.3, the angle of impact shall be  $20^\circ \pm 2^\circ$  to ground reference level.
- 11.3.10 For tests with the adult headform impactor to the bonnet and windscreen the angle of impact shall always be  $65^\circ \pm 2^\circ$  to the Ground Reference Level. Tests to the roof shall be performed with an impact angle of  $45^\circ \pm 2^\circ$  to the Ground reference Level. For tests with the adult headform impactor to heavy vehicles, as defined in the Vehicle Specification, Selection, Testing and Retesting Protocol, the angle of impact shall always be  $50^\circ \pm 2^\circ$  to the Ground Reference Level.
- 11.3.11 The effect of gravity shall be taken into account when the impact angle is obtained from measurements taken before the time of first contact.
- 11.3.12 The centreline of the headform impactor shall be within a  $\pm 10\text{mm}$  tolerance to the selected grid point.
- 11.3.13 Set the speed control on the propulsion system to give a velocity of  $11.1 \pm 0.2\text{m/s}$  at the point of first contact. The velocity measuring device should be able to measure to an accuracy of at least  $\pm 0.02\text{m/s}$ . The effect of gravity shall be taken into account when the impact velocity is obtained from measurements taken before the point of first contact.
- 11.3.14 Fire the propulsion system.

#### **11.4 Test Procedure - Post Test**

- 11.4.1 Take at least two still photographs of the resultant dent, one from the side and one from the front. Each photograph shall have some means of identifying the vehicle and test location. The preferred method shall be to use unique run numbers for each test.
- 11.4.2 Additional photographs may be required for an individual test at the Project Manager's discretion.
- 11.4.3 Check that no CAC has been exceeded before conducting the next test, if this has occurred then the impactor must be re-certified before the next test.
- 11.4.4 Replace any damaged part of the vehicle which would affect the results of the next test with new parts according to Section 8.3.
- 11.4.5 Repeat procedure for the next impact location.

## GLOSSARY OF TERMS

**Dynamic pedestrian tests** - Synchronisation of the headform propulsion device and system deployment to achieve correct head impact time.

**Static pedestrian tests** - Test to be carried out without the need to trigger the bonnet in due time. Bonnet is deployed and maintained in place with appropriate systems recommended by vehicle manufacturer.

**Locking devices** - Systems that reach and remain in the intended position before head impact.

**Non locking devices** - Systems that do not remain in a permanent deployed position or systems that do not reach the intended position before head impact.

**Initiate deployment** - Initiation of deployment means that there must be visible movement of the deployable component, such as the bonnet top. The signal sent from the ECU to the deployable components alone is NOT considered as 'initiation of deployment'.

**Deployment time** – The duration from the initiation (triggering) of the deployment module to when the deployable pedestrian protection system reaches the final position. For example, where there is a movable bonnet, the end of the deployment time would be where the bonnet has passed any locking devices and does not travel below this point. It is not necessarily the highest point of travel.

## REFERENCES

- *Reference: Fredriksson and Rosén, Accident Analysis and Prevention Journal 2010*