



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

**SLED TEST PROCEDURE
FOR ASSESSING KNEE IMPACT AREAS**

For 2020 implementation

Version 4.0
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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.

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).

1 INTRODUCTION

- 1.1 Where knee airbags are fitted to a car, it is not possible to carry out an assessment of the knee contact zone in the normal way. Seat belt systems with devices such as double pretensioners may also make the conventional assessment, used by Euro NCAP, inappropriate. In other cases, the judgement may be marginal and manufacturers may wish to check potentially hazardous areas dynamically.
- 1.2 All sled testing is to be performed using a pulse that is representative of a 50km/h MPDB test. The pulse requirements to be met are detailed in Section 5.
- 1.3 The manufacturer must demonstrate, for the areas in question, that femur loads are less than 3.8kN and knee slider values are less than 6mm in order to avoid knee modifiers. It should be noted that under normal circumstances, where the variable load modifier is not applied, the concentrated load modifier is also not applied.
- 1.4 The Euro NCAP assessment for knee modifiers considers occupants of larger/smaller stature and weight than the 50th percentile occupant used in the full scale test. The use of the 95th percentile dummy for knee mapping ensures that a penetration deeper than that of the 50th percentile is achieved. Therefore, the full depth of the assessment zone (50th percentile penetration + 20mm) is covered by the test. Additionally, a 5th percentile female dummy may be required to assess those areas where the 95th dummy leg is unable to contact the hazards in the fascia due to space restrictions.
- 1.5 In normal circumstances, the tests can be conducted prior to the full vehicle test based on a Manufacturer's assessment of the knee inspection zone. However, there is the possibility that not all hazards are identified beforehand and additional hazards may be highlighted for assessment in the inspection report.

2 PREREQUISITES FOR KNEE MAPPING

2.1 Vehicles that show large structural post test distortion are not eligible for knee mapping. Any of the following post test conditions disqualify the vehicle from knee mapping for any frontal occupants:

- Femur loads >3.8kN in the full vehicle test (driver or passenger)
- Knee Slider >6mm in the full vehicle test (driver or passenger)
- Vehicles that qualify for the application of a structural modifiers i.e. Integrity of the passenger compartment and/or footwell rupture
- Vehicles with A-pillar displacements above 65mm (using the standard Euro NCAP measurement)
- Where any frontal impact restraining devices, such as airbags & pretensioners, deploy incorrectly, knee mapping data may not be accepted for that occupant

2.2 It is the experience of the Euro NCAP secretariat that in cases where no additional knee protection technology (e.g. dual pretensioning, collapsible steering column design knee airbag or other suitable technology) is present, the knee mapping has been shown to not be successful. However, the presence of any particular technology to limit knee loads is not a pre-requisite for knee mapping.

3 HARDWARE SETUP

3.1 Sled facility

3.1.1 An acceleration or deceleration based sled rig may be used. A “body in white” buck of the car model being assessed shall be mounted on the sled. All features which may influence knee impact protection must be installed in the body in white.

3.2 Body preparation

3.2.1 The bodyshell must be mounted on the sled such that there will be no permanent deformation of the body or its mounts, during the test programme. This is necessary to help ensure good repeatability. The pitch angle of the bodyshell shall be set to 0 degrees, according to the manufacturer’s specification.

3.2.2 The default yaw angle for the sled shall be 0 degrees. If the vehicle manufacturer can identify the need for a yaw angle other than 0 degrees in order to enable a stable contact with an identified hard point, this can be used throughout the main test program. In no cases, would Euro NCAP allow the yaw angle to be greater than 30 degrees.

3.2.3 Parts can be removed from the body in white, provided that there is no question that their removal could influence the performance of the knee impact area. Any structural or inertial support of the knee impact area must be fully simulated. This would include the support given by the steering column or loads transmitted through it.

3.2.4 The doors may be removed and the door aperture reinforced, to provide a clear view for the cameras. All components added to the bodyshell shall be to the same specification as those used in the Euro NCAP frontal impact test. The restraint system and any active devices must be replaced for each individual test.

3.2.5 Intrusion may occur which does not directly affect the knee impact area but which might provide additional support to structures supporting the knee impact area. These will be identified in the Euro NCAP inspection. For the sled tests, it may be acceptable for this type of intrusion to be simulated statically e.g. wooden spacers.

3.3 Active restraints

Any active components of restraint systems must be identical to those used in the Euro NCAP frontal impact test. However, it is acceptable for them to be triggered remotely to match the Euro NCAP frontal impact test firing times within ± 3 ms. Where remote triggering is used, full details of the firing time, proportion of charge used and any other relevant details should be supplied, along with a comparison with relevant data from the Euro NCAP frontal impact test.

4 MAIN TEST PROGRAMME

4.1 Sled Acceleration

4.1.1 The pulse performed on the sled facility shall be at least as severe as the representative MPDB test pulse, measured at the struck side B-pillar, and will be assessed according to the method detailed in Section 5.

4.2 Steering column adjustment

4.2.1 The angular adjustment shall be positioned fully upwards with the axial adjustment in the mid position.

4.3 Dummy and instrumentation

4.3.1 A 95th percentile male Hybrid III dummy shall normally be used. However, where it is not possible for the 95th percentile knee to contact the hazard due to its size, the 5th percentile female shall be used. The specific dummy to be used will be confirmed during the Euro NCAP inspection.

4.3.2 Whichever stature of dummy is to be used, it shall be equipped with at least instrumentation to record femur axial force and knee slider displacement for both legs. Shoulder belt loads shall also be recorded to demonstrate that the pre-tensioning and load limiting characteristics of the restraint system are similar to those in the Euro NCAP frontal impact test.

4.3.3 Additional instrumentation may be necessary in order to establish knee penetration.

4.4 Driver seat position

4.4.1 For 95th percentile dummies, adjust the vehicle seat according to the procedure described in Section 5 of the Euro NCAP MPDB test protocol.

4.4.2 Use the procedure described under Section 6.1 of the MPDB test protocol to determine the H-point.

4.4.3 Then move the seat rearward by 30mm. If the seat has no locking position 30mm rearward choose the next notch forward.

4.4.4 In the event that the dummy is installed in the vehicle and there is insufficient space between the knee and fascia to position the knee in the desired area, then the H-point should be moved rearward to allow correct position. Should this be insufficient, the seat should be moved rearward until there is sufficient space up to the 95th percentile seating position.

4.4.5 For 5th percentile dummies, the seat shall be positioned to the manufacturers 5th percentile seating position in the fore/aft direction. All other seat adjustments are to be set to enable a stable knee contact with the target point.

4.5 Driver dummy positioning

4.5.1 The tolerances below detail the standard dummy position in the test programme. If the point cannot be contacted by the knee after following the steps detailed below, it may be necessary to deviate from one or all of these values. In particular, the foot position must be such that the correct knee impact area will be reached. Care should be taken that deviation from the original position is as small as possible.

4.5.2 *Initial H-point of the HIII 95th:*

- The HIII 95th dummy H-point shall be within 13mm horizontally of a point 30mm rearward of the H-point measured with the SAE J826 device during seat adjustment
- If the target H-point in the horizontal direction can not be achieved with the given seat position move the seat one notch in the appropriate direction and try to position the dummy again.

4.5.3 *Pelvic angle:*

- The pelvic angle measurement gauge should read $22.5^{\circ} \pm 2.5^{\circ}$ from the horizontal.

4.5.4 *Head:*

- The transverse instrumentation platform of the head shall be within 2.5° of horizontal.

4.5.5 *Arms + Hands:*

- For driver testing, place hands on the steering wheel in a similar fashion to that of the Euro NCAP test. However, minor adjustments on the arm and hand positions are allowed if this allows for better camera views of the knee impact area.
- For passenger testing, place the arms as in the Euro NCAP test setup.

4.5.6 *Torso:*

- The torso should line up with the centre of the seat. However, the torso might have to be twisted to one side to allow for the knees to strike the points indicated in the Euro NCAP inspection. During twisting it is acceptable for the H-point location to change.

4.5.7 *Legs:*

- The legs should initially be positioned according to the Euro NCAP frontal test protocol, but then their position shall be modified laterally so that the main load bearing knee will come into contact with the potential hard-point as indicated in the inspection report. The other knee shall be aimed at an area where it would be expected to receive experience little or no loading. Frequently, this would be achieved by positioning it laterally where it has the greatest spacing from the fascia. The lateral position of the knees can be achieved with a variation of the knee spread and/or a twist of the torso.

4.5.8 *Feet:*

- The feet should be placed as flat as possible on the toe board parallel to the centreline of the vehicle. If either of the feet comes into contact with a footrest or a wheel arch, place the foot fully onto that rest. It is permissible to adjust the foot position to ensure that the correct knee impact location can be obtained. In order to ensure a stable knee contact, it may also be necessary to prevent the relevant foot from moving forwards in the footwell.

4.6 Passenger dummy positioning

4.6.1 The minimum knee penetration required for all of the passenger femur load tests within main test programme is based on the limit of the inspection zone. This will be detailed in the inspection report and be based upon the penetration of the passenger knee obtained in the official Euro NCAP test including an additional 20mm.

4.6.2 The passenger dummy positioning procedure will follow the procedure described in Sections 4.4 & 4.5 However, if this seating/dummy position does not achieve a minimum knee penetration equal to that of the limit of the inspection zone, the seat and dummy should be adjusted so that this limit is reached by the knee throughout the main test programme.

4.6.3 The penetration of the passenger knee will be established using high speed video footage and/or pelvic displacement calculations. Alternative measurement methods for establishing pelvic displacement will also be accepted which can be shown to be of equal accuracy as using pelvis acceleration to establish knee penetration. If the position of the dummy is limited by the knees contacting the hazard and/or the amount of available seat travel, that most forward position should be used.

4.6.4 Situations where potential hazards for knee slider are highlighted are treated equivalent to test for potential knee hazards. The dummy positioning procedure will follow the procedure described in Sections 4.4 & 4.5. However, if this seating/dummy position does not achieve a minimum knee displacement equal to that of the limit of the inspection zone (20mm), the seat and dummy shall be adjusted so that this limit is reached. If knee slider is a concern it needs to be ensured that there is stable contact between the tibia and potential hazard. It may be necessary to make small adjustments to the angle of the Tibia to ensure contact with the correct location.

4.7 Ensuring a stable knee contact to the potential hard point

4.7.1 In order for a knee mapping sled test to be valid, it needs to be ensured that the main load bearing knee remains in stable contact with the potential hard point during the impact sequence. If the knee is deflected, the test will not be accepted as a valid measure of the potential hazard. It is important that the other knee is loaded as little as possible by either not contacting the fascia or impacting the least supported area of the fascia.

- 4.7.2 In order to ensure this it is allowable for the knee spread to be artificially fixed (i.e. by the application of structural foam or similar, between the legs). Furthermore, it might be necessary to prevent the feet from moving forward during crash in order to prevent a dynamic drop of the knee during the impact sequence.
- 4.7.3 If a stable contact can not be achieved with artificial knee spreading alone it is allowable to use an appropriate yaw angle of the sled other than 0 degrees to assess an individual hard point.
- 4.7.4 In any case, it is essential to confirm the stable knee contact with the use of appropriate high speed camera footage.
- 4.8 Dummy painting
 - 4.8.1 In the absence of acceptable camera evidence, paint or other suitable alternatives may be used in order to identify that the correct point has been contacted.
- 4.9 Performance criteria
 - 4.9.1 In the Euro NCAP inspection, the potential hazards will be identified and it will be necessary for all of them to be fully explored in the test programme.
 - 4.9.2 The performance criteria used for the assessment will be femur forces below 3.8kN and the knee slider responses shall be less than 6mm. No adjustment to the performance criteria is made for any change in dummy size.

5 SLED PULSE REQUIREMENTS

- 5.1 The pulse used for the knee mapping tests may be based on either the actual struck side vehicle pulse from the official MPDB test or one of four pre-defined generic pulses.
- 5.2 Where a generic pulse is used, the maximum permissible different in OLC between the B-pillar pulse of the official test and chosen generic pulse is +/- 5g. Where this tolerance is exceeded, the official test pulse is to be used for all sled tests.
- 5.3 The generic pulses are divided into four OLC ranges, see below:

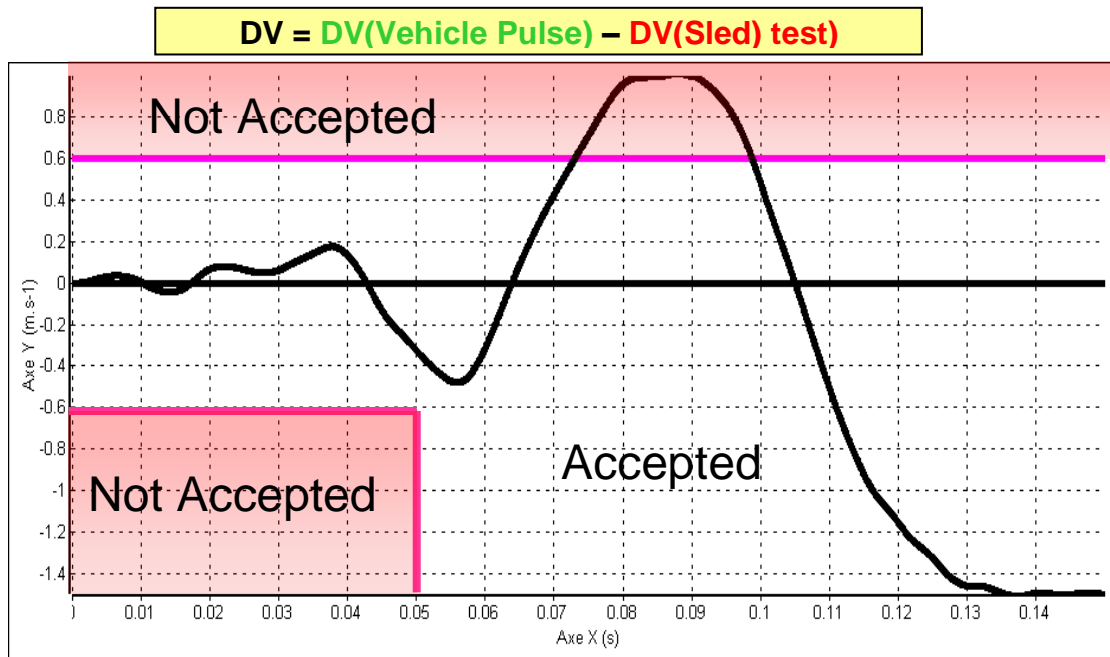
Class	OLC range	OLC generic
A	< 22.0g	18.8g
B	22.0g < 29.0g	25.5g
C	29.0g < 36.0g	32.0g
D	>36.0	39.0g

- 5.4 The pulse performed on the sled facility should be close to or more severe as the vehicle test pulse. To validate this point, the following process should be used:
 - 5.4.1 Change the orientation to have sled pulse and vehicle pulse in globally positive values
 - 5.4.2 Calculate by integration the Delta V from vehicle pulse DV1(t), setting the initial velocity to 0
 - 5.4.3 Calculate by integration the Delta V from sled test DV2(t), setting the initial velocity to 0
 - 5.4.4 Calculate the difference $DV = DV1 - DV2$
 - 5.4.5 Calculate by integration of DV1 the X displacement from vehicle pulse DX1(t), setting the initial value to 0
 - 5.4.6 Calculate by integration of DV2 the X displacement from sled test DX2(t), setting the initial value to 0
 - 5.4.7 Calculate the difference $DX(t) = DX1(t) - DX2(t)$
 - 5.4.8 Calculate DX at 100ms

5.5 Requirement #1:

- If all the DV values up to 100ms are in the zone as shown below, requirement #1 is OK – check requirement #2
- If some DV values up to 100ms are outside the zone, requirement #1 is not OK,

→ sled test is less severe than the vehicle test pulse and cannot be accepted

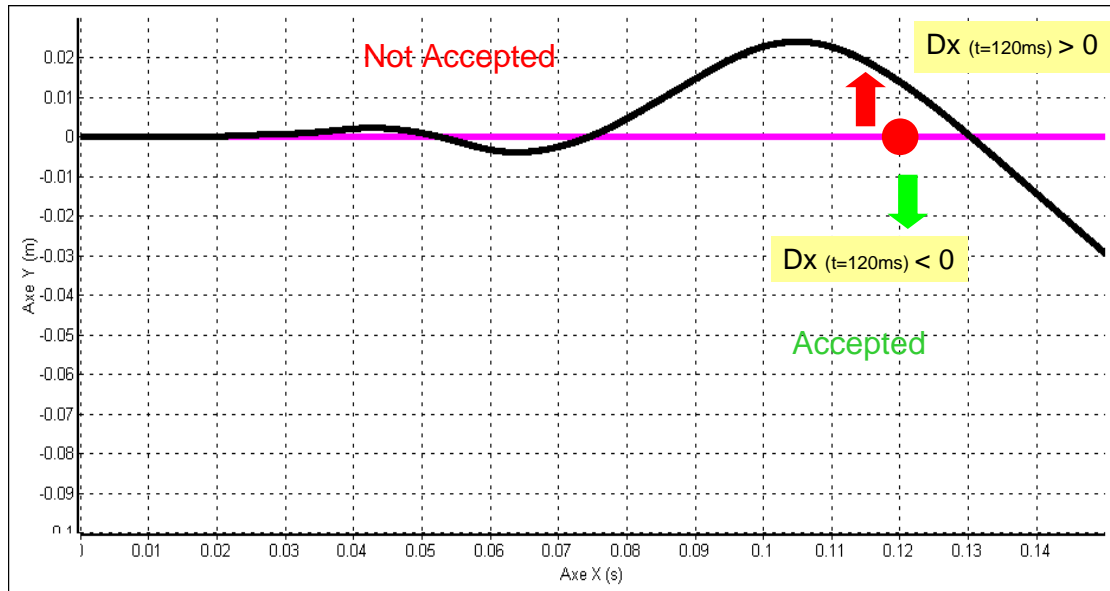


Sample pulse showing a sled test that cannot be accepted as parts of DV are outside the acceptable zone

5.6 Requirement #2:

- If DX value at 100ms is negative, requirement #2 is OK
→ **sled test is accepted for knee mapping**
- If DX value at 100ms is positive, requirement #2 is not OK
→ **sled test cannot be accepted**

$$DX = \text{Integration}(DV(\text{or Vehicle Pulse}) - DV(\text{Sled}))dt$$



Sample picture shows a sled test that cannot be accepted as DX is positive @ 120 ms

6 STATIC DEPLOYMENT TESTS

In order to ensure that the airbag creates no hazard from deployment against a knee or leg positioned close to the facia, it is necessary to carry out static deployment tests. The concern is that a deploying airbag may load the leg just below the knee causing excessive forces to be transmitted through the knee joint. These tests are required up to the end of 2021 but no assessment is currently made based on the knee slider displacement in these test.

- 6.1 Where the knee slider displacement in any full scale test is above 3mm as a result of airbag deployment, static deployment tests are required.
- 6.2 A 5th female, 50th percentile male or 95th percentile male dummy with fully instrumented legs shall be positioned to achieve the closest possible driving position, to address the worst case scenario posed by the deployment of the knee airbag.
- 6.3 The full set of data from the legs shall be supplied to confirm that there is no deployment hazard. Simulation data may also be supplied to support the test data.
- 6.4 Where no static deployment data is supplied, knee mapping will not be accepted and the knee modifiers identified in the inspection report will be applied.

7 PHOTOGRAPHIC RECORD

7.1 High speed film

7.1.1 High speed film is required for ALL knee mapping testing.

7.1.2 Sled mounted high speed cameras must be used to record the whole of the relevant scene. This would include the seat, seat belt system, facia, steering column, door aperture and dummy trajectory from both left and right sides. It should record the knee impact location and provide verification that the knee was not deflected from the chosen location and that the feet remained stable on the toe board. This should include a camera view showing the knees and a camera view that shows the feet for the complete impact sequence. The high speed camera frame rate must be of the order of 1000 frames per second.

7.2 Still photography

7.2.1 In order for any knee mapping results to be accepted by Euro NCAP, it is essential that adequate photographic evidence of the test is provided by the manufacturer.

7.2.2 Pre and post test still photography is required to clearly show the sled set-up and BIW construction. Still photographs must show the fixings of the body in white to the sled, in particular the steering column and facia mounting and the appropriate body reinforcements before and after the series of tests. Additionally, any structures added to simulate intrusion which could support the knee impact area should also be recorded.

7.2.3 The structures present in the facia must be clearly visible to provide evidence that the sled set-up is representative of a production vehicle and that all required components have been included.

7.2.4 It is essential that the position of the dummy and particularly its knees are clearly shown, along with a photographic record of the paint applied to the knees. After each test, a record must be made of the knee contact area, any paint transfer marks, and any damage to any of the knee impact area components.

7.2.5 Any broken, damaged or fatigued components shall also be fully recorded using photographs. In some cases it will be necessary to remove these from the facia after the tests in order to provide the best view.

7.3 Insufficient high speed or still photography could result in the knee mapping not being accepted by the Euro NCAP Secretariat.

8 DATA PROCESSING AND REPORTING

8.1 Data processing

8.1.1 The test data must be sampled and filtered as specified in the Euro NCAP frontal impact test protocol.

8.2 Reporting

8.2.1 Full information about the test set up shall be supplied to Euro NCAP. This must include details of any work that has been done to compensate for supportive intrusion, how the steering column lower mass and attachments have been simulated and any special arrangements related to dummy positioning. Anything which could influence the assessment should be fully reported.

8.2.2 For the main test programme, the locations being investigated shall be detailed and the outcome from each test must be given. In both cases, full data shall be supplied, including graphical plots. A full explanation and comparative analysis must be supplied.

9 KNEE AIRBAGS

- 9.1 The test set-up and the assessment criteria described above are also applicable for vehicles with knee airbags. Knee mapping test data must be provided in order to avoid the variable load modifier. However, it is assumed that a properly deploying knee airbag substitutes the function of foam and load spreader in order to avoid the concentrated load modifier. The presence of a knee airbag will not automatically lead to the removal of the concentrated load modifier; knee mapping data will be required to prove the effectiveness of the system. The presence of a knee airbag will not automatically lead to the removal of the concentrated load modifier; knee mapping data will be required to prove the effectiveness of the system.
- 9.2 Where the measured femur force is less than 3.8kN and the knee slider displacement is below 6mm, the variable contact and concentrated load modifiers will not be applied provided that, there is no bottoming out of the knee airbag.
- 9.3 It must be clear that there is no risk associated with the presence of the airbag module or its support structures.
- 9.4 Where a knee airbag does bottom out in the official MPDB test, an additional sled test with the HIII 50% percentile dummy in the MPDB test seating position is required with an airbag deployment time 10ms later than that observed in the official test. Where the femur loads or/and knee slider displacement exceed the acceptance criteria in Section 9.2, the variable load modifier will be applied.
- 9.4.1 Bottoming out of the knee airbag will be identified from the femur traces using sharp increases in femur load of at least 1kN in 5ms, and an accompanying increase in pelvis acceleration. There may also be physical damage to any underlying structures and evidence from high speed film.
- 9.4.2 If a knee airbag is deemed to have bottomed out in any of the tests and the femur loads and/or knee slider results exceed the acceptance criteria in Section 9.2, the variable load modifier will be applied.

10 INTERACTION WITH EURO NCAP

- 10.1 Any manufacturer who intends to present knee mapping test results to Euro NCAP is required to advise the Secretariat when completing the vehicle matrix.
- 10.2 Where additional Euro NCAP inspector or Secretariat time or resources are required to consider knee mapping data or to hold additional meetings, the costs will have to be funded by the manufacturer.