

**Ministry of Transportation and
Communications**

**Taiwan New Car Assessment Program
(TNCAP)**

Second Version

**3.7 Sled Test Procedure for Assessing Knee
Impact Areas**

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3.7.1 Introduction

- 3.7.1.1 When knee airbags are fitted to a car, the standard method for assessing the knee contact zone becomes impractical. Seat belt systems with devices such as double pretensioners may also make the conventional assessment inappropriate. In other cases, the judgement may be marginal and manufacturers may wish to check potentially hazardous areas dynamically.
- 3.7.1.2 A generic pulse, determined from a representative batch of LHD and RHD Euro NCAP ODB 64km/h tests, has been developed which can be used for any knee mapping tests, either on driver or front passenger seats. The corresponding acceleration and velocity change curves are attached in Section 3.7.10.
- 3.7.1.3 Where a manufacturer requests, TNCAP would accept a full series of knee mapping tests to be performed using the pulse from a full scale 64km/h ODB impact test instead of the generic pulse. ALL knee mapping tests must be done using the same pulse whether it be the generic or vehicle pulse.
- 3.7.1.4 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 shall be noted that under normal circumstances, where the variable load modifier is not applied, the concentrated load modifier is also not applied.
- 3.7.1.5 The TNCAP executive agency assessment for knee modifiers considers occupants of larger/smaller stature and weight than the 50th percentile Hybrid III used in the TNCAP full vehicle 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.
- 3.7.1.6 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.
- 3.7.1.7 A validation test will be required by the TNCAP executive agency if certain preconditions are not met (see Section 3.7.4.1) to ensure that the test configuration is fully representative of the full scale TNCAP test. Test houses shall also be familiar with the TNCAP testing protocols, which are

frequently referenced in this procedure. Details of the validation test requirements are in Section 3.7.4. The components used in the testing must be of the same design, specification, feature content and quality as those used in the official TNCAP test.

3.7.2 Prerequisites for Knee Mapping

3.7.2.1 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:

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

3.7.2.2 The presence of any particular technology to limit knee loads is not a prerequisite for knee mapping.

3.7.3 Hardware Setup

3.7.3.1 Sled Facility

3.7.3.1.1 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.

3.7.3.2 Body Preparation

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

3.7.3.2.2 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 the TNCAP executive agency allow the yaw angle to be greater than 30 degrees.

3.7.3.2.3 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 shall be fully simulated. This would include the support given by the steering column or loads transmitted through it.

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

3.7.3.2.5 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 shall be identified in the TNCAP inspection. For the sled tests, it may be acceptable for this type of intrusion to be simulated statically e.g. wooden spacers.

3.7.3.3 Active Restraints

3.7.3.3.1 Any active components of restraint systems shall be identical to those used in the TNCAP ODB frontal impact test. However, it is acceptable for them to be triggered remotely to match the TNCAP ODB 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 shall be supplied, along with a comparison with relevant data from the TNCAP ODB frontal impact test.

3.7.4 Validation Test

3.7.4.1 Exemption from the validation test

3.7.4.1.1 Where all of the following test conditions are met by the driver (only) in the nominated full scale test, a validation test is not required:

- (1) Pillar displacement below 35mm (using the standard TNCAP measurement)
- (2) No significant seat, seat mounting or floor deformation that cannot be replicated in the main test program.
- (3) Driver compressive femur loads below 1.0kN and passenger femur loads below 2.0kN.

3.7.4.2 Sled Acceleration

3.7.4.2.1 It needs to be demonstrated that the sled test sufficiently replicates a 64km/h ODB frontal impact of the subject vehicle. Therefore, the test can either be conducted with the pulse of the official TNCAP crash test or a representative development test. The vehicle used in the

representative full scale test shall be similar to that intended for assessment in the official TNCAP test in terms of engine, transmission and safety equipment. If the specification of vehicle for the official test is not known, or a different hand of drive is used, the manufacturer shall provide data from a range of at least three different vehicle specifications. The manufacturer may then choose the representative test from the various examples provided and use it for the validation.

3.7.4.2.2 The sled acceleration shall be measured and compared with that measured, at the base of the impact side B-pillar, in the representative full scale test selected by the manufacturer.

3.7.4.2.3 The suitability of the correlation between the vehicle and sled pulses will be checked according to the method detailed in Section 3.7.10.

3.7.4.3 Steering column adjustment

3.7.4.3.1 The steering column shall be positioned the same as was the case in the TNCAP frontal ODB frontal impact test.

3.7.4.4 Dummy and Instrumentation

3.7.4.4.1 The validation test shall be performed using the driver dummy only regardless of whether driver or passenger knee mapping is to be performed. A Hybrid III 50th percentile dummy shall be placed in the driver's seat.

3.7.4.4.2 The dummy shall be instrumented to the same level or greater to that specified for the TNCAP ODB frontal impact test. Although the principal comparisons will be made using knee and femur responses, this additional data can aid understanding and explain any anomalies.

3.7.4.5 Seat Position

3.7.4.5.1 The seat shall be positioned as in the TNCAP ODB frontal impact test.

3.7.4.6 Dummy Positions

3.7.4.6.1 The dummy shall be positioned as in the TNCAP ODB frontal impact test, with extra care taken to ensure that the knee impact areas will be comparable.

3.7.4.7 Performance Criteria

3.7.4.7.1 The knee impact locations and loads shall be comparable to those occurring in the full scale test. To determine that this is so, the femur loads, the knee slider displacements and the damage to the fascia will all need to be compared. Overall, the severity shall be at least as severe as that in the representative test.

3.7.4.7.2 In order to achieve the above, it might be necessary for the structural deformation to be simulated statically or, where sled test technology

allows, dynamically. Furthermore, it might be necessary to introduce an alternative yaw angle of the body shell, see Section 3.7.3.2.

3.7.5 Main Test Program

3.7.5.1 Sled Acceleration

3.7.5.1.1 The pulse performed on the sled facility shall be at least as severe as the generic or the representative 64km/h ODB test pulse, whichever is used, and will be assessed according to the method detailed in Section 3.7.10.

3.7.5.2 Steering Column Adjustment

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

3.7.5.3 Dummy and Instrumentation

3.7.5.3.1 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 TNCAP inspection.

3.7.5.3.2 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 TNCAP ODB frontal impact test.

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

3.7.5.4 Driver Seat Position

3.7.5.4.1 For 95th percentile dummies, adjust the vehicle seat according to the procedure described in Section 3.1.5 of the TNCAP ODB frontal crash test protocol.

3.7.5.4.2 Use the procedure described in Section 3.1.6.1 or 3.1.6.2 respectively of the frontal crash test protocol to determine the H-point.

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

3.7.5.4.4 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 shall be moved rearward to allow correct position. Shall this be insufficient, the seat shall be moved rearward until there is sufficient space up to the 95th percentile seating position.

3.7.5.4.5 For 5th percentile dummies, the seat shall be positioned to the manufacturer's 5th percentile seating position in the fore/aft direction.

All other seat adjustments shall be set to enable a stable knee contact with the target point.

3.7.5.5 Driver Dummy Positioning

3.7.5.5.1 The tolerances below detail the standard dummy position in the test program. 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 shall be taken that deviation from the original position is as small as possible.

3.7.5.5.2 Initial H-point of the HIII-95M dummy:

- (1) 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.
- (2) If the target H-point in the horizontal direction cannot be achieved with the given seat position move the seat one notch in the appropriate direction and try to position the dummy again.

3.7.5.5.3 Pelvic Angle

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

3.7.5.5.4 Head

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

3.7.5.5.5 Arms and Hands

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

3.7.5.5.6 Torso

The torso shall 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 TNCAP inspection. During twisting it is acceptable for the H-point location to change.

3.7.5.5.7 Legs

The legs shall initially be positioned according to the TNCAP ODB 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.

3.7.5.5.8 Feet

The feet shall 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.

3.7.5.6 Passenger Dummy Positioning

3.7.5.6.1 The minimum knee penetration required for all of the passenger femur load tests within main test program 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 TNCAP test including an additional 20mm.

3.7.5.6.2 The passenger dummy positioning procedure will follow the procedure described in Sections 3.7.5.4 & 3.7.5.5. 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 shall be adjusted so that this limit is reached by the knee throughout the main test program.

3.7.5.6.3 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 shall be used.

3.7.5.6.4 Situations were 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 3.7.5.4 & 3.7.5.5. 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.

3.7.5.7 Ensure a stable knee contact with the potential hard point.

3.7.5.7.1 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.

3.7.5.7.2 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.

3.7.5.7.3 If a stable contact cannot 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.

3.7.5.7.4 In any case, it is essential to confirm the stable knee contact with the use of appropriate high speed camera footage.

3.7.5.8 Dummy Painting

3.7.5.8.1 If 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.

3.7.5.9 Performance Criteria

3.7.5.9.1 In the TNCAP inspection, the potential hazards will be identified and it will be necessary for all of them to be fully explored in the test program.

3.7.5.9.2 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.

3.7.6 Photographic Record

3.7.6.1 High Speed Film

3.7.6.1.1 High speed film is required for ALL knee mapping testing including the validation test.

3.7.6.1.2 Sled mounted high speed cameras shall be used to record the whole of the relevant scene. This would include the seat, seat belt system, fascia,

steering column, door aperture and dummy trajectory from both left and right sides. It shall 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 shall 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 shall be of the order of 1000 frames per second.

3.7.6.2 Still Photography

3.7.6.2.1 In order for any knee mapping results to be accepted by the TNCAP executive agency, it is essential that adequate photographic evidence of the test is provided by the manufacturer.

3.7.6.2.2 Pre and post test still photography is required to clearly show the sled set-up and BIW construction. Still photographs shall show the fixings of the body in white to the sled, in particular the steering column and fascia 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 shall also be recorded.

3.7.6.2.3 The structures present in the fascia shall 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.

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

3.7.6.2.5 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 fascia after the tests in order to provide the best view.

3.7.6.3 Insufficient high speed or still photography could result in the knee mapping not being accepted by the TNCAP executive agency.

3.7.7 Data Processing and Reporting

3.7.7.1 Data Processing

3.7.7.1.1 The test data shall be sampled and filtered as specified in the TNCAP ODB frontal impact test protocol.

3.7.7.2 Reporting

3.7.7.2.1 Full information about the test set up shall be supplied to TNCAP executive agency. This shall 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 shall be fully reported.

3.7.7.2.2 For the validation test, a comparison shall be provided to satisfy the TNCAP executive agency that the test set up and pulse is suitable for the assessment work.

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

3.7.8 Knee Airbags

3.7.8.1 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.

3.7.8.2 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.

3.7.8.3 It must be clear that there is no risk associated with the presence of the airbag module or its support structures.

3.7.8.4 Where a knee airbag does bottom out in the official ODB test, an additional sled test with the 50% percentile dummy in the ODB test seating position (setup as of validation test) is required with an airbag deployment time 10ms later than that used in the official ODB test. Where the femur loads or/and knee slider displacement exceed the acceptance criteria in Section 3.7.8.2, the variable load modifier will be applied.

3.7.8.4.1 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.

3.7.8.4.2 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 3.7.8.2, the variable load modifier will be applied.

3.7.9 Interaction with TNCAP

3.7.9.1 Any manufacturer who intends to present knee mapping test results to the TNCAP executive agency is required to advise the TNCAP executive agency upon completion of the vehicle matrix form and submit the knee mapping test data before conducting the frontal offset impact test. If the data cannot be submitted within the aforementioned timeframe, it must be provided no later than six weeks after the frontal offset impact test.

3.7.9.2 Where additional the TNCAP inspector or the TNCAP executive agency 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.

3.7.10 Sled Pulse

3.7.10.1 The pulse performed on the sled facility shall be close to or more severe as the generic test pulse. To validate this point, the following process shall be used:

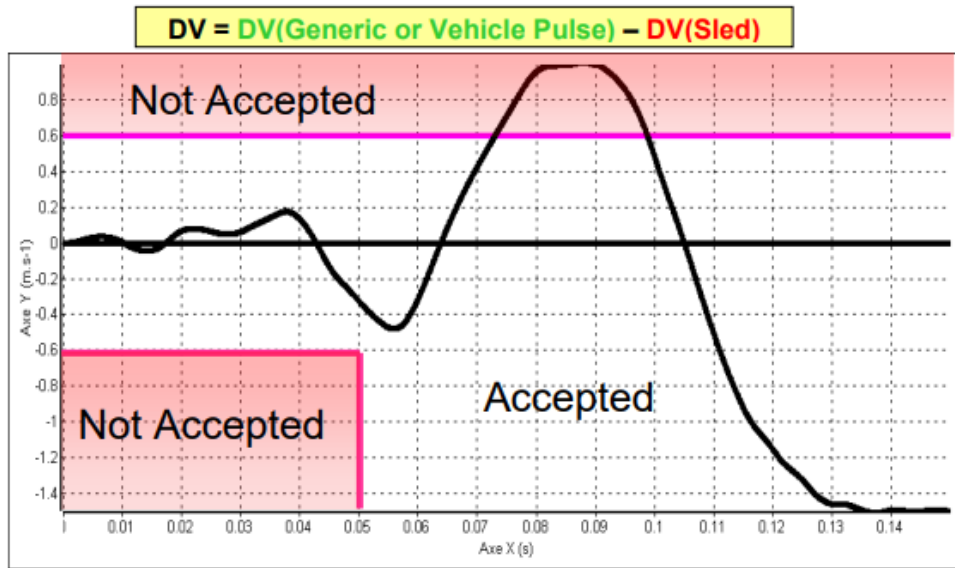
- (1) Change the orientation to have sled pulse and generic pulse in globally positive values
- (2) Calculate by integration the Delta V from generic pulse $DV1(t)$, setting the initial velocity to 0
- (3) Calculate by integration the Delta V from sled test $DV2(t)$, setting the initial velocity to 0
- (4) Calculate the difference $DV = DV1 - DV2$
- (5) Calculate by integration of $DV1$ the X displacement from generic pulse $DX1(t)$, setting the initial value to 0
- (6) Calculate by integration of $DV2$ the X displacement from sled test $DX2(t)$, setting the initial value to 0
- (7) Calculate the difference $DX(t) = DX1(t) - DX2(t)$
- (8) Calculate DX at 120 ms

3.7.10.2 Requirement #1:

- (1) If all the DV values up to 120 ms are in the zone as shown below, requirement #1 is OK – check requirement #2.
- (2) If some DV values up to 120 ms are outside the zone, requirement #1 is not OK.

Sled test is less severe than the generic or ODB test pulse and cannot be

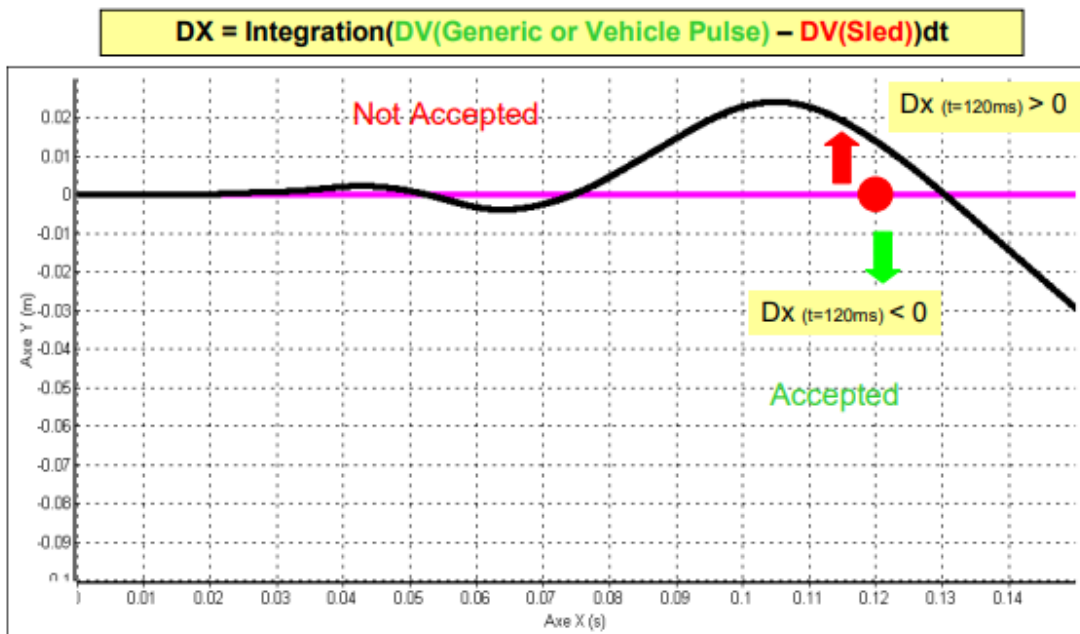
accepted for knee mapping.



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

3.7.10.3 Requirement #2:

- (1) If DX value at 120 ms is negative, requirement #2 is OK, sled test is accepted for knee mapping.
- (2) If DX value at 120 ms is positive, requirement #2 is not OK, sled test cannot be accepted for knee mapping.



Example: Sample picture shows a sled test that cannot be accepted for knee mapping as DX is positive @ 120 ms

