EURO NCAP
#FORSAFERCARS

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# Data Acquisition And Injury Calculation

## Crash Protection

# Technical Bulletin CP 005

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## PREFACE

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 TEST DATA

A complete Euro NCAP assessment consists of many tests. To ensure consistency in the general folder structure, this chapter details the required folder structure. For each (sub)test where measurements are performed on dummies, vehicles or other test equipment, all test data needs to be provided in ISO-MME 1.6 format and needs to be fully compliant with the ISO/TS 13499 standard. It should be noted that some filenames are also prescribed in this document. All data shall be provided using SI units unless specified otherwise.

## 1.1 General test series folder structure

The following folder structure, generated automatically in the Euro NCAP sharing platform, is to be used for all test series where the name of the main folder containing all tests consists of:

- The year of test
- OEM abbreviation
- Euro NCAP internal number (4 digits)
- Make and Model

Where Euro NCAP tests contain a number of sub-tests, the next paragraph details the folder structure, names of the sub-system test folders and where applicable the filenames.

On the highest level, the folder structure is as follows with on the right an example using the Volvo XC90 that is assumed to be tested in 2022 with a Euro NCAP internal number of 9999.

| • **MAIN FOLDER NAME** | • **22-VOL-9999-Volvo XC90** | **Uploaded by:** |
|---|---|---|
| <Frontal MPDB test number> | 22-VOL-9999-MP1 | Laboratory |
| <Frontal FW test number> | 22-VOL-9999-FW1 | Laboratory |
| <Side MDB test number> | 22-VOL-9999-MD1 | Laboratory |
| <Side Pole test number> | 22-VOL-9999-PO1 | Laboratory |
| <Side Pole O2O test number> | 22-VOL-9999-O2O1 | Laboratory |
| <Far side test number> | 22-VOL-9999-FAR | OEM |
| <Knee mapping> | 22-VOL-9999-KNE | OEM |
| Whiplash tests folder | 22-VOL-9999-WHL | Laboratory |
| Child Occupant Protection folder | 22-VOL-9999-COP | Laboratory |
| VRU tests folder | 22-VOL-9999-VRU | Laboratory |
| AEB Pedestrian test folder | 22-VOL-9999-AEBP | Laboratory |
| AEB Bicyclist test folder | 22-VOL-9999-AEBB | Laboratory |
| AEB Motorcyclist test folder | 22-VOL-9999-AEBM | Laboratory |
| AEB Car-to-Car tests folder | 22-VOL-9999-AEBC | Laboratory |
| SAS tests folder | 22-VOL-9999-SAS | Laboratory |
| LSS tests folder | 22-VOL-9999-LSS | Laboratory |
| OSM information | 22-VOL-9999-OSM | Laboratory |
| Inspection – *Lab name* | 22-VOL-9999-INS-*lab name* | Laboratory |

Note: The term PO1 shall be applied to pole test using one WorldSID. The term O2O shall be applied to pole test using two WorldSIDs.

### 1.1.1 MPDB sub-test folders

| | |
|---|---|
| • **MAIN FOLDER NAME** | • **22-VOL-9999-Volvo XC90** |
| … | … |
| Frontal MPDB test number | 22-VOL-9999-MP1 |
| Channel | Channel |
| Document | Document |
| Movie | Movie |
| Photo | Photo |
| Report | Report |
| Static | Static |
| MME-file | 22-VOL-9999-MP1.mme |
| … | … |

### 1.1.2 FWT sub-test folders

| | |
|---|---|
| • **MAIN FOLDER NAME** | • **22-VOL-9999-Volvo XC90** |
| … | … |
| Frontal FW test number | 22-VOL-9999-FW1 |
| Channel | Channel |
| Document | Document |
| Movie | Movie |
| Photo | Photo |
| Report | Report |
| Static | Static |
| MME-file | 22-VOL-9999-FW1.mme |
| … | … |

### 1.1.3 Side MDB sub-test folders

| | |
|---|---|
| • **MAIN FOLDER NAME** | • **22-VOL-9999-Volvo XC90** |
| … | … |
| Side MDB test number | 22-VOL-9999-MD1 |
| Channel | Channel |
| Document | Document |
| Movie | Movie |
| Photo | Photo |
| Report | Report |
| Static | Static |
| MME-file | 22-VOL-9999-MD1.mme |
| … | … |

### 1.1.4 Side Pole sub-test folders

- **MAIN FOLDER NAME**
- …
- Side pole test number
  - Channel
  - Document
  - Movie
  - Photo
  - Report
  - Static
  - MME-file
- …

- **22-VOL-9999-Volvo XC90**
- …
- 22-VOL-9999-PO1
  - Channel
  - Document
  - Movie
  - Photo
  - Report
  - Static
  - 22-VOL-9999-PO1.mme
- …

### 1.1.5 Far side sub-test folders

The Far side sled test data folder contains four sub-test folders. This is data provided to Euro NCAP by the OEM. Note: In accordance with the VTC protocol, Euro NCAP will assign a unique test number that must be used in the physical far side sled tests, XXX in the example below.

- **MAIN FOLDER NAME**
- …
- Far Side test number
  - AE-MDB
  - Pole
    - Channel
    - Document
    - Report
    - Movie
    - Photo
    - MME-file
    - Data plot report .pdf
  - AE-MDB reference pulse
  - Pole reference pulse
    - Channel
    - Document
  - Far side summary report .pdf
- …

- **22-VOL-9999-Volvo XC90**
- …
- 22-VOL-9999-FAR
  - 22-VOL-9999-FARXXX-1
  - 22-VOL-9999-FARXXX-2
    - Channel
    - Document
    - Report
    - Movie
    - Photo
    - 22-VOL-9999-FARXXX-2.mme
    - Data plot report.pdf
  - 22-VOL-9999-FAR-AE
  - 22-VOL-9999-FAR-PO
    - Channel
    - Document
  - Far side summary report .pdf
- …

### 1.1.6 Knee mapping sub-test folders

The Knee mapping test folder contains a number of sub-test folders, one for each knee mapping test. This is data provided to Euro NCAP by the OEM.

- **MAIN FOLDER NAME**
- …
- Knee mapping
  - <Test number>
  - <Test number>
    - Channel
    - Movie
    - Photo
      - MME-file
      - Data plot report .pdf
  - Knee mapping summary report .pdf
-

- **22-VOL-9999-Volvo XC90**
- …
- 22-VOL-9999-KNE
  - 22-VOL-9999-KNE-1
  - 22-VOL-9999-KNE-2
    - Channel
    - Movie
    - Photo
      - 22-VOL-9999-KNE-2.mme
      - Data plot report.pdf
  - Knee mapping summary report .pdf
- …

### 1.1.7 Whiplash sub-test folders

The Whiplash test folder contains 3 sub-test folders. Two contain the dynamic data from the two dynamic pulses tested; Medium and High. In addition, the static whiplash data is contained in a separate folder, which also contains the static measurement file. The whiplash test report and the summary data plot report will be filed in the main Whiplash folder.

- **MAIN FOLDER NAME**
- …
- Whiplash tests folder
  - <Whiplash Medium test number>
    - xCrash summary data plot report .pdf
  - <Whiplash High test number>
    - xCrash summary data plot report .pdf
  - <Whiplash Static test number>
    - Static measurement file .xlsx
    - Whiplash test report .pdf
  - <Whiplash Rear test number>
    - Static measurement file .xlsx
    - Rear whiplash test report .pdf
    - Photo
- …

- **22-VOL-9999-Volvo XC90**
- …
- 22-VOL-9999-WHL
  - 22-VOL-9999-WM1
    - 22-VOL-9999-WM1 .pdf
  - 22-VOL-9999-WH1
    - 22-VOL-9999-WH1 .pdf
  - 22-VOL-9999-WHS
    - 22-VOL-9999-WHLStatic .xls
    - 22-VOL-9999-WHL .pdf
  - 22-VOL-9999-WHR
    - 22-VOL-9999-WHRStatic .xls
    - 22-VOL-9999-WHR .pdf
    - Photo
- …

### 1.1.8 COP sub-test folders

The COP test folder contains 3 sub-test folders. They contain pictures and documents from both vehicle based assessment and the CRS installation checks as well as the vehicle manual (COP section). The COP test report will be filed in the main COP folder.

- **MAIN FOLDER NAME**
- …
- COP tests folder
  - CRS installation
  - Vehicle based assessment
  - Manual - CRS vehicle lists
  - COP test report .pdf
- …

- **22-VOL-9999-Volvo XC90**
- …
- 22-VOL-9999-COP
  - CRS installation
  - Vehicle based assessment
  - Manual-CRS vehicle lists
  - 22-VOL-9999-COP .pdf
- …

### 1.1.9 Vulnerable road user sub-test folders

The Vulnerable Road User test folder contains five sub-test folders. The document, photo, report and static folders containing general files from all tests including certification documents, test temperatures and grid/test point 3D measurements. The folder test data contains a folder for every tested point. For each of these tests there will be a separate sub-test folder (e.g. A10-5 folder), which needs to contain the channel and picture folders and the MME-file. The movie folder is needed where filming has been performed as defined in the film and photo protocol.

The test numbers for each sub-test consists of the Euro NCAP test number followed by the GRID point label.

The test report and the summary data plot report should be in the main report folder where the summary data plot report should contain all plots of all tests combined in one file called (20-VOL-9999-VRU.pdf).

- **MAIN FOLDER NAME**
- …
- VRU tests folder
  - Document
  - Photo – grid and selected points
  - Report
    - VRU test report .pdf
  - Static
  - Test data
    - <Adult Headform test number>
    - <Child Headform test number>
    - …
    - <Upper Legform test number>
    - …
    - <Legform test number>
      - Channel

- **22-VOL-9999-Volvo XC90**
- …
- 22-VOL-9999-VRU
  - Document
  - Photo
  - Report
    - 22-VOL-9999-VRU .pdf
  - Static
  - Test data
    - 22-VOL-9999-VRU-A10-5
    - 22-VOL-9999-VRU-C3+1
    - …
    - 22-VOL-9999-VRU-U+2
    - …
    - 22-VOL-9999-VRU-L-4
      - Channel

- Movie
- Photo
- Report
  - xCrash data plot report .pdf
  - MME-file
- …

- Movie
- Photo
- Report
  - 22-VOL-9999-VRU xCrash Summary .pdf
  - 22-VOL-9999-VRU-L-4.mme
- …

### 1.1.10 Inspection folder structure

The Inspection test folder contains one sub-test folder for each crash test.

- **MAIN FOLDER NAME**
- …
- Inspection
  - MPDB inspection photos
  - FW inspection photos
  - AE-MDB inspection photos
  - Pole inspection photos
- …

- **22-VOL-9999-Volvo XC90**
- …
- 22-VOL-9999-INS
  - 22-VOL-9999-MP1
  - 22-VOL-9999-FW1
  - 22-VOL-9999-MD1
  - 22-VOL-9999-PO1
- …

## 1.2 ISO MME folder structure

The ISO MME folder structure is to be applied to all applicable tests and the files contained in these folders follow the ISO/TS 13499 standard. The main directory contains six folders and two files. The following folders and files (comment files when needed) need to be provided for every test performed, where the test number is the one as specified in the previous section.

For each file and folder (where necessary) the required contents are specified in detail in the paragraphs below.

- **TEST NUMBER**
  - Channel
  - Document
  - Movie
  - Photo
  - Report
  - Static
  - <test number>.mme
  - <test number>.txt

### 1.2.1 Channel folder

The channel folder contains all channels from the vehicle, impactors and dummies used in the test as defined in Section 2.

- **TEST NUMBER**
  - Channel

- <test number>.xxx
- <test number>.chn
- …

### 1.2.2 Document folder

The document folder contains the calibration documents and temperature log files for the test dummies used in the test.

- **TEST NUMBER**
  - …
  - Document
    - < test number _ name of document file 1>
    - < test number _ name of document file d>
  - …

### 1.2.3 Movie folder

The movie folder contains the inspection quality films, using the exact names as specified in the Euro NCAP Film and Photo protocol.

- **TEST NUMBER**
  - …
  - Movie
    - < test number _ name of movie file 1>
    - < test number _ name of movie file m>
  - …

### 1.2.4 Photo folder

The photo folder contains the inspection quality photos in two folders “Before” and “After”, where the name of the photo file consists of the test number followed by a number as specified in the Euro NCAP Film and Photo protocol.

- **TEST NUMBER**
  - …
  - Photo
    - Before
    - < test number _ name of photo file 1>
    - < test number _ name of photo file p>
    - After
    - < test number _ name of photo file 1>
    - < test number _ name of photo file p>
  - …

### 1.2.5 Report folder

The report folder contains the test report containing the assessment data as described in the different test protocols and the data plots.

- **TEST NUMBER**
  - …
  - Report
    - < test number _ name of test report>
    - < test number _ name of data plots>
    - < test number _ Belt buckle force report>
    - < test number _ Door opening force report>
    - < test number _ High voltage report>
    -
  - …

### 1.2.6 Static folder

The static folder contains the static measurements file where applicable containing the data as described in the different test protocols. In the MPDB test, this folder shall also contain the data required for the compatibility assessment and details of barrier reconstruction where applicable. Please note, the raw data file of the MPDB face scan is not required. In AE-MDB and pole impacts, this folder shall contain the post test door intrusion measurements. Where applicable, HPD and HCz reports shall be provided in the static folder for the relevant side or pole impact test.

- **TEST NUMBER**
  - Frontal MPDB test number
    - Static
    - < test number _ name of static measurement file>
    - < test number _ Compatibility assessment .xlsx>
  - …

  - Side MDB and Side Pole test number
    - Static
    - < test number _ Door intrusion measurements file
    - < test number _ HPD report file> (pole test only)
    - < test number _ HCz report file> (pole test only)
  - …

### 1.2.7 MME-file

The mme-file contains the information of the test where the type of test and subtype of test shall be selected from the table below.

- **TEST NUMBER**
  - …
  - <test number>.mme

The mme-file shall contain at least the following header:

| Item | Header | Remarks |
|---|---|---|
| Data format edition number | :1.6 | |
| Laboratory name | :<lab name> | |
| Customer name | :Euro NCAP | |
| Customer test ref. number | :<test number> | Full file name (Reference-Extension-Run) |
| Customer project ref. number | :<test series number> | 4 digits number |
| Title | :Euro NCAP <year of test> | |
| Timestamp | :<date> <time> | |
| Type of the test | :<see table> | |
| Subtype of the test | :<see table> | |
| Regulation | :<test protocol version> | |
| Date of the test | :<date> | |
| Name of test object 1 | :<make and model> | |
| Ref. number of test object 1 | :<VIN > | |
| Velocity test object 1 lon. | :<VUT longitudinal velocity> | Desired (scenario) velocity |
| Velocity test object 1 lat. | :<VUT lateral velocity> | Desired (scenario) velocity |
| Mass test object 1 | :<VUT mass> | |
| Driver position object 1 | :<1/3> | LHD=1, RHD=3 |
| Impact side test object 1 | :<LE,RI> | LHD=RI, RHD=LE |
| .Dimensions test object 1 | :<length>, <width> | Dimensions as defined in protocol |
| .Profile-X test object 1 | :X1, X2, X3, X4, X5, X6, X7 | |
| .Profile-Y test object 1 | :Y1, Y2, Y3, Y4, Y5, Y6, Y7 | |
| Name of test object 2 | :<MPDB/GVT/PEDa/PEDc/EBT/EMT/…> | |
| Velocity test object 2 | :<target velocity> | Desired (scenario) velocity |

| | | |
|---|---|---|
| Type of data source | :<type> | Simulation or Hardware |

Note: the non-standard attributes need to be preceded by a point ".xxx"

| **Additional mandatory lines for Virtual tests:** | | |
|---|---|---|
| Virtual Testing reference ID: | : <Virtual Testing reference ID> | Identifier according to Table 3&4 e.g. FS_Pole_75_x-ref_z-ref_50M_Test_1 |
| Euro NCAP Validation Test Reference Number | :<FS reference number provided by Euro NCAP> | Only included in hardware tests used for validation of virtual tests. Empty for simulations. |
| Dummy Simulation Model Specification | :<dummy simulation model type> <name> <version> (<supplier>) | e.g. WSID 50 M v3.4.1. (Humanetics) |
| Reference to Dummy Model Qualification Documentation | :<name of pdf>.pdf | Document name e.g. WSID-v3_2022-11-03.pdf |
| Solver Name | : <FE software name> | e.g. LS-Dyna |
| Solver Version | :<FE software solver version> | e.g. ls-dyna_mpp_s_R9_3_1_x64_ centos65_ifort131_sse2_openmpi183 |
| Solver Precision | :<Solver precision> | SP or DP |
| Platform Name | :<name of platform on which simulations have been run> | e.g. centos78_openmpi2.1.3 |
| Number of CPUs | :<cores x CPUs> | e.g. 2x32 |
| Time step setting | :<min. time step size in seconds> | e.g. min. time step 1-e7 s |
| Contact Type between dummy and seat | :<contact documentation> | S2S SOFT2 nu=0.2 |
| Contact Type between dummy and seatbelt | :<contact documentation> | S2S SOFT2 nu=0. |
| Number of contacts used in the overall simulation setup | : <total number of contacts> | e.g. 10 |
| Number of elements | : <total number of contacts> | e.g. 20000 |
| Mass of total setup (used for quality checks) | : <total mass in kg> | Fill in in kg e.g. 1500 |
| Mass of dummy in kg | : <total mass in kg> | Fill in in kg e.g. 75 |
| Mass of seat in kg | : <total mass in kg> | Fill in in kg e.g. 50 |
| Mass of sled in kg | : <total mass in kg> | Fill in in kg e.g. 500 |
| Mass of centre console in kg | : <total mass in kg> | Fill in in kg e.g. 500 |
| Distance between head CoG and green line | : <distance in meters> | Fill in in meters e.g. 0.2. |

| | | |
|---|---|---|
| Distance between head CoG and yellow line | : <distance in meters> | Fill in in meters e.g. 0.3. |
| Distance between head CoG and orange line | : <distance in meters> | Fill in in meters e.g. 0.4. |
| Distance between head CoG and red line | : <distance in meters> | Fill in in meters e.g. 0.5. |

Note: the non-standard attributes need to be preceded by a point ".xxx"

The type and subtype of tests is summarised below:

| **Euro NCAP test** | **Type of Test** | **Subtype of test** |
|---|---|---|
| Frontal MPDB | Frontal Impact | MPDB |
| Frontal FW | Frontal Impact | FW |
| Side MDB | Side Impact | AE-MDB |
| Side Pole | Side Impact | Pole 75 degree - single occupancy[1] |
| Side O2O | Side Impact | Pole 75 degree & O2O - dual occupancy[2]<br>O2O – dual occupancy[3] |
| Whiplash | Rear Sled Test | Whiplash-Medium |
| | | Whiplash-High |
| VRU | VRU | Adult / Child Headform |
| | | Upper Legform / Legform |

1. PO1 folder is NOT required where only a dual occupancy test is performed.
2. Where only one dual occupancy pole test is performed, O2O1, the driver dummy is assessed in the pole loading phase (struck side) and the interaction phase with the passenger.
3. This test is only performed in accordance with the Side Impact protocol. In the dual occupancy pole test, O2O1, the driver dummy is assessed in the interaction phase with the passenger only. The driver dummy is assessed in the pole loading phase (struck side) from the single occupancy pole test PO1.

### 1.2.8 Txt file

The text file contains details of any test artefacts, errors or warnings associated with the test and how they should be considered.

- **TEST NUMBER**
  - …
  - <test number>.txt

# 2 CHANNEL NAMES AND FILTERS

For each dummy, impactors and test objects used in the different Euro NCAP tests the following channel names shall be used. All channels shall be supplied either unfiltered or prefiltered. The appropriate filters for calculation of injury criteria and plotting of these channels will be performed by the analysis software used.

## 2.1 Hybrid III 50% Male

| Location | Parameter | ISO code | CFC | Injury Calculation |
|---|---|---|---|---|
| Head | Accelerations, $A_x$ $A_y$ $A_z$ | ??HEAD0000H3AC[X,Y,Z]P | 1000 | Peak resultant acceleration<br>$HIC_{15}$<br>Resultant 3ms cumulative exceedence |
| Neck | Forces, $F_x$ $F_y$ $F_z$ | ??NECKUP00H3FO[X,Y,Z]P | 1000 | Tension ($+F_z$) continuous exceedence<br>Shear ($+F_x$ & $-F_x$) continuous exceedence<br>Peak Extension ($M_y$) |
| | Moments, $M_x$ $M_y$ $M_z$ | ??NECKUP00H3MO[X,Y,Z]P | 600 | |
| Chest | Accelerations, $A_x$ $A_y$ $A_z$ | ??CHST0000H3AC[X,Y,Z]P | 180 | Peak resultant acceleration<br>Resultant 3ms cumulative exceedence<br>Peak deflection<br>Viscous Criterion |
| | Deflection, $D_{chest}$ | ??CHST0003H3DSXP | 180 | |
| Pelvis | Accelerations, $A_x$ $A_y$ $A_z$ | ??PELV0000H3AC[X,Y,Z]P | 600 | |
| Lumbar Spine | Forces, $F_x$ $F_z$ | ??LUSP0000H3FO[X,Z]P | 600 | |
| | Moments, $M_y$ | ??LUSP0000H3MOYP | 600 | |
| Femurs (L & R) | Forces, $F_z$ | ??FEMR[LE,RI]00H3FOZP | 600 | Compressive Axial Force ($-F_z$)<br>continuous exceedence |
| Knees (L & R) | Displacements, $D_{knee}$ | ??KNSL[LE,RI]00H3DSXP | 180 | Peak displacement (-D) |
| Upper Tibia (L & R) | Forces, $F_x$ $F_z$ | ??TIBI[LE,RI]UPH3FO[X,Z]P | 600 | Peak Tibia Compression ($-F_z$)<br>Tibia Index |
| | Moments, $M_x$ $M_y$ | ??TIBI[LE,RI]UPH3MO[X,Y]P | 600 | |
| Lower Tibia (L & R) | Forces, $F_x$ $F_z$ ($F_y$) | ??TIBI[LE,RI]LOH3FO[X,Y,Z]P | 600 | Peak Tibia Compression ($-F_z$)<br>Tibia Index |
| | Moments, $M_x$ $M_y$ | ??TIBI[LE,RI]LOH3MO[X,Y]P | 600 | |

## 2.2 THOR 50% Male

| Location | Parameter | | ISO code | CFC | Injury calculation |
|---|---|---|---|---|---|
| Head | Acceleration, $A_x$ $A_y$ $A_z$ | | ??HEAD0000T3AC[X,Y,Z]P | 1000 | Peak Resultant acceleration<br>$HIC_{15}$<br>Resultant 3ms<br>DAMAGE |
| | Angular rate sensor | | ??HEAD0000T3AV[X,Y,Z]P | 60 | |
| | Tilt sensor, X Y | | ??HEADPR00T3AN[X,Y]P | | |
| Neck Cable | Force, Z | | ??NECK[FR,RE]00T3FOZP | 1000 | |
| Upper Neck | Force | $F_x$ $F_y$ $F_z$ | ??NECKUP00T3FO[X,Y,Z]P | 1000 | Tension (+$F_z$)<br>Shear (+$F_x$ & -$F_x$)<br>Peak Extension ($M_y$) |
| | Moment, $M_x$ $M_y$ $M_z$ | | ??NECKUP00T3MO[X,Y,Z]P | 600 | |
| T1 | Acceleration, $A_x$ $A_y$ $A_z$ | | ??THSP0100T3AC[X,Y,Z]P | 600 | Peak acceleration |
| T4 | Acceleration, $A_x$ $A_y$ $A_z$ | | ??THSP0400T3AC[X,Y,Z]P | 600 | Peak acceleration |
| Clavicle (L&R) | Inner & Outer Force, $F_x$ $F_z$ | | ??CLAVLE[IN,OU]T3FO[X,Z]P | 600 | Peak force |
| Thorax | Distance, DC0 | | ??CHST[LE,RI][UP,LO]T3DC0P | 180 | Peak displacement<br>Viscous criterion |
| | Angle, Y Z | | ??CHST[LE,RI][UP,LO]T3AN[Y,Z]P | 180 | |
| Mid Sternum | Acceleration, $A_x$ | | ??STRN0000T3ACXP | 600 | Peak acceleration |
| Abdomen | Distance, DC0 | | ??ABDO[LE,RI]00T3DC0P | 180 | Peak displacement<br>Viscous criterion |
| | Angle, Y Z | | ??ABDO[LE,RI]00T3AN[Y,Z]P | 180 | |
| | Acceleration, $A_x$ | | ??ABDO0000T3AC[X,Y,Z]P | 600 | Peak acceleration |
| T12 | Acceleration, $A_x$ $A_y$ $A_z$ | | ??THSP1200T3AC[X,Y,Z]P | 180 | Peak acceleration |
| | Force, $F_x$ $F_y$ $F_z$ | | ??LUSP0000T3FO[X,Y,Z]P | 600 | Peak force |
| | Moment, $M_x$ $M_y$ | | ??LUSP0000T3MO[X,Y]P | 600 | Peak moment |
| Pelvis | Acceleration, $A_x$ $A_y$ $A_z$ | | ??PELV0000T3AC[X,Y,Z]P | 600 | Peak acceleration |
| | Tilt sensor, X Y | | ??PELVPR00T3AN[X,Y]P | - | |
| ASIS (L & R) | Force, $F_x$, | | ??ILAC[LE,RI]00T3FOXP | 600 | |
| | Moment, $M_y$ | | ??ILAC[LE,RI]00T3MOYP | 600 | |
| Acetabulum (L & R) | Force, $F_x$ $F_y$ $F_z$ | | ??ACTB[LE,RI]00T3FO[X,Y,Z]P | 600 | Compressive Force |

| | | | | |
|---|---|---|---|---|
| Femurs (L & R) | Force, $F_x$ $F_y$ $F_z$ | ??FEMR[LE,RI]00T3FO[X,Y,Z]P | 600 | Compressive Axial Force ($-F_z$) |
| | Moment, $M_x$ $M_y$ $M_z$ | ??FEMR[LE,RI]00T3MO[X,Y,Z]P | | |
| Knees (L & R) | Displacement, $D_{knee}$ | ??KNSL[LE,RI]00T3DSXP | 180 | Peak displacement (-D) |
| Upper Tibia (L & R) | Force, $F_x$ $F_z$ | ??TIBI[LE,RI]UPT3FO[X,Z]P | 600 | Peak Tibia Compression ($-F_z$)<br>Tibia Index |
| | Moment, $M_x$ $M_y$ | ??TIBI[LE,RI]UPT3MO[X,Y]P | 600 | |
| Lower Tibia (L & R) | Force, $F_x$ $F_z$ | ??TIBI[LE,RI]LOT3FO[X,Y,Z]P | 600 | Peak Tibia Compression ($-F_z$)<br>Tibia Index |
| | Moment, $M_x$ $M_y$ | ??TIBI[LE,RI]LOT3MO[X,Y]P | 600 | |

### 2.3 Hybrid III 5% Female

| Location | Parameter | ISO code | CFC | Injury Calculation |
|---|---|---|---|---|
| Head | Accelerations, $A_x$ $A_y$ $A_z$ | ??HEAD0000HFAC[X,Y,Z]P | 1000 | Peak Resultant acceleration<br>$HIC_{15}$<br>Resultant 3ms cumulative exceedence |
| Neck | Forces, $F_x$ $F_y$ $F_z$ | ??NECKUP00HFFO[X,Y,Z]P | 1000 | Tension ($+F_z$) continuous exceedence<br>Shear ($+F_x$ & $-F_x$) continuous exceedence<br>Peak Extension ($M_y$) |
| | Moments, $M_x$ $M_y$ $M_z$ | ??NECKUP00HFMO[X,Y,Z]P | 600 | |
| Chest | Accelerations, $A_x$ $A_y$ $A_z$ | ??CHST0000HFAC[X,Y,Z]P | 180 | Peak resultant acceleration<br>Resultant 3 ms cumulative exceedence<br>Peak deflection<br>Viscous Criterion |
| | Deflection, $D_{chest}$ | ??CHST0003HFDSXP | 180 | |
| Pelvis | Accelerations, $A_x$ $A_y$ $A_z$ | ??PELV0000HFAC[X,Y,Z]P | 600 | |
| Iliac (L & R) | Forces, $F_x$ | ??ILAC[LE,RI]00HFFOXP | 600 | |
| | Moments, $M_y$ | ??ILAC[LE,RI]00HFMOYP | 600 | |
| Lumbar Spine | Forces, $F_x$ $F_z$ | ??LUSP0000HFFO[X,Z]P | 600 | |
| | Moments, $M_y$ | ??LUSP0000HFMOYP | 600 | |
| Femurs (L & R) | Forces, $F_z$ | ??FEMR[LE,RI]00HFFOZP | 600 | Compressive Axial Force ($-F_z$) |

| | | | | |
|---|---|---|---|---|
| | | | | Continuous exceedence |
| Knees<br>(L & R) | Displacements, $D_{knee}$ | ??KNSL[LE,RI]00HFDSXP | 180 | Peak displacement (-D) |
| Upper Tibia<br>(L & R) | Forces, $F_x$ $F_z$ | ??TIBI[LE,RI]UPHFFO[X,Z]P | 600 | Peak Tibia Compression ($-F_z$)<br>Tibia Index |
| | Moments, $M_x$ $M_y$ | ??TIBI[LE,RI]UPHFMO[X,Y,Z]P | 600 | |
| Lower Tibia<br>(L & R) | Forces, $F_x$ $F_z$ ($F_y$) | ??TIBI[LE,RI]LOHFFO[X,Y,Z]P | 600 | Peak Tibia Compression ($-F_z$)<br>Tibia Index |
| | Moments, $M_x$ $M_y$ | ??TIBI[LE,RI]LOHFMO[X,Y,Z]P | 600 | |

## 2.4 Hybrid III 95% Male

| Location | Parameter | ISO code | CFC | Injury Calculation |
|---|---|---|---|---|
| Head | Accelerations, $A_x$ $A_y$ $A_z$ | ??HEAD0000H3AC[X,Y,Z]P | 1000 | Peak resultant acceleration<br>$HIC_{15}$<br>Resultant 3ms cumulative exceedence |
| Neck | Forces, $F_x$ $F_y$ $F_z$ | ??NECKUP00H3FO[X,Y,Z]P | 1000 | Tension ($+F_z$) continuous exceedence<br>Shear ($+F_x$ & $-F_x$) continuous exceedence<br>Peak Extension ($M_y$) |
| | Moments, $M_x$ $M_y$ $M_z$ | ??NECKUP00H3MO[X,Y,Z]P | 600 | |
| Chest | Accelerations, $A_x$ $A_y$ $A_z$ | ??CHST0000H3AC[X,Y,Z]P | 180 | Peak resultant acceleration<br>Resultant 3ms cumulative exceedence<br>Peak deflection<br>Viscous Criterion |
| | Deflection, $D_{chest}$ | ??CHST0003H3DSXP | 180 | |
| Pelvis | Accelerations, $A_x$ $A_y$ $A_z$ | ??PELV0000H3AC[X,Y,Z]P | 600 | |
| Lumbar Spine | Forces, $F_x$ $F_z$ | ??LUSP0000H3FO[X,Z]P | 600 | |
| | Moments, $M_y$ | ??LUSP0000H3MOYP | 600 | |
| Femurs<br>(L & R) | Forces, $F_z$ | ??FEMR[LE,RI]00H3FOZP | 600 | Compressive Axial Force ($-F_z$)<br>continuous exceedence |
| Knees | Displacements, $D_{knee}$ | ??KNSL[LE,RI]00H3DSXP | 180 | Peak displacement (-D) |

| | | | | |
|---|---|---|---|---|
| (L & R) | | | | |
| Upper Tibia<br>(L & R) | Forces, $F_x$ $F_z$ | ??TIBI[LE,RI]UPH3FO[X,Z]P | 600 | Peak Tibia Compression ($-F_z$)<br>Tibia Index |
| | Moments, $M_x$ $M_y$ | ??TIBI[LE,RI]UPH3MO[X,Y]P | 600 | |
| Lower Tibia<br>(L & R) | Forces, $F_x$ $F_z$ ($F_y$) | ??TIBI[LE,RI]LOH3FO[X,Y,Z]P | 600 | Peak Tibia Compression ($-F_z$)<br>Tibia Index |
| | Moments, $M_x$ $M_y$ | ??TIBI[LE,RI]LOH3MO[X,Y]P | 600 | |

## 2.5 WorldSID 50% Male

| Location | Parameter | | CFC | Injury Calculation |
|---|---|---|---|---|
| Head | Accelerations, $A_x$ $A_y$ $A_z$ | ??HEAD0000WSAC[X,Y,Z]P | 1000 | $HIC_{15}$<br>Peak acceleration<br>3ms exceedence (cumulative)<br>DAMAGE |
| | Angular rate sensor | ??HEAD0000WSAV[X,Y,Z]P | 60 | |
| Upper Neck | Forces, $F_x$ $F_y$ $F_z$ | ??NECKUP00WSFO[X,Y,Z]P | 1000 | |
| | Moments, $M_x$ $M_y$ $M_z$ | ??NECKUP00WSMO[X,Y,Z]P | 600 | |
| Lower Neck | Forces, $F_x$ $F_y$ $F_z$ | ??NECKLO00WSFO[X,Y,Z]P | 1000 | |
| | Moments, $M_x$ $M_y$ $M_z$ | ??NECKLO00WSMO[X,Y,Z]P | 600 | |
| Shoulder | Forces, Fx, Fy, Fz | ??SHLD[LE,RI]00WSFO[X,Y,Z]P | 600 | Peak lateral force |
| | Distance, R | ??SHRI[LE,RI]00WSDC0P | 180 | Peak lateral displacement (Y)<br>Viscous criterion |
| | Rotation, α | ??SHRI[LE,RI]00WSANZP | 180 | |
| Thorax | Distance, R | ??TRRI[LE,RI][01,02,03]WSDC0P | 180 | Peak lateral displacement (Y)<br>Viscous criterion |
| | Rotation, α | ??TRRI[LE,RI][01,02,03]WSANZP | 180 | |
| T4 | Accelerations, $A_x$ $A_y$ $A_z$ | ??THSP0400WSAC[X,Y,Z]P | 180 | |
| Abdomen | Distance, R | ??ABRI[LE,RI][01,02]WSDC0P | 180 | Peak lateral displacement (Y)<br>Viscous criterion |
| | Rotation, α | ??ABRI[LE,RI][01,02]WSANZP | 180 | |
| T12 | Accelerations, $A_x$ $A_y$ $A_z$ | ??THSP1200WSAC[X,Y,Z]P | 180 | |
| Lumbar Spine | Forces, $F_x$ $F_y$ $F_z$ | ??LUSP0000WSFO[X,Y,Z]P | 600 | |
| | Moments, $M_x$ $M_y$ $M_z$ | ??LUSP0000WSMO[X,Y,Z]P | 600 | |
| Pelvis | Accelerations, $A_x$ $A_y$ $A_z$ | ??PELV0000WSAC[X,Y,Z]P | 600 | Pubic Symphysis Force |
| | Forces, $F_y$ | ??PUBC0000WSFOYP | 600 | |
| Femoral Neck | Forces, $F_x$ $F_y$ $F_z$ | ??FEAC[LE,RI]00WSFO[X,Y,Z]P | 600 | |

## 2.6 BioRID UN

| Location | Parameter | | CFC | Injury Calculation |
|---|---|---|---|---|
| Head | Accelerations, $A_x$ $A_y$ $A_z$ | ??HEAD0000BRAC[X,Y,Z]P | 60 | NIC |
| | Velocity, $V_x$ | ??HEAD0000BRVEXV | 30 | Head rebound velocity |
| | Contact | ??HERE000000EV00 | | Head contact time |
| Cervical Spine | Accelerations, $A_x$ $A_z$ | ??CESP0400BRAC[X,Z]P | 60 | |
| Neck Upper | Forces, $F_x$ $F_y$ $F_z$ | ??NECKUP00BRFO[X,Y,Z]P | 1000 | Nkm<br>Neck shear (+$F_x$ & -$F_x$)<br>Neck tension (+Fz) |
| | Moments, $M_x$ $M_y$ $M_z$ | ??NECKUP00BRMO[X,Y,Z]P | 600 | Nkm |
| Neck Lower | Forces, $F_x$ $F_y$ $F_z$ | ??NECKLO00BRFO[X,Y,Z]P | 1000 | |
| | Moments, $M_x$ $M_y$ $M_z$ | ??NECKLO00BRMO[X,Y,Z]P | 600 | |
| Thoracic Spine T1 (L & R) | Accelerations, $A_x$ $A_z$ | ??THSP01[LE,RI]BRAC[X,Z]P | 60 | T1- X-acceleration (avg)<br>NIC |
| Thoracic Spine T8 | Accelerations, $A_x$ $A_z$ | ??THSP0800BRAC[X,Z]P | 60 | |
| Lumbar Spine | Accelerations, $A_x$ $A_z$ | ??LUSP0100BRAC[X,Z]P | 60 | |
| Pelvis | Accelerations, $A_x$ $A_y$ $A_z$ | ??PELV0000BRAC[X,Y,Z]P | 60 | |

## 2.7 Q6

| Location | Parameter | ISO code | CFC | Injury Calculation |
|---|---|---|---|---|
| Head | Accelerations, $A_x$ $A_y$ $A_z$ | ??HEAD0000Q6AC[X,Y,Z]P | 1000 | $HIC_{15}$<br>Resultant 3ms exceedence (cumulative) |
| Neck Upper | Forces, $F_x$ $F_y$ $F_z$ | ??NECKUP00Q6FO[X,Y,Z]P | 1000 | Peak Tensile Force $F_z$ Resultant Force (side) |
| | Moments, $M_x$ $M_y$ $M_z$ | ??NECKUP00Q6MO[X,Y,Z]P | 600 | |
| Thorax | Accelerations, $A_x$ $A_y$ $A_z$ | ??THSP0000Q6AC[X,Y,Z]P | 180 | Resultant 3ms exceedence (cumulative) |
| | Displacement, D | ??CHST0000Q6DSXP | 180 | Peak deflection |

## 2.8 Q10

| Location | Parameter | ISO code | CFC | Injury Calculation |
|---|---|---|---|---|
| Head | Accelerations, $A_x$ $A_y$ $A_z$ | ??HEAD0000QBAC[X,Y,Z]P | 1000 | $HIC_{15}$<br>Resultant 3ms exceedence (cumulative) |
| Neck Upper | Forces, $F_x$ $F_y$ $F_z$ | ??NECKUP00QBFO[X,Y,Z]P | 1000 | Peak Tensile Force $F_z$<br>Resultant Force (side) |
| | Moments, $M_x$ $M_y$ $M_z$ | ??NECKUP00QBMO[X,Y,Z]P | 600 | |
| Shoulder (side only) | Forces, $F_x$ $F_y$ $F_z$ | ??SHLD[LE,RI]00QBFO[X,Y,Z]P | 1000 | |
| T1 (side only) | Accelerations, $A_y$ | ??THSP01[LE,RI]QBACYP | 1000 | |
| Chest (T4) | Accelerations, $A_x$ $A_y$ $A_z$ | ??THSP0400QBAC[X,Y,Z]P | 180 | Resultant 3ms exceedence (cumulative) |
| Chest (frontal only) | Distance, R | ??CHST[LO,UP]00QBDC0P | 180 | Peak deflection |
| | Rotation, α | ??CHST[LO,UP]00QBANZP | 180 | |
| Chest (side only) | Distance, R | ??CHST[LE,RI][LO,UP]QBDC0P | 180 | |
| | Rotation, α | ??CHST[LE,RI][LO,UP]QBANZP | 180 | |
| Lumbar Spine | Forces, $F_x$ $F_y$ $F_z$ | ??LUSP0000QBFO[X,Y,Z]P | 1000 | |
| | Moments, $M_x$ $M_y$ $M_z$ | ??LUSP0000QBMO[X,Y,Z]P | 600 | |
| Pelvis-Sacrum | Accelerations, $A_x$ $A_y$ $A_z$ | ??PELV0000QBAC[X,Y,Z]P | 180 | |

| | | | | |
|---|---|---|---|---|
| Pelvis-Pubis (side only) | Forces, $F_y$ | ??PUBC0000QBFOYP | 1000 | |

## 2.9 Adult headform

| Location | Parameter | ISO code | CFC | Injury Calculation |
|---|---|---|---|---|
| Head | Accelerations, $A_x$ $A_y$ $A_z$ | D0HEAD0000PJAC[X,Y,Z]P | 1000 | $HIC_{15}$ |

## 2.10 Small adult / child headform

| Location | Parameter | ISO code | CFC | Injury Calculation |
|---|---|---|---|---|
| Head | Accelerations, $A_x$ $A_y$ $A_z$ | D0HEAD0000PSAC[X,Y,Z]P | 1000 | $HIC_{15}$ |

## 2.11 Upper legform

| Location | Parameter | ISO code | CFC | Injury Calculation |
|---|---|---|---|---|
| Femur | Forces, $F_x$ | D0FEMR[UP,LO]00PUFOXP | 180 | Sum of Forces |
| | Moments, $M_y$ | D0FEMR[UP,MI,LO]00PUMOYP | 180 | Bending Moment |

## 2.12 Legform (aPLI)

| Location | Parameter | ISO code | CFC | Injury Calculation |
|---|---|---|---|---|
| Upper Mass | Accelerations, $A_x$ $A_y$ $A_z$ | ??PELV0000PMAC[X,Y,Z]P | | |
| | Angular velocity | ??PELV0000PMAV[X,Y]P | | |
| Femur | Moments, $M_x$ | ??FEMR[UP,MI,LO]00PMMOXP | | Bending Moment |
| Knee | Displacement, $D_{MCL}$ | ??KNEEMC00PMDS0P | | MCL Elongation |
| | Displacement, $D_{PCL}$ | ??KNEEPC00PMDS0P | | PCL Elongation |
| | Displacement, $D_{ACL}$ | ??KNEEAC00PMDS0P | | ACL Elongation |
| Tibia | Moments, $M_x$ | ??TIBI[UP,LO]00PMMOXP<br>??TIBIMI[UP,LO]PMMOXP | | Bending Moment |

## 2.13 Vehicle for passive safety tests

| Location | Parameter | ISO code | CFC | Injury Calculation |
|---|---|---|---|---|
| B-Pillar | Accelerations, $A_x$ $A_y$ | [14,16]BPILL00000AC[X,Y]P | 60 | |
| Seatbelt, B3 | Force, $F_{seatbelt}$ | ??SEBE0003B3FO0P | 60 | Seat belt force modifier |
| Seatbelt, B6 | Force, $F_{seatbelt}$ | ??SEBE0003B6FO0P | 60 | |
| Vehicle trunk | Angular rate sensor | 18TUNN000000AV[X,Y,Z]P | 60 | |

## 2.14 Trolley

| Location | Parameter | ISO code | CFC | Injury Calculation |
|---|---|---|---|---|
| CoG | Accelerations, $A_x$ | M0MBARCG0000ACXP | 60<br>180 | <br>For velocity integration |

## 2.15 Sled

| Location | Parameter | ISO code | CFC | Injury Calculation |
|---|---|---|---|---|
| Sled | Accelerations, $A_x$ | S0SLED000000ACXP | 60 | |

# 3 INJURY CRITERIA CALCULATION

This chapter describes the calculation for each injury criterion including the filters that are applied to each channel used in these calculations. The analysis software used by the Euro NCAP labs will follow these calculations in detail.

For all of the calculations and for all of the dummies used, only the loading phase of the crash is considered. Usually, the loading phase for all dummies in the frontal tests will end at the point in time where the filtered head acceleration $A_x$ crosses zero g after the minimum acceleration peak value. This does not apply to the farside occupant-to-occupant test, the loading phase to evaluate occupant-to-occupant interaction will end when all parts of both dummies are moving outboard.

It is up to Euro NCAP to confirm and determine the actual end of the loading phase.

## 3.1 Head criteria

### 3.1.1 Head resultant acceleration

The head resultant acceleration is calculated with the following formula:

$$A_R = \sqrt{{A_x}^2 + {A_y}^2 + {A_z}^2}$$

with:

| | | |
|---|---|---|
| $A_x$ | Filtered Head Acceleration $A_x$ | ??HEAD0000??ACXA |
| $A_y$ | Filtered Head Acceleration $A_y$ | ??HEAD0000??ACYA |
| $A_z$ | Filtered Head Acceleration $A_z$ | ??HEAD0000??ACZA |

### 3.1.2 $HIC_{15}$

The $HIC_{15}$ value is calculated with the following formula:

$$HIC_{15} = (t_2 - t_1)\left(\frac{1}{(t_2 - t_1)}\int_{t_1}^{t_2} A_R dt\right)^{2.5}$$

with:

$A_R$ Head Resultant Acceleration

### 3.1.3 Diffuse axonal multi-axis general evaluation (DAMAGE)

The DAMAGE criterion is calculated with the following formulae over the time window specified below. Head rotational velocity, filtered at CFC 60, shall be used to generate rotational acceleration throughout the impact.

$$\begin{bmatrix} m_x & 0 & 0 \\ 0 & m_y & 0 \\ 0 & 0 & m_z \end{bmatrix} \begin{Bmatrix} \ddot{\delta}_x \\ \ddot{\delta}_y \\ \ddot{\delta}_z \end{Bmatrix} + \begin{bmatrix} c_{xx}+c_{xy}+c_{xz} & -c_{xy} & -c_{xz} \\ -c_{xy} & c_{xy}+c_{yy}+c_{yz} & -c_{yz} \\ -c_{xz} & -c_{yz} & c_{xz}+c_{yz}+c_{zz} \end{bmatrix} \begin{Bmatrix} \dot{\delta}_x \\ \dot{\delta}_y \\ \dot{\delta}_z \end{Bmatrix} +$$

$$\begin{bmatrix} k_{xx}+k_{xy}+k_{xz} & -k_{xy} & -k_{xz} \\ -k_{xy} & k_{xy}+k_{yy}+k_{yz} & -k_{yz} \\ -k_{xz} & -k_{yz} & k_{xz}+k_{yz}+k_{zz} \end{bmatrix} \begin{Bmatrix} \delta_x \\ \delta_y \\ \delta_z \end{Bmatrix} = \begin{bmatrix} m_x & 0 & 0 \\ 0 & m_y & 0 \\ 0 & 0 & m_z \end{bmatrix} \begin{Bmatrix} \ddot{u}_x \\ \ddot{u}_y \\ \ddot{u}_z \end{Bmatrix}$$

$$DAMAGE = \beta max_t\{|\vec{\delta}(t)|\}$$

$$\vec{\delta}(t) = [\delta_x(t) \quad \delta_y(t) \quad \delta_z(t)]^T, \ \beta = \text{scale factor}$$

$$\text{m} = \text{mass}, c_{ij} = \text{damping}, k_{ij} = \text{stiffness}$$

$$\ddot{\delta}, \dot{\delta}, \delta = acceleration, velocity, displacement$$

$$\ddot{u} = applied\ angular\ acceleration$$

$$m_x = 1\ kg, m_y = 1\ kg, m_z = 1\ kg$$

$$k_{xx} = 32142\ N/m, k_{yy} = 23493\ N/m, k_{zz} = 16935\ N/m,$$

$$k_{xy} = 0\ N/m, k_{yz} = 0\ N/m, k_{xz} = 1636.3\ N/m, a1 = 5.9148\ ms, \beta = 2.9903\ 1/m$$

$$[c] = a1 \times [k]$$

When calculating DAMAGE, a time window is specified to exclude certain secondary contacts between the head and vehicle interior. Note, this window does not apply to either HIC or 3ms exceedance calculations. The exclusion criteria are based upon those used by JNCAP.

This criterion will be evaluated during the loading and early rebound phases of the impact over a max period from T0 up to 200ms. The time window will be reduced to less than 200ms if, during head rebound, a secondary impact results in an external force on the head drops below -500N.

The external force acting on the head shall be calculated using the head x acceleration and upper neck x force using the formula below. End the calculation when: F external x < -500N

$$F_{external\ x} = -M_{Head} \times a_{Head\ x} + F_{Neck_{upper}x}$$

Where $M_{Head}$ = 4.2kg.

### 3.1.4 Head restraint contact time

The head restraint contact time is calculated with the following formula:

$$T_{HRC} = T_{HRC,end} - T_{HRC,start}$$

with:

| | | |
|---|---|---|
| $T_{HRC,start}$ | Time of first contact of head and HR after T=0 | ??HERE000000EV00 |
| $T_{HRC,end}$ | Time where contact is lost | ??HERE000000EV00 |

Head restraint contact time $T_{HRC(Start)}$ is defined as the time (calculated from T=0) of first contact between the rear of the ATD head and the head restraint, where the subsequent continuous contact duration exceeds 40ms. For the purposes of assessment, $T_{HRC(Start)}$ shall be rounded to the nearest millisecond. Gaps up to 1ms are ignored if proven to be the result of poor electrical contact. $T_{HRC_{(end)}}$ is defined as the time at which the head first loses contact with the head restraint, where the subsequent continuous loss of contact duration exceeds 40ms.

### 3.1.5 Head rebound velocity

The head rebound velocity (in the horizontal/X direction) shall be determined using dummy head CoG target tracking from camera footage. Head rebound velocity shall be calculated as follows:

$$V_{Rebound} = V_{Head\ CoG\ (abs)} - V_{Sled\ (abs)}$$

Where:

$V_{Rebound}$ = Instantaneous rebound X-velocity of the head c-of-g, relative to the sled

$V_{Head\ CoG\ (abs)}$ = Instantaneous X-velocity of head centre of gravity, absolute.

$V_{Sled\ (abs)}$ = Instantaneous X-velocity of sled, absolute.

### 3.1.6 T1 x-acceleration

The T1 x-acceleration value is calculated with the following formula:

$$T1 = \frac{T1_{left} + T1_{right}}{2}$$

with:

| | | |
|---|---|---|
| $T1_{left}$ | Filtered left T1 acceleration | ??THSP01LEBRACXD |
| $T1_{right}$ | Filtered right T1 acceleration | ??THSP01RIBRACXD |

The maximum, $T1_{max}$, should be generated from this average T1 channel, considering only the portion of data from T-zero until T-$HRC_{(end)}$ as follows:

$$T1_{max} = \underset{T-HRC_{(end)}}{\text{Max}} [T1(t)]$$

## 3.2 Neck criteria

### 3.2.1 Neck extension bending moment @ OC

The neck extension bending moment is calculated with the following formula:

$M_{OCy} = M_y - F_x \cdot d$

with:

| | | |
|---|---|---|
| $M_y$ | Filtered Bending Moment | ??NECKUP00??MOYB |
| $F_x$ | Filtered Shear Force | ??NECKUP00??FOXB |
| d | 0.01778m for HIII-50M & HIII-05F and 0.0195m for WorldSID | |

### 3.2.2 Neck lateral flexion bending moment @ OC

The neck lateral flexion bending moment is calculated with the following formula:

$M_{OCx} = M_x + F_y \cdot d$

with:

| | | |
|---|---|---|
| $M_x$ | Filtered Bending Moment | ??NECKUP00WSMOXB |
| $F_y$ | Filtered Shear Force | ??NECKUP00WSFOYB |
| d | 0.0195m WorldSID | |

### 3.2.3 Neck extension bending moment

The neck extension bending moment is calculated with the following formula:

$M_y = abs\left(\min\left(M_y\right)\right)$

with:

$M_y$ Filtered Bending Moment for THOR ??NECKUP00??MOYB

$M_y$ Filtered Bending Moment for WorldSID

??NECKLO00??MOYB

### 3.2.4 Neck lateral flexion bending moment @ Neck base

The neck lateral flexion bending moment is calculated with the following formula:

$Mx_{(base\ of\ neck)} = \max(\ \mathrm{abs}(Mx_M - Fy_m \times Dz)\ )$

with:

| | | |
|---|---|---|
| $Mx_M$ = | Filtered Bending Moment | ??NECKLO00WSMOXB |
| $Fy_M$ = | Filtered Shear Force | ??NECKLO00WSFOYB |
| Dz = | 0.0145m for WorldSID (ISO 15830) | |

$My_{(base\ of\ neck)} = \ |\min(My_M + Fx_M * Dz)|$

with:

| | | |
|---|---|---|
| $My_M$ = | Filtered Bending Moment | ??NECKLO00WSMOYB |
| $Fx_M$ = | Filtered Shear Force | ??NECKLO00WSFOXB |
| Dz = | 0.0145m for WorldSID (ISO 15830) | |

### 3.2.5 Upper and lower neck shear force and tension

Positive shear shall indicate head-rearwards motion and positive tension should be associated with pulling the head upwards, generating a tensile force in the neck. Firstly, the Fx and Fz channels shall be filtered as defined in Section 2.6. Peak values shall be determined for each of the forces, considering only the portion of data from T-zero until T-HRC(end), as follows:

$$Fx_{max} = \underset{T-HRC_{(end)}}{\mathrm{Max}}[Fx(t)]$$

$$Fz_{max} = \underset{T-HRC_{(end)}}{\mathrm{Max}}[Fz(t)]$$

### 3.2.6 NIC

The NIC value is calculated with the following formula:

$$NIC = 0.2 \cdot A_{rel} + {v_{rel}}^2$$

with:

$$A_{rel} = T1 - A_{x,head}$$

$$v_{rel} = \int A_{rel}$$

| | | |
|---|---|---|
| T1 | Average T1 acceleration | |
| $A_{x,head}$ | Filtered Head Acceleration $A_x$ | ??HEAD0000BRACXD |

### 3.2.7 Nkm

The Nkm value is calculated with the following formula:

$$Nkm(t) = N_{ep}(t) + N_{ea}(t) + N_{fp}(t) + N_{fa}(t)$$

with:

$$N_{ep}(t) = \frac{M_{ocye}(t)}{-47.5Nm} + \frac{F_{xp}(t)}{-845N}$$

$$N_{ea}(t) = \frac{M_{ocye}(t)}{-47.5Nm} + \frac{F_{xa}(t)}{845N}$$

$$N_{fp}(t) = \frac{M_{ocyf}(t)}{88.1Nm} + \frac{F_{xp}(t)}{-845N}$$

$$N_{fa}(t) = \frac{M_{ocyf}(t)}{88.1Nm} + \frac{F_{xa}(t)}{845N}$$

$$M_{OCy}(t) = M_y(t) - D \cdot F_x(t)$$

| | | |
|---|---|---|
| $F_x(t)$ | Filtered Upper Neck Shear Force $F_x$ | ??NECKUP00BRFOXB |
| $M_y(t)$ | Filtered Upper Neck Moment $M_y$ | ??NECKUP00BRMOYB |

| | |
|---|---|
| D | 0.01778m |
| $F_{xp}(t)$ | negative portion of $F_x(t)$ |
| $F_{xa}(t)$ | positive portion of $F_x(t)$ |
| $M_{ye}(t)$ | negative portion of $M_{OCy}(t)$ |
| $M_{yf}(t)$ | positive portion of $M_{OCy}(t)$ |

When the 4 criteria are calculated, particular forces and moments must be set to 0. This is an AND condition. That is if one of the summands is zero, the condition is also zero. Consider only the portion of data from T-zero until $T\text{-}_{HRC(end)}$.

## 3.3 Shoulder criteria

### 3.3.1 Lateral shoulder force

The Lateral Shoulder Force is calculated with the following formula:

$$Fy_{shoulder} = abs\left(\min\left(F_y(t)\right)\right)$$

with:

$F_y$ Filtered Shoulder Force $F_y$ ??SHLD[LE,RI]00WSFOYB

### 3.3.2 Lateral shoulder rib displacement

The lateral shoulder rib displacement is calculated with the following formula:

$$Dy_{shoulder} = \max\left(D_y(t) - D_y(0)\right)$$

with:

$$D_y(t) = R(t) \cdot \sin(\Phi(t))$$

R(t) Filtered Shoulder sensor length ??SHRI[LE,RI]00WSDC0C

$\Phi(t)$ Filtered Shoulder sensor rotation ??SHRI[LE,RI]00WSANZC

$D_y(0)$ Lateral Shoulder Rib Displacement @ t=0

Further details regarding definitions for measurement coordinate system, sensor offsets and polarities, and post-processing can be found in ISO/TS21002.

## 3.4 Chest criteria

### 3.4.1 Chest deflection

The chest deflection value is calculated with the following formula:

$$D_{chest} = \max\left(D_{chest}(t)\right)$$

with:

$D_{chest}(t)$ Filtered Chest Deflection $D_{chest}$ ??CHST0003??DSXC

### 3.4.2 Chest rib displacement

The chest rib displacement is calculated with the following formula:

$$D_{rib} = max\left(\sqrt{D_x(t)^2 + D_y(t)^2 + D_z(t)^2}\right)$$

with:

$$D_x(t) = \delta \cdot sin(\Phi_y(t)) + R(t) \cdot cos(\Phi_z(t)) \cdot cos(\Phi_y(t)) - D_x(0)$$
$$D_y(t) = R(t) \cdot sin(\Phi_z(t)) - D_y(0)$$
$$D_z(t) = \delta \cdot cos(\Phi_y(t)) - R(t) \cdot cos(\Phi_z(t)) \cdot sin(\Phi_y(t)) - D_z(0)$$

R(t) Filtered Chest Rib sensor length
??CHST[LE,RI][UP,LO]T3DC0C
$\Phi_y(t)$ Filtered Chest Rib sensor rotation
??CHST[LE,RI][UP,LO]T3ANYC
$\Phi_z(t)$ Filtered Chest Rib sensor rotation
??CHST[LE,RI][UP,LO]T3ANZC
$D_{[x,y,z]}(0)$ Chest Rib Displacement in x,y,z direction @ t=0
δ +15.65mm for Upper Chest Rib and -15.65mm for Lower Chest Rib

Definitions regarding measurement coordinate system, sensor offsets and polarities, and post-processing can be found in ISO/TS21002. Where a vehicle is equipped with pretensioners that activate before T0, the displacement prior to activation shall be used for $D_{x,y,z}(0)$.

Rmax is used for the injury calculation.

### 3.4.3 Chest displacement

The Q10 chest displacement in the MPDB test is calculated for the upper and lower measurement system with the following formula:

$$D_{rib} = max\left(\sqrt{D_x(t)^2 + D_y(t)^2}\right)$$

with:

$$D_x(t) = R(t) \cdot cos(\Phi_z(t)) - D_x(0)$$
$$D_y(t) = R(t) \cdot sin(\Phi_z(t)) - D_y(0)$$

R(t) Filtered sensor length ??CHST[LO,UP]00QBDC0C
$\Phi_z(t)$ Filtered sensor rotation
??CHST[LO,UP]00QBANZC
$D_{[x,y]}(0)$ Chest Displacement @ t=0

Definitions regarding measurement coordinate system, sensor offsets and polarities, and post-processing can be found in ISO/TS21002. Where a vehicle is equipped with pretensioners that activate before T0, the displacement prior to activation shall be used for $D_{[x,y]}(0)$.

### 3.4.4 Seatbelt force

The Seatbelt force modifier is calculated with the following formula:

$F_{seatbelt} = \max(F_{seatbelt}(t))$
with:
$F_{seatbelt}$ Filtered Seatbelt Force
??SEBE0003B3FO0D

### 3.4.5 Lateral Thoracic Rib Displacement

The lateral thoracic rib displacement is calculated with the following formula:

$Dy_{thorax} = \max\left(D_y(t) - D_y(0)\right)$
with:
$D_y(t) = R(t) \cdot \sin(\Phi(t))$
R(t) Filtered Thoracic sensor length
??TRRI[LE,RI]01??DC0C
Φ (t) Filtered Thoracic sensor rotation
??TRRI[LE,RI]01??ANZC
$D_y(0)$ Lateral Thoracic Rib Displacement @ t=0

Definitions regarding measurement coordinate system, sensor offsets and polarities, and post-processing can be found in ISO/TS21002.

### 3.4.6 Viscous Criterion

The VC is calculated with the following formula:

$VC = sf \cdot V(t) \times C(t)$
With:
sf 1.3 for HIII-50M, 1.3 for HIII-05F and 1.0 for WorldSID

$$V(t) = \frac{8(D_{chest}(t+1) - D_{chest}(t-1)) - (D_{chest}(t+2) - D_{chest}(t-2))}{12\Delta t}$$

$$C(t) = \frac{D_{chest}(t)}{D_{constant}}$$

$D_{chest}(t)$ Filtered Chest Deflection $D_{chest}$
??CHST0003??DSXC
for WorldSID use calculated Lateral Thoracic Rib Displacement $Dy_{thorax}$
Δt Time step
$D_{constant}$ 0.229 for HIII-50M, 0.187 for HIII-05F and 0.170 for WorldSID [Q10 TBC]

## 3.5 Abdominal criteria

### 3.5.1 T12 resultant acceleration

The T12 resultant acceleration is calculated with the following formula:

$$A_R = \sqrt{{A_x}^2 + {A_y}^2 + {A_z}^2}$$

with:

| | | |
|---|---|---|
| $A_x$ | Filtered T12 Acceleration $A_x$ | ??THSP1200WSACXC |
| $A_y$ | Filtered T12 Acceleration $A_y$ | ??THSP1200WSACYC |
| $A_z$ | Filtered T12 Acceleration $A_z$ | ??THSP1200WSACZC |

### 3.5.2 Abdominal rib displacement (THOR)

The abdominal rib displacement is calculated with the following formula:

$$D_{rib} = max(D_x(t))$$

with:

$$D_x(t) = R(t) \cdot cos(\Phi_z(t)) \cdot cos(\Phi_y(t)) - D_x(0)$$

R(t) Filtered Abdominal Rib sensor length
??ABDO[LE,RI]00T3DC0C

$\Phi_y(t)$ Filtered Abdominal Rib sensor rotation
??ABDO[LE,RI]00T3ANYC

$\Phi_z(t)$ Filtered Abdominal Rib sensor rotation
??ABDO[LE,RI]00T3ANZC

$D_{[x,y,z]}(0)$ Abdominal Rib Displacement in x,y,z direction @ t=0

Definitions regarding measurement coordinate system, sensor offsets and polarities, and post-processing can be found in ISO/TS21002. Where a vehicle is equipped with pretensioners that activate before T0, the displacement prior to activation shall be used for $D_{x,y,z}(0)$.

### 3.5.3 Lateral abdominal rib displacement

The lateral abdominal rib displacement is calculated with the following formula:

$$Dy_{abdomen} = \max\left(D_y(t) - D_y(0)\right)$$

with:

$$D_y(t) = R(t) \cdot \sin(\Phi(t))$$

| | | |
|---|---|---|
| R(t) | Filtered Abdominal sensor length | ??ABRI[LE,RI]01WSDC0C |
| $\Phi(t)$ | Filtered Abdominal sensor rotation | ??ABRI[LE,RI]01WSANZC |
| $D_y(0)$ | Lateral Abdominal Rib Displacement @ t=0 | |

Definitions regarding measurement coordinate system, sensor offsets and polarities, and post-processing can be found in ISO/TS21002.

### 3.5.4 Viscous criterion

The VC is calculated with the following formula:

$$VC = sf \cdot V(t) \times C(t)$$

With:

sf 1.0 for WorldSID

$$V(t) = \frac{8(D_{y,abdomen}(t+\Delta t) - D_{y,abdomen}(t-\Delta t)) - (D_{y,abdomen}(t+2\Delta t) - D_{y,abdomen}(t-2\Delta t))}{12\Delta t}$$

$$C(t) = \frac{D_{y,abdomen}(t)}{D_{constant}}$$

$Dy_{abdomen}(t)$ Calculated Lateral Abdominal Rib Displacement

$\Delta t$ Time step

$D_{constant}$ 0.170 for WorldSID

## 3.6 Lower extremity criteria

### 3.6.1 Iliac force drop

The iliac force drop value is calculated with the following formula:

$$IFD = \max(IFD(t))$$

With:

$$IFD(t) = F_{iliac}(t + 0.001s) - F_{iliac}(t)$$

$F_{iliac}(t)$ Filtered Iliac Force $F_{iliac}$

??ILAC[LE,RI]00??FOXB

### 3.6.2 Acetabulum force

The resultant acetabulum force value is calculated with the following formula for time intervals where $F_{acetabulum,X}$ is in compressive load:

$$F_{acetabulum} = \max\left(\sqrt{F_{acetabulum,X}^2 + F_{acetabulum,Y}^2 + F_{acetabulum,Z}^2}\right)$$

With:

$F_{acetabulum,X}$ Filtered Femur Force $F_{acetabulum,X}$

??ACTB[LE,RI]00T3FOXB

$F_{acetabulum,Y}$ Filtered Femur Force $F_{acetabulum,Y}$

??ACTB[LE,RI]00T3FOYB

$F_{acetabulum,Z}$ Filtered Femur Force $F_{acetabulum,Z}$

??ACTB[LE,RI]00T3FOZB

### 3.6.3 Knee displacement

The knee displacement value is calculated with the following formula:

$$D_{knee} = |\min(D_{knee}(t))|$$

With:

$D_{knee}(t)$ Filtered Knee Displacement $D_{knee}$ ??KNSL[LE,RI]00??DSXC

### 3.6.4 Femur force

The femur force value is calculated with the following formula:

$$F_{femur} = \text{abs}\left(\min\left(F_{femur}(t)\right)\right)$$

With:

$F_{femur}(t)$ Filtered Femur Force $F_{femur}$ ??FEMR[LE,RI]00??FOZB

### 3.6.5 Tibia index

The tibia index is calculated with the following formula:

$$TI(t) = \left|\frac{M_R(t)}{(M_R)_C}\right| + \left|\frac{F_z(t)}{(F_z)_C}\right|$$

with:

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

$M_x$ Filtered Bending Moment $M_x$
??TIBI[LE,RI][UP,LO]??MOXB

$F_z$ Filtered Force $F_z$
??TIBI[LE,RI][UP,LO]??FOZB

$(M_R)_C$ 225Nm for HIII-50M & THOR and 115Nm for HIII-05F

$(F_z)_C$ 35.9kN for HIII-50M & THOR and 22.9N for HIII-05F

# 4 VEHICLE & SLED CRITERIA CALCULATION

This section describes the calculation for each vehicle criteria including the filters that are applied (where applicable) to each channel used in these calculations. The analysis software used by the Euro NCAP labs will follow these calculations in detail.

## 4.1 Occupant load criterion

The calculation for the test vehicle and trolley OLC in the MPDB test is as follows.

Measured X-acceleration ($A_X$) on the centre of gravity of MPDB shall be filtered using CFC180.

The acceleration from the backup CoG accelerometer shall only be used for the OLC calculation where there is a channel failure of the primary accelerometer.

The filtered acceleration pulse shall be integrated with the following equation to derive the velocity course of the barrier:

$$V_t = \int A_X(t)\, dt + V_0$$

Where $V_0$ is the initial velocity at $t = 0s$.

$OLC_{SI-unit}$, $t_1$ and $t_2$ can be calculated with solving the following equation system:

$$\begin{cases} \int_{t=0}^{t=t_1} V_0\, dt - \int_{t=0}^{t=t_1} V(t)\, dt = 0.065 \\ \int_{t=t_1}^{t=t_2} \left(V_0 - OLC_{SI-unit} \times (t - t_1)\right) dt - \int_{t=t_1}^{t=t_2} V(t)\, dt = 0.235 \\ V_0 - OLC_{SI-unit} \times (t_2 - t_1) = V(t_2) \end{cases}$$

Where:

- $t_1$ is end of the free-flight-phase of a virtual dummy in vehicle or on the barrier along a displacement of 0.065m, and
- $t_2$ is end of the restraining-phase of a virtual dummy in vehicle or on the barrier along a displacement of 0.235m after the free-flight-phase (i.e. in total 0.300m displacement for the virtual dummy).

OLC shall be converted from SI units into g (standard gravity) with the conversion factor of 1g = 9.81m/s²

## 4.2 Whiplash seatback dynamic deflection

The seatback dynamic deflection is defined as the maximum change in angle achieved at any time during the test between the T zero position and $T_{-HRC(end)}$. Measure the seatback dynamic deflection from the targets defined in the Euro NCAP Film and Photo protocol as follows:

- Define a line between the upper and lower seatback targets, ST2 and ST3.
- Define a second line between the forward and rearward sled base targets, B1 and B2.

- Calculate the angle between these two lines at the T-zero position. The instantaneous seatback deflection is defined as the instantaneous difference in angle between the T-zero position and the deflected position. Track the change in instantaneous angle between these two lines, throughout the dynamic test.

## 4.3 Compatibility assessment

$$C_{modifier} = OLC_{modifier} + SD_{modifier} + BO_{modifier}$$

with:

$$OLC_{modifier} = \begin{cases} 0 & OLC \leq 25g \\ OLC\% * 2 & 25g < OLC \leq 40g \\ 2 & OLC > 40g \end{cases}$$

$$SD_{modifier} = \begin{cases} SD\% * 2 & OLC \leq 25g \\ SD\% * ([2 + OLC\% * 6] - [OLC\% * 2]) & 25g < OLC \leq 40g \\ SD\% * 6 & OLC > 40g \end{cases}$$

$$OLC\% = \frac{OLC - 25}{40 - 25}$$

$$SD\% = \frac{SD - 50}{150 - 50}$$

where:

$C_{modifier}$ Compatibility modifier in points (capped to a maximum of 8 points)
$OLC_{modifier}$ Occupant Load Criterion modifier based on the OLC of the MPDB trolley in g
$SD_{modifier}$ Standard Deviation modifier based on the deformation of the PDB element
$BO_{modifier}$ Bottoming-Out modifier based on the deformation of the PDB element

Please note, for the purposes of the compatibility modifier, data is required at a sampling rate of 20kHz. The calculation of velocity change (dV), a CFC of 180 shall be used.