Crash Analysis

Description of Injury Criteria for Vehicle Safety Tests

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`Subject to Changes`

Working Group
Data Processing
Vehicle Safety

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CONTENT

1

Crash Analysis Criteria

The following section contains descriptions of the crash analysis criteria of the working group measurement data processing vehicle safety, algorithm working group. The order in which the crash analysis criteria are described follows mainly the structure of the human body.

For each criterion there is a description of the name, the criterion and the mathematical calculation as well as the input channels or values with the coding in compliance with ISO TS 13499 and a list of rules and regulations of the algorithm, which is not complete and which may not be up to date.

Note All descriptions are subject to a SAE J1733 conform signal polarity (Sign convention).

Changes - additions or corrections - to this document can be found in the chapter Document Change History at the end of this document.

Explanations to ISO TS 13499

The ISO TS 13499 (Technical Specification) describes a simple exchange format for multimedia data from vehicle safety tests.

The ISO TS 13499 describes the data storage structure and the coding of measurement or calculated channels and their attributes in the channel description.

In the current version you can encode the measurement channels as well as the criteria values described in this documentation.

Documents

The following table lists the meaning and source of the various single documents that the ISO TS 13499 contains.

Figure 1-1. Single documents of ISO TS 13499

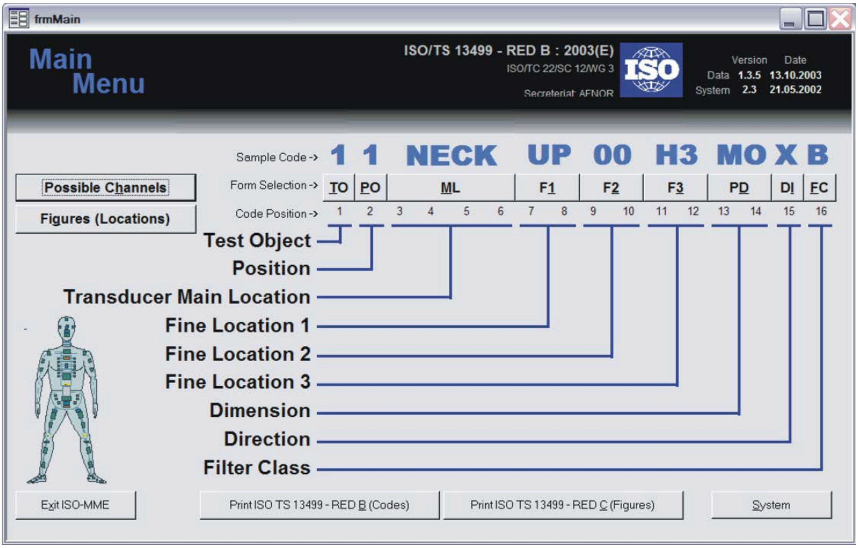
Document/Version	Contents	Source	Costs
ISO TS 13499	Main document	www.iso.org	yes
RED*A	Examples and hints	https://standards.iso.org/iso/13499	free of charge
RED B	Channel codes		
RED C	Figures		
RED D	NHTSA compatibility		
RED E	Calculated channels		

*RED - Related Electronic Document

Codes

The document RED B describes the channel codes used in this documentation. You can download the channel codes as a data base free of charge from `https://standards.iso.org/iso/13499`.

Figure 1-2. Main menu of the ISO TS 13499 database on the internet



2

Description of the Head Criteria

The following head criteria are described in this chapter:

HIC — Head Injury Criterion

HAC — Head Acceptability Criterion

HIC(d) — Performance Criterion

HPC — Head Performance Criterion

HCD — Head Contact Duration

BrIC — Brain Injury Criterion

HIC

HIC is the abbreviation for **H**ead **I**njury **C**riterion.

Description

The HIC value is the standardized maximum integral value of the head acceleration. The length of the corresponding time interval is:

- HIC: unlimited
- HIC36: maximum length of 36 ms
- HIC15: maximum length of 15 ms

Mathematical Calculation

The HIC value is calculated with the following formula:

$$HIC = sup_{t_1,t_2}\left\{\left(\frac{1}{t_2 - t_1}\int_{t_1}^{t_2} a\, dt\right)^{2.5} (t_2 - t_1)\right\}$$

$$a = \sqrt{a_x^2 + a_y^2 + a_z^2}$$

with the resultant acceleration *a* of the center of gravity of the head in units of acceleration of gravity (1 g = 9.81 m/s²). Tests in compliance with TRIAS assume (1 g = 9.80 m/s²) for the acceleration of gravity. t1 and t2 mark the lower and upper limit of the time range during an impact in which the HIC value is maximum. Measured times are to be given in seconds.

Determining Input Values

The measured channels of the head acceleration (a_X, a_Y, a_Z) are filtered in accordance with CFC 1000 (c.f. *CFC Filters*).

Only in accordance with UN-R80, the measured channels of the head acceleration (a_X, a_Y, a_Z) are filtered in accordance with CFC 600.

ISO TS 13499 Code

The ISO code describes the input channels for the HIC as follows:

```
? ? HEAD 00 00 ?? AC X A :Head Acceleration X, CFC 1000
? ? HEAD 00 00 ?? AC Y A :Head Acceleration Y, CFC 1000
? ? HEAD 00 00 ?? AC Z A :Head Acceleration Z, CFC 1000
? ? HEAD 00 00 ?? AC X B :Head Acceleration X, CFC 600, (UN-R80)
? ? HEAD 00 00 ?? AC Y B :Head Acceleration Y, CFC 600, (UN-R80)
```

? ? HEAD 00 00 ?? AC Z B :Head Acceleration Z, CFC 600, (UN-R80)

Relevant Laws and Regulations

- SAE J2052, 3.2
- SAE J1727,6.1
- ISO/TC22/SC12/WG3 N 282 Issued 1990-03-16
- ADR69/00, 5.3.1
- FMVSS 208, S6.2
- UN-R80, Annex 4, 1
- UN–R22, 7.3.2.5
- Euro NCAP, Frontal Impact, 10, 10.1
- Euro NCAP, Side Impact, 10, 10.1
- Euro NCAP, Pole Side Impact, 10, 10.1
- Euro NCAP, Assessment Protocol , 5
- Euro NCAP, Pedestrian Testing Protocol, 10.2
- TRIAS 47, Frontal Impact, 2-6
- TRIAS 63, Pedestrian Impact, 2.4
- ISO-MME, RED E (Calculated Value Codes and Channels)

HAC

HAC is the abbreviation for **H**ead **A**cceptability **C**riterion

Caution The calculation instruction in the UN-R80 is outdated. The current UN version uses the HIC instead (see *HIC*).

Description

The HAC value is the standardized maximum integral value of the head acceleration.

Mathematical Calculation

The HAC value is calculated with the following formula:

$$HAC = sup_{t_1,t_2}\left\{\left(\frac{1}{t_2 - t_1}\int_{t_1}^{t_2} a\,dt\right)^{2.5}(t_2 - t_1)\right\}$$

$$a = \sqrt{a_x^2 + a_y^2 + a_z^2}$$

With the resultant acceleration a of the center of gravity of the head in units of acceleration of gravity (1 g = 9,81 m/s²). t1 and t2 mark the lower and upper limit of the time range during an impact in which the HAC value is maximum. Measured times are to be given in seconds.

Determining Input Values

The measured channels of the head acceleration (a_X, a_Y, a_Z) are filtered in accordance with **CFC 600** (c.f. *CFC Filters*).

ISO TS 13499 Code

The ISO code describes the input channels for the HAC as follows:

```
? ? HEAD 00 00 ?? AC X B :Head Acceleration X, CFC 600
? ? HEAD 00 00 ?? AC Y B :Head Acceleration Y, CFC 600
? ? HEAD 00 00 ?? AC Z B :Head Acceleration Z, CFC 600
```

Relevant Laws and Regulations

- UN–R80, 5.2.2.1.1
- UN–R80, Annex 7, 1.1
- Directive 74/408/EWG, Annex III, Appendix 4, 1.1

HIC(d)

HIC(d) is the Performance Criterion used for free motion headform tests only.

Description

The HIC(d) value is the weighted standardized maximum integral value of the head acceleration and is calculated from the HIC36 value.

Mathematical Calculation

The HIC(d) value is calculated with the following formula:

$$HIC(d) = 0.75446 * HIC36 + 166.4$$

with *HIC36* HIC 36 value

(See also *HIC*)

Determining Input Values

The measured channels of the head acceleration (a_x, a_y, a_z) are filtered in accordance with CFC 1000 (see *CFC Filters*).

ISO TS 13499 Code

The ISO code describes the input channels for the HIC(d) as follows:

```
? ? HEAD 00 00 ?? AC X A :Head Acceleration X, CFC 1000
? ? HEAD 00 00 ?? AC Y A :Head Acceleration Y, CFC 1000
? ? HEAD 00 00 ?? AC Z A :Head Acceleration Z, CFC 1000
```

Relevant Laws and Regulations

- FMVSS 201, S7
- FMVSS 201 U, Page 4
- NHTSA 49 CFR 571[Docket No. 92-28; Notice8], [RIN No. 2127-AG07];S7
- NHTSA 49 CFR 571,572,589[Docket No. 92-28; Notice7], [RIN No. 2127-AB85]; S7
- SAE J1727, 6.2

HPC

HPC is the abbreviation for **H**ead **P**erformance **C**riterion (criterion for the head strain).

Description

The HPC value is the standardized maximum integral value of the head acceleration and is identical to the HIC value (see *HIC*).

Mathematical Calculation

The HPC value is calculated with the following formula:

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

$$a = \sqrt{a_x^2 + a_y^2 + a_z^2}$$

with the resultant acceleration *a* of the center of gravity of the head in units of acceleration of gravity (1 g = 9,81 m/s²).

Frontal Impact and Side Impact

If there was no head contact, this criterion is fulfilled.

If the beginning of the head contact can be determined satisfactorily, t_1 and t_2 are the two time points, given in seconds, which define a period between the beginning of the head contact and the end of the recording, at which the HPC36 (max. 36ms) is maximum.

If the beginning of the head contact cannot be determined satisfactorily, t_1 and t_2 are the two time points, expressed in seconds, which define a period between the beginning of the head contact and the end of the recording, at which the HPC36 is at its maximum.

Pedestrian Protection

The corresponding time interval is a maximum of 15 ms (HPC15).

Determining Input Values

The measured channels of the head acceleration (a_x, a_y, a_z) are filtered in accordance with CFC 1000 (see *CFC Filters*).

ISO TS 13499 Code

The ISO code describes the input channels for the HPC as follows:

```
? ? HEAD 00 00 ?? AC X A :Head Acceleration X, CFC 1000
? ? HEAD 00 00 ?? AC Y A :Head Acceleration Y, CFC 1000
? ? HEAD 00 00 ?? AC Z A :Head Acceleration Z, CFC 1000
```

Relevant Laws and Regulations

- Directive 96/79/EG, Annex II, 3.2.1.1
- Directive 96/79/EG, Annex II, Appendix 2, 1.2
- Directive 2003/102/EG
- Directive 2004/90/EG, 2.10
- UN-R94, Annex 4, 1.2
- UN-R95, 5.2.1.1
- UN-R95, Annex 4, Appendix 1, 1.
- Euro NCAP, Pedestrian Testing Protocol
- EEVC AG 17 Pedestrian Safety, Terms of Reference 2002

HCD

HCD is the abbreviation for **H**ead **C**ontact **D**uration.

Description

The HCD value is the standardized maximum integral value of the head acceleration during head contact intervals. The contact intervals are determined using the resultant contact force (calculated from neck force of the upper neck transducer, head acceleration and head mass).

Mathematical Calculation

To determine the contact interval, the resultant contact force *F* has to be calculated first.

$$F = \sqrt{(m * a_x - F_x)^2 + \left(m * a_y - F_y\right)^2 + (m * a_z - F_z)^2}$$

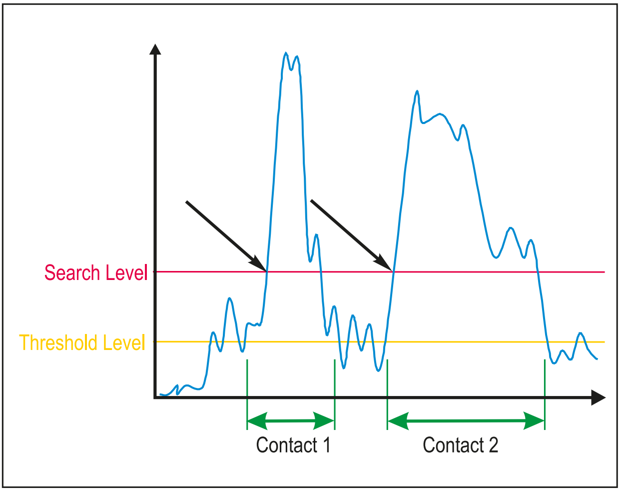
with m Mass of the head

a_i Head acceleration in the i direction

F_i Upper neck force in the i direction

Contact intervals are all the intervals in which a lower threshold value (threshold level = 200 N) is constantly exceeded and a lower search level (search level = 500 N) is exceeded at least once as the following figure shows.

Figure 2-1. Contact intervals



The HIC_j value is calculated for every contact interval *Kj*.

$$K_j = t_j^{beg}; \quad t_j^{end}$$

$$HIC_j = HIC(t_1, t_2); \quad t_j^{beg} \le t_1 < t_2 \le t_j^{end}$$

with t_j^{beg} Start point for contact interval *Kj*

t_j^{end} End time for contact interval *Kj*

The HCD value is then the maximum HIC value of all the contact intervals.

$$HCD = max_j\{ HIC_j\}$$

Determining Input Values

The measured channels of the head acceleration (a_X, a_Y, a_Z) and the neck force (F_X, F_Y, F_Z) are filtered in accordance with CFC 1000 (see *CFC Filters*).

ISO TS 13499 Code

The ISO code describes the input channels for the HCD as follows:

```
? ? HEAD 00 ?? ?? AC X A :Head Acceleration X, CFC 1000
? ? HEAD 00 ?? ?? AC Y A :Head Acceleration Y, CFC 1000
? ? HEAD 00 ?? ?? AC Z A :Head Acceleration Z, CFC 1000
? ? NECK UP ?? ?? FO X A :Upper Neck Force X, CFC 1000
? ? NECK UP ?? ?? FO Y A :Upper Neck Force Y, CFC 1000
? ? NECK UP ?? ?? FO Z A :Upper Neck Force Z, CFC 1000
```

Relevant Laws and Regulations

- SAE J2052, 3.3
- SAE J2052, 5
- ISO/TC22/SC12/WG3 N 282 (Issued 1990-03-16)
- TRANS/SC1/WP29/GRSP/R.48/Rev.1, page 19, Annex 4, Appendix 1

BrIC

BrIC is the abbreviation for **Br**ain **I**njury **C**riterion.

Description

The BrIC value estimates the injury risk of the brain due to rotary movements of the skull.

Mathematical Calculation

To specify the BrIC value, the maximum angular velocity of the head for every direction is divided by the associated critical value and then added. When the BrIC value approaches the value 1, the injury risk increases.

$$BrIC = \sqrt{\left(\frac{max(|\omega_x|)}{\omega_{xC}}\right)^2 + \left(\frac{max(|\omega_y|)}{\omega_{yC}}\right)^2 + \left(\frac{max(|\omega_z|)}{\omega_{zC}}\right)^2}$$

with	$\omega_{[x,y,z]}$	Head angular velocity in the x, y, and z direction *[rad/s]*
	$max(\lvert\omega_{[x,y,z]}\rvert)$	Maximum head angular velocity in the x, y, and z direction *[rad/s]*
	$\omega_{[x,y,z]C}$	Critical value of the maximum head angular velocity in the x, y, and z direction $\omega_{xC} = 66.25\ rad/s$ $\omega_{yC} = 56.45\ rad/s$ $\omega_{zC} = 42.87\ rad/s$

Determining Input Values

The measured channels of the head angular velocity (ω_x, ω_y, ω_z) are filtered according to CFC 60 (see *CFC Filters*).

ISO TS 13499 Code

The ISO code describes the input channels for the BrIC as follows:

```
? ? HEAD 00 ?? ?? AV X D :Head Angular Velocity X, CFC 60
? ? HEAD 00 ?? ?? AV Y D :Head Angular Velocity Y, CFC 60
? ? HEAD 00 ?? ?? AV Z D :Head Angular Velocity Z, CFC 60
```

Relevant Laws and Regulations

- Takhounts, 2013
- NHTSA, Draft 2013-11-15

3

Description of the Neck Criteria

The following neck criteria for a frontal and a rear impact are described:

Frontal Impact:

MOC — Total Moment about Occipital condyle

MTO — Total Moment (Lower Neck)

Time-dependent loading criterion (Time at Level) — Exceeding lower threshold duration

NIC (Frontal Impact ECE) — Neck Injury Criterion

NIC (Frontal Impact Euro NCAP) — Neck Injury Criterion

NIC (Frontal Impact FMVSS) — Neck Injury Criterion

NIC (IIHS) — Neck Injury Criterion

NIJ — Normalized Neck Injury Criterion

Rear Impact:

T1max (Rear Impact Euro NCAP) — Spine Injury Criterion

NIC (Rear Impact) — Neck Injury Criterion

NIC (Rear Impact Euro NCAP) — Neck Injury Criterion

Nkm — Neck Criterion rear impact

LNL — Lower Neck Load Index

MOC

MOC is the abbreviation for Total **M**oment about **O**ccipital **C**ondyle.

Description

The criterion for the Total Moment calculates the total moment in relation to the moment measurement point.

Mathematical Calculation

The Total Moment Moc value for the Upper-Load-Cell is calculated in accordance with SAE J1727 and SAE J1733 as follows:

$$M_{OCy} = M_y - (F_x * D)$$
$$M_{OCx} = M_x + (F_y * D)$$

with	MOC_i	Total moment in i-direction [Nm]
	M_i	Neck moment in i-direction [Nm]
	F_i	Neck force in i-direction [N]
	D	Distance between the force sensor axis and the condyle axis [m]

Determining Input Values

The measured values for the forces and moments are filtered in accordance with CFC 600 (see *CFC Filters*). This filtering applies independently of the filter classes for forces, specified in SAE J211 (see also FMVSS208 S6.6(1)).

The following table lists the lever arms of the Upper Load Cell for the calculation in accordance with SAE J1727, for different dummy types.

Table 3-1. Lever Arms of the Upper Neck Load Cell

Dummy Type	Load Cell Type Denton; FTSS; MSC	Axial Directions	D[m]
Hybrid III; male 95%	1716; IF-2564, IF-205, IF-207, IF-242; 555B/6UN	6	0.01778
Hybrid III; male 50%	1716; IF-2564, IF-205, IF-207, IF-242; 555B/6UN	6	0.01778
	2062	3	0.008763
Hybrid III, female 5%	1716; IF-2564, IF-205, IF-207, IF-242; 555B/6UN	6	0.01778
Hybrid III; 10-year	1716; IF-2564, IF-205, IF-207, IF-242; 555B/6UN	6	0.01778
Hybrid III; 6-year	1716; IF-2564, IF-205, IF-207, IF-242; 555B/6UN	6	0.01778
Hybrid III; 3-year	3303; IF-234; 560G/6ULN	6	0
Crabi 12; 18 months	2554; IF-954; 560G/6ULN	6	0.005842
TNO P1,5	2554; IF-954; 560G/6ULN	6	0.0247
Crabi 6 months	2554; IF-954; 560G/6ULN	6	0.0102
TNO P 3/4; P3	2331; IF-212, IF-235; 5583G/3ULN	3	0
	2587; IF-212, IF-235; 558G/6UN	6	0
ES-2	1485	3	0
	4085, IF-240; 5552G/6UN	6	0.02
TNO Q-Series	3715, IF-217; 5563G/6LN	6	0
SID-IIs	1716; IF-2564, IF-205, IF-207, IF-242; 555B/6UN	6	0.01778
BioRID	2062	3	0.008763
	4949	6	0.01778
	2564	3	0.01778
	4985	3	0.01778
WORLDSID 50%	W50-71000	6	0.0195
WORLDSID 5%	W50-71000	6	0.0195

ISO TS 13499 Code

The ISO code describes the input channels for the MOC as follows:

```
? ? NECK UP 00 ?? MO X B :Upper Neck Moment X, CFC 600
? ? NECK UP 00 ?? MO Y B :Upper Neck Moment Y, CFC 600
? ? NECK UP 00 ?? FO X B :Upper Neck Force X, CFC 600
? ? NECK UP 00 ?? FO Y B :Upper Neck Force Y, CFC 600
```

Relevant Laws and Regulations

- SAE J1727,6.5
- SAE J1733
- Denton Sign Convention for Load Cells (S.A.E. J-211)

MTO

MTO is the abbreviation for **To**tal **M**oment and applies for the lower neck.

Description

The criterion for the Total Moment calculates the total moment in relation to the moment measurement point.

Mathematical Calculation

The Total Moment MTO value for the Lower Neck Load Cell is calculated in accordance with SAE J1733 as follows:

$$M_{TOx} = M_x - (F_y * D_z)$$

$$M_{TOy} = M_y + (F_x * D_z) + (F_z * D_x)$$

$$M_{TOz} = M_z - (F_y * D_x)$$

with M_{TOi} Total moment in i-direction [Nm]

M_i Neck moment in i-direction [Nm]

F_i Neck force in i-direction [N]

D_j Distance between the force sensor axis and the condyle axis [m]

Determining Input Values

The measured values for the forces and moments are filtered in accordance with CFC 600 (see *CFC Filters*). This filtering applies independently of the filter classes for forces, specified in SAE J211 (see also FMVSS208 S6.6(1)).

The following table lists the lever arms D_x and D_z in the Lower Load Cell for the calculation in accordance with SAE J1733 in relation to the dummy type.

Table 3-2. Lever Arms D_X and D_Z of the Lower Neck Load Cell

Dummy Type	Load Cell Type Denton; FTSS	D_X[m]	D_Z[m]
Hybrid III; male 95%	1794; IF-210, IF-219	0.0508	0.028575
	4894		
Hybrid III; male 50%	1794; IF-210, IF-219		
	4894		
Hybrid III; female 5%	1794; IF-211, IF-228, IF-238	0.04445	0.028575
	4541		
Hybrid III; 10-year	5124	0	0.0188
Hybrid III; 6-year	1794; IF-222	0.03175	0.0237236
Hybrid III; 3-year	3303	0	0.0168
CRABI 6,12,18,TNO, P1 1/2	2554LN; IF-954	0	0.0127
TNO Q1, Q3, Q6	3715	0	0
SID-IIs	1794; IF-255	0.04445	0.0254
	3166		
SID HIII	5294	0	0.0127
THOR 50%	2357	0	0.0254
THOR 5%	2357	0	0.0191
	4366		
EuroSID-1	4365; IF-221	0	0.022
	3300		
ES-2	- ; IF-221	0.04445	0.028575
BioRID	1794	0.0508	0.0254
BioRID 2	5580	0	0
BioSID	1794	0.0508	0.0254
WORLDSID	W50-1700	0	0.0145

Note You must use special formulas for the adjustable load cells 2992, 3471, and 3717. Refer to the publication *Denton Sign Convention for Load Cells (SAE J211) (27AUG02)* for further information.

Note Lower Neck Load Cell of BioRID; 1794, validated in dynamic testing *LNL*.

ISO TS 13499 Code

The ISO code describes the input channels for the MTO as follows:

```
? ? NECK LO 00 ?? MO X B :Lower Neck Moment X, CFC 600
? ? NECK LO 00 ?? MO Y B :Lower Neck Moment Y, CFC 600
? ? NECK LO 00 ?? MO Z B :Lower Neck Moment Z, CFC 600
? ? NECK LO 00 ?? FO X B :Lower Neck Force X, CFC 600
? ? NECK LO 00 ?? FO Y B :Lower Neck Force Y, CFC 600
? ? NECK LO 00 ?? FO Z B :Lower Neck Force Z, CFC 600
```

Relevant Laws and Regulations

- SAE J1727,6.6
- SAE J1733
- Denton Sign Convention for Load Cells (SAE J211)

Time-dependent loading criterion (Time at Level)

Time-dependent loading criterion (Time-dependent loading criterion) used for neck and femur forces, also named Duration of Loading

Description

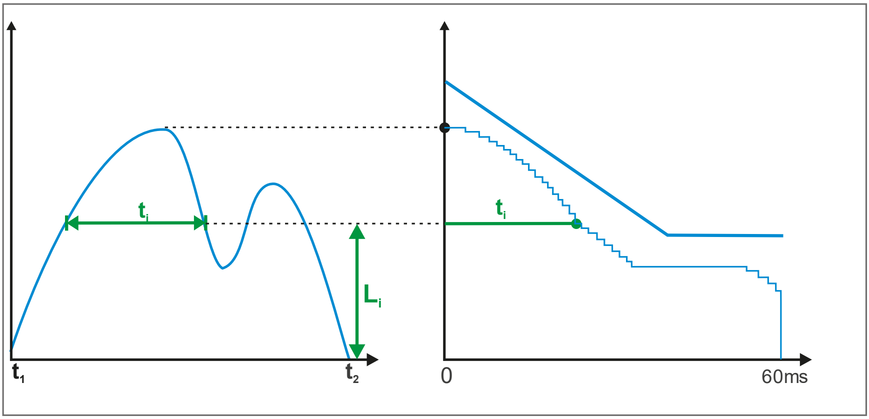
The time-dependent loading criterion describes the maximum time interval for which the measurement value of a signal has exceeded a specific lower threshold. The value is determined either from the continuous time interval (continuous calculation) or from the sum of all the time intervals (cumulative calculation).

Mathematical Calculation

Continuous Calculation (SAE)

To determine the relationship between the measured value of the signal (for example the force) and its corresponding time-at-level, the time-dependent "load criterion curve" is determined, as the following figure shows.

Figure 3-1. Time-dependent load criterion curve



1. The threshold values are plotted on the ordinate, the times-at-level are plotted on the abscissa.
2. The maximum measured value and the time-at-level zero are assigned to the highest threshold value.
3. In a matrix with two columns and 101 rows, all the threshold values are stored in the first column, starting with the maximum value. All the threshold values in this column are equal to the preceding ones minus the quotient, which is the maximum value divided by 100. Zero is assigned to the threshold value in the last row.
4. The largest continuous time interval in which the threshold value is exceeded by the measurement signal is determined for every threshold value in the first column. Use linear

interpolation to determine the time interval, round it to the nearest millisecond, and enter it in the second column.

5. Every line in this matrix describes a value pair (point) that consists of the threshold value and the Time-dependent loading criterion – the ”load criterion curve” – which are plotted in a coordinate system (criterion graph) and thus compared to the injury assessment boundary. Times at level are only used if they are less than 60 ms.
6. To compare the “load criterion curve” to the injury assessment boundary, the ratio between the load criterion value and the injury assessment boundary value is determined for each value pair and multiplied by 100. The highest value is the “injury assessment reference” value which is entered in the coordinate system.

Cumulative Calculation (Euro NCAP)

If the sampling rate is constant, the accumulated values can be calculated with the following algorithm:

1. Sort the values in descending order.
2. The value (sorted) after x ms is the y-value.

Determining Input Values

—

Relevant Laws and Regulations

- SAE J1727, 6.10
- Euro NCAP, Frontal Impact, 10.2.2

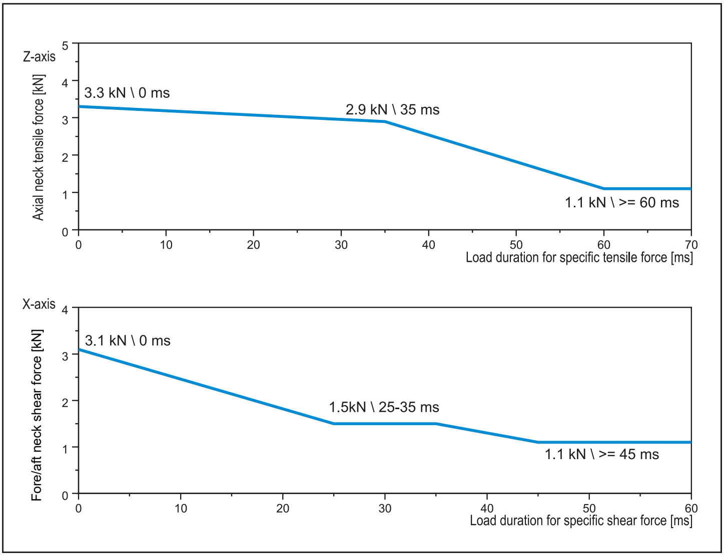
NIC (Frontal Impact UN)

NIC is the abbreviation for **N**eck **I**njury **C**riterion.

Description

The criteria for neck injuries on the hybrid III 50% dummy are determined by the axial compression force, the axial tensile force, and the shearing forces at the transition from head to neck, expressed in kN, and the duration of these forces in ms. The following figure shows these forces.

Figure 3-2. Neck injury at Hybrid III 50% dummy



Mathematical Calculation

For all the above-mentioned signals, the continuous time-at-level is calculated and compared to the limit values (see *Time-dependent loading criterion*).

Determining Input Values

The measurement values of the axial force F_Z and the side shear force F_X are filtered according to CFC 1000 (see *CFC Filters*).

ISO TS 13499 Code

The ISO code describes the input channels for the NIC (frontal impact UN) as follows:

? ? NECK UP 00 ?? FO X A :(+)pos. Upper Neck Force X, CFC 1000

? ? NECK UP 00 ?? FO Z A :Upper Neck Force Z, CFC 1000

Relevant Laws and Regulations

- Directive 96/79/EG, Annex II, 3.2.1.2
- Directive 96/79/EG, Annex II, Appendix 2, 2
- UN-R94, 5.2.1.2
- UN-R94, Annex 4, 2
- SAE J1733

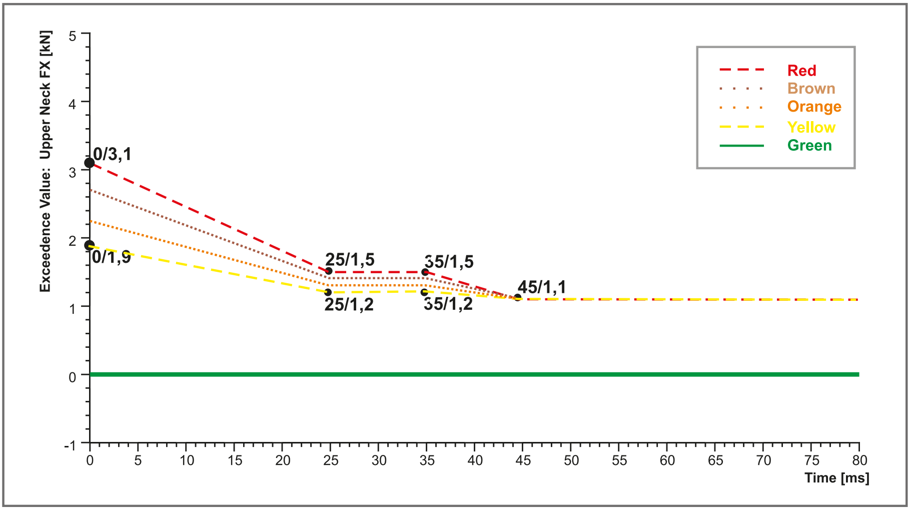
NIC (Frontal Impact Euro NCAP)

NIC is the abbreviation for **N**eck **I**njury **C**riterion.

Description

The criteria for neck injuries are determined by the axial tensile force $F_Z(+)$, and the shearing forces at the transition from head to neck, expressed in kN, and the duration of these forces in ms. The following figures illustrate these forces.

Figure 3-3. Neck injury through shear forces $F_X(+)$



Note The dotted lines are determined from the *Lower Limit* and *Upper Limit* by linear scaling.

Figure 3-4. Neck injury through shear forces $F_X(-)$

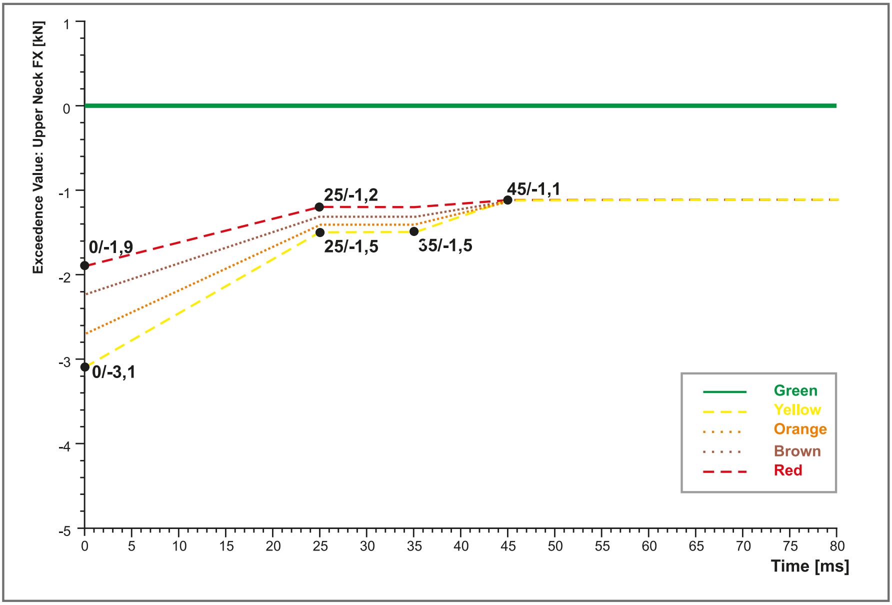
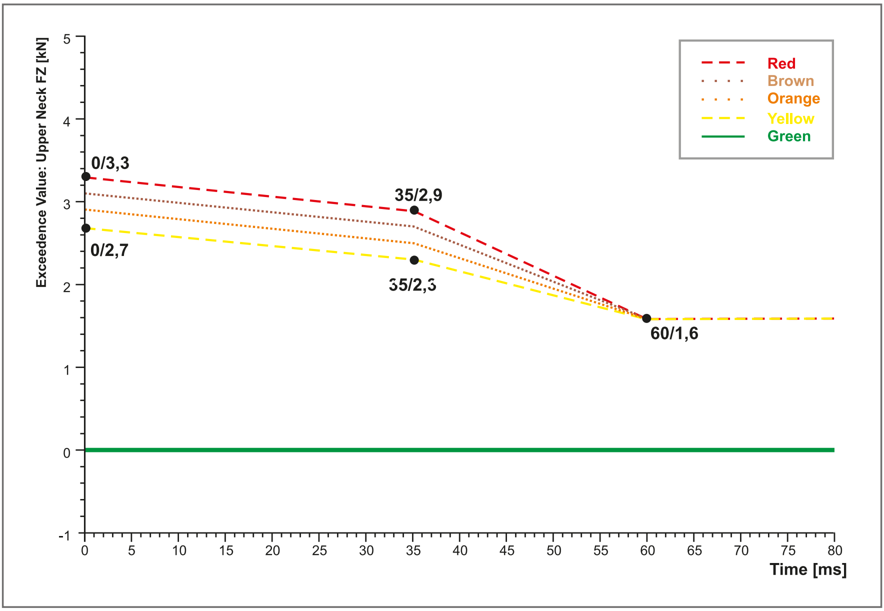


Figure 3-5. Neck injury through axial tensile forces $F_Z(+)$



Mathematical Calculation

For all the above-mentioned signals, the cumulative time-at-level is calculated and compared to the limit values (see *Time-dependent loading criterion*).

Determining Input Values

The measured channels of the axial force F_Z and the shear force F_X are filtered according to CFC 1000 (see *CFC Filters*).

ISO TS 13499 Code

The ISO code describes the input channels for the NIC (frontal impact Euro NCAP) as follows:

```
? ? NECK UP 00 ?? FO X A :Upper Neck Force X, CFC 1000
? ? NECK UP 00 ?? FO Z A :Upper Neck Force Z, CFC 1000
```

Relevant Laws and Regulations

- Euro NCAP, Frontal Impact, 10.2
- SAE J1733
- Euro NCAP, Assessment Protocol and Biomechanical Limits

NIC (Frontal Impact FMVSS)

NIC is the abbreviation for **N**eck **I**njury **C**riterion.

Description

NIC is the criterion for neck injury. The (a) Normalized Neck Injury Criterion (Nij) and the (b) Peak tension and Peak compression are elements of the NIC.

Mathematical Calculation

See also *NIJ*.

The following table shows the limit values for each dummy type.

Table 3-3. Limit values

Position	Dummy Type	Fz [N] Peak Tension	Fz [N] Peak Compression
In position	Hybrid III; male 50%	4170	-4000
	Hybrid III; female 5%	2620	-2520
	Hybrid III; 6-year	1490	-1820
	Hybrid III; 3-year	1130	-1380
	CRABI; 12 months	780	-960
Out of position	Hybrid III; female 5%	2070	-2520

Determining Input Values

The measurement value of the limit value monitoring is filtered in accordance with CFC 600 (see *CFC Filters*).

ISO TS 13499 Code

The ISO code describes the input channels for the NIC (frontal impact FMVSS) as follows:

```
? ? NECK UP 00 ?? FO Z B :Upper Neck Force Z, CFC 600
? ? NECK UP 00 ?? MO Y B :Upper Neck Moment Y, CFC 600
```

Relevant Laws and Regulations

- FMVSS 208 (May 2000), S6.6 (b)(c); (HyIII-50%)
- FMVSS 208 (May 2000), S15.3.6 (b)(c); (HyIII-5%)
- FMVSS 208 (May 2000), S19.4.4 (b)(c)(HyIII-12M)
- FMVSS 208 (May 2000), S21.5.5 (b)(c); (HyIII-3-year)
- FMVSS 208 (May 2000), S23.5.5 (b)(c); (HyIII-6-year)
- FMVSS 208 (May 2000), S25.4 (b)(c); (HyIII-5% Out of position)

NIC (IIHS)

This description of the **N**eck **I**njury **C**riterion (NIC) is taken from the Guidelines for Rating Injury Measures by the Insurance Institute for Highway Safety (IIHS).

Description

The criteria for neck injuries on the hybrid III 50% dummy are determined by the axial compression force, the axial tensile force, and the shearing forces at the transition from head to neck, expressed in kN, and the duration of these forces in ms. The following figures show these forces. The curves display the limit of the rating "Good": Values below the curves are considered to be good, values above the curves are considered to be acceptable.

Figure 3-6. Force Duration Corridor for Neck Tension Force

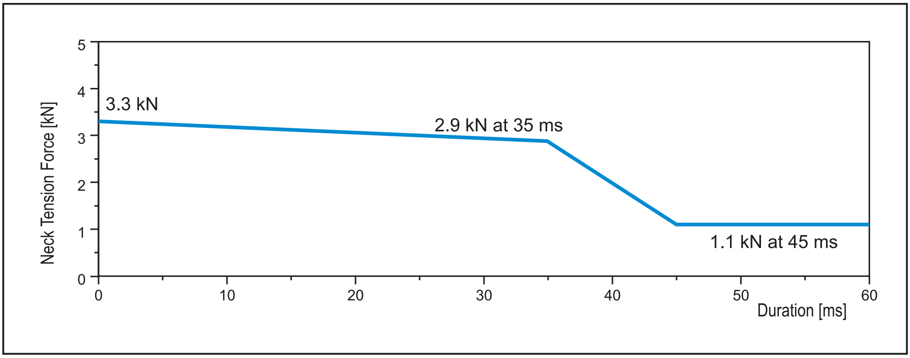


Figure 3-7. Force Duration Corridor for Neck Compression Force

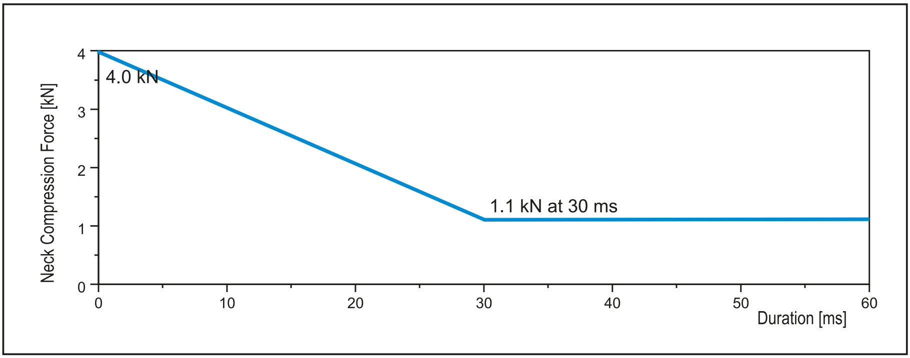
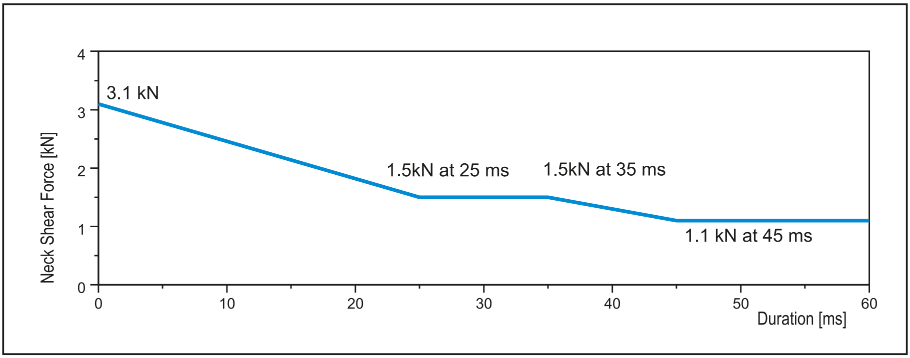


Figure 3-8. Force Duration Corridor for Neck Shear Force



Mathematical Calculation

For all the above-mentioned signals, the continuous time-at-level is calculated and compared to the limit values (see *Time-dependent loading criterion*).

Determining Input Values

The measurement values of the axial force F_Z and the shear force F_X are filtered according to CFC 1000 (see *CFC Filters*).

ISO TS 13499 Code

The ISO code describes the input channels for the NIC (IIHS) as follows:

```
? ? NECK UP 00 ?? FO Z A : Upper Neck Force Z (+)pos., CFC 1000

? ? NECK UP 00 ?? FO Z A : Upper Neck Force Z (-)neg., CFC 1000

? ? NECK UP 00 ?? FO X A : Upper Neck Force X (abs), CFC 1000
```

Relevant Laws and Regulations

- IIHS, Frontal Offset Crashworthiness Evaluation, Head and Neck, Figure 1-3
- SAE J1727 6.10

NIJ

Nij is the abbreviation for Normalized Neck Injury Criterion and is the maximum of the four neck criteria (Neck Injury Predictor) NTE (tension-extension), NTF (tension-flexion), NCE (compression-extension) and NCF (compression-flexion).

Description

The criteria for neck injuries are determined using the axial compression force, the axial tensile force, and the shearing forces at the transition from head to neck, expressed in kN, and the duration of these forces in ms. The neck bending moment criterion is determined by the bending moment, expressed in Nm, around a lateral axis at the transition from the head to the neck, and recorded.

Mathematical Calculation

The N_{ij} value is calculated with the following formula:

$$N_{ij} = \frac{F_z}{F_{zc}} + \frac{M_{OCy}}{M_{yc}}$$

With	F_z	Force at the point of transition from head to neck.
	F_{zc}	Critical force
	M_{OCy}	Total Moment (see *MOC*)
	M_{yc}	Critical moment

Determining Input Values

The measured channels of the tensile force and compression force are filtered in accordance with CFC 600 (see *CFC Filters*). The Total Moment is calculated in accordance with *MOC*.

When the 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. The following table lists the dependencies between forces and moments.

Table 3-4. Dependencies between critical forces and moments

Criterion NIJ	Forces	Moments
N_{CF}	Compression (compression force) F < 0	Flexion (bending forwards) M > 0
N_{CE}		Extension (bending backwards) M < 0

Table 3-4. Dependencies between critical forces and moments

Criterion NIJ	Forces	Moments
N_{TF}	Tension (tensile force) F > 0	Flexion (forwards bending) M > 0
N_{TE}		Extension (backwards bending) M < 0

The following table specifies the critical forces F_{ZC} and moments M_{YC} for the 'in position test' according to the dummy types.

Table 3-5. Critical forces and moments for "in position test"

Dummy Type	F_{ZC} [N] Tension	F_{ZC} [N]* Compression	M_{YC} [Nm] Flexion	M_{YC} [Nm]* Extension
Hybrid III; male 50%	6806	-6160	310	-135
Hybrid III; female 5%	4287	- 3880	155	- 67

*The negative signs of F_{ZC} and M_{YC} result in positive Nij values (signal polarity in accordance with SAE J211 and SAE J1733).

The following table specifies the critical forces F_{ZC} and moments M_{YC} for the 'out of position test' according to the dummy types.

Table 3-6. Critical forces and moments for "out of position test"

Dummy Type	F_{ZC} [N] Tension	F_{ZC} [N]* Compression	M_{YC} [Nm] Flexion	M_{YC} [Nm]* Extension
Hybrid III; female 5%	3880	-3880	155	-61
Hybrid III; 6-year	2800	-2800	93	-37
Hybrid III; 3-year	2120	-2120	68	-27
Hybrid III; 12 months	1460	-1460	43	-17

*The negative signs for F_{ZC} and M_{YC} result in positive Nij values (signal polarity in accordance with SAE J211 and SAE J1733).

ISO TS 13499 Code

The ISO code describes the input channels for the NIJ as follows:

```
? ? NECK UP 00 ?? FO Z B :Upper Neck Force Z, CFC 600

? ? NECK UP 00 ?? MO Y B :Upper Neck Moment Y, CFC 600
```

Relevant Laws and Regulations

- FMVSS 208 (May 2000), S6.6
- FMVSS 208 (May 2000), S15.3.6
- FMVSS 208 (May 2000), S19.4.4
- FMVSS 208 (May 2000), S21.5.5
- FMVSS 208 (May 2000), S23.5.5
- SAE J1727, 6.7

Publications:

- Supplement: Development of Improved Injury Criteria for the Assessment of Advanced Automotive Retrain Systems-II; Rolf Eppinger, Emily Sun, Shashi Kuppa (NTBRC) and Roger Saul (VRTC); March 2000 NHTSA

T1max (Rear Impact Euro NCAP)

T1max is the **max**imum mean acceleration of the first thoracic vertebra (**T1**), intended for the BioRID.

Description

In a rear impact, the T1max criterion is specified by the mean acceleration between the left and right acceleration of the first thoracic vertebra and is the maximum of it within the interval from the beginning of the impact (t_0) to the end of the contact of the head with the headrest (T-HRC$_{(end)}$).

Mathematical Calculation

The T1max value is calculated with the following formula:

$$T1_{max} = Max\{T1(t) \mid t_0 \leq t \leq t_{end}\}$$

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

with	t_0	Time of impact
	t_{end}	T-HRC$_{(end)}$
	$T1_{left}(t)$	Acceleration of the first thoracic vertebra T1 on the left side.
	$T1_{right}(t)$	Acceleration of the first thoracic vertebra T1 on the right side.

Determining Input Values

The measurement channel of the T1 acceleration is filtered in accordance with CFC 60 (see *CFC Filters*).

ISO TS 13499 Code

The ISO code describes the input channels for the T1max as follows:

```
? ? THSP 01 LE BR AC X D :Thoracic Spine left Acceleration X, CFC 60

? ? THSP 01 RI BR AC X D :Thoracic Spine right Acceleration X, CFC 60
```

Relevant Laws and Regulations

- Euro NCAP, The Dynamic Assessment of Car Seats for Neck Injury Protection Testing Protocol, 12.2

NIC (Rear Impact)

NIC is the abbreviation for **N**eck **I**njury **C**riterion.

Description

The criterion for the neck injury with a rear impact is expressed by the relative acceleration between the upper and lower neck acceleration, in m/s², and the relative velocity, in m/s.

Mathematical Calculation

The NIC value (without dimensions) is calculated with the following formula:

$$NIC = a_{relative} * 0.2 + v_{relative}^2$$

with:

$$a_{relative} = a_{x\_T1} - a_{x\_Head}$$

$$v_{relative} = \int a_{relative}$$

and a_{x_T1} Acceleration in x-direction of the first thorax spine in [m/s²]

a_{x_Head} Acceleration in x-direction measured at the height of the c.o.g. of the head [m/s²]

Determining Input Values

The measurement channels of the accelerations are filtered in accordance with CFC 180 (see *CFC Filters*). ax_T1 usually is an average of left and right acceleration.

The NIC_{max} value specifies and documents the maximum value of the NIC within an interval of 150 ms after the start of the sled acceleration. If the head changes the direction of the relative movement at any time within the 150 ms interval after contact with the headrest, this point in time limits the NIC interval for determining the NIC_{max} value.

Note The result of the NIC calculation is a value without dimension.

ISO TS 13499 Code

The ISO code describes the input channels for the NIC (rear impact) as follows:

```
? ? HEAD 00 00 ?? AC X C : Head Acceleration X, CFC 180
? ? THSP 01 00 ?? AC X C : Thoracic Spine T1 Acceleration X, CFC 180
or
? ? THSP 01 LE ?? AC X C : Thoracic Spine T1 Left Acc. X, CFC 180
? ? THSP 01 RI ?? AC X C : Thoracic Spine T1 Right Acc. X, CFC 180
```

Relevant Laws and Regulations

This injury criterion is in the research phase.

Publications:

- A SLED TESTS PROCEDURE PROPOSAL TO EVALUATE THE RISK OF NECK INJURY IN LOW SPEED REAR IMPACTS USING A NEW NECK INJURY CRITERION (NIC); Paper no. 98-S7-O-07; Ola Boström, Yngve Håland, Rikard Frediksson, Autoliv Research Sweden, Mats Y Svensoson Hugo Mellander, Chalmers University of Technology Sweden; 16 th ESV Conference; June 1-4, 1998 Windsor Canada
- EVALUATION OF THE APPLACABILITY OF THE NECK INJURY CRITERION (NIC) IN REAR END IMPACTS ON THE BASIS OF HUMAN SUBJECT TESTS; A.Eichberger, H. Steffan, B.Geigl, M.Svensson, O. Boström, P.E. Leinzinger, M.Darok; IRCOBI Conference – Göteborg, September 1998
- Proposal for the ISO/TC22N2071, ISO/TC22/SC10 (Collision Test Procedures): TEST PROCEDURE FOR THE EVALUATION OF THE INJURY RISK TO THE CERVICAL SPINE IN A LOW SPEED REAR END IMPACT; M. Muser, H. Zellmer, F. Walz, W. Hell, K. Langwieder, K. Steiner, H. Steffan; Rear end impact test procedure, working draft 5, 05/2001
- SAE J1727, 6.8

NIC (Rear Impact Euro NCAP)

NIC is the abbreviation for **N**eck **I**njury **C**riterion.

Description

The criterion for the neck injury with a rear impact is expressed by the relative acceleration between the upper and lower neck acceleration, in m/s², and the relative velocity, in m/s.

Mathematical Calculation

The NIC value (without dimensions) is calculated with the following formula:

$$NIC_{max} = \mathrm{Max}\{\ NIC(t)\ \mid t_0\ \leq t \leq t_{end}\}$$

$$NIC(t) = 0.2\,\gamma_{x\_rel}(t) + \left[V_{x\_rel}(t)\right]^2$$

$$\gamma_{x\_rel} = \gamma_{x\_T1} - \gamma_{x\_Head}$$

$$V_{x\_rel} = \int_0^t \gamma_{x\_rel}\,(\tau)d\tau$$

with

γ_{x_rel}	Relative acceleration between the head and the first thoracic vertebra T1 in [m/s²]
γ_{x_T1}	Acceleration in X direction measured on the first thoracic vertebra T1 in [m/s²]
γ_{x_Head}	Acceleration in X direction measured at the head in [m/s²]
$\gamma_{x\_rel}(t)$	Relative velocity between head and the first thoracic vertebra T1 in [m/s2]
$\gamma_{x\_rel}(t)$	Channel of the neck criterion
$NIC_{max} t_0$	Time of impact
t_{end}	End of the head restraint contact interval T-HRC(end)
NIC_{max}	Maximum neck criterion

Determining Input Values

The measurement channels of the accelerations are filtered in accordance with CFC 60 (see *CFC Filters*). $ax_{\_T1}$ usually is an average of left and right acceleration.

The NIC_{max} value specifies and documents the maximum value of the NIC in an interval of t_0 after start of the sled acceleration and $T\text{-}HRC_{(end)}$. The $T\text{-}HRC_{(end)}$ value is the end value of the contact interval.

Note The result of the NIC calculation is a value without dimension.

ISO TS 13499 Code

The ISO code describes the input channels for the NIC (rear impact) as follows:

```
? ? HEAD 00 00 ?? AC X D : Head Acceleration X, CFC 60
? ? THSP 01 00 ?? AC X D : Thoracic Spine T1 Acceleration X, CFC 60
or
? ? THSP 01 LE ?? AC X D : Thoracic Spine T1 Left Acc. X, CFC 60
? ? THSP 01 RI ?? AC X D : Thoracic Spine T1 Right Acc. X, CFC 60
```

Relevant Laws and Regulations

- Euro NCAP, The Dynamic Assessment of Car Seats for Neck Injury Protection Testing Protocol, 12.5

Nkm

Nkm corresponds to the 4 neck criteria N_{fa} (flexion-anterior), N_{ea} (extension-anterior), N_{fp} (flexion-posterior), and N_{ep} (extension-posterior).

Description

The criteria for neck injuries for the rear impact are calculated by the addition of the standardized shear force F_x and the standardized corrected bending moment (see *MOC*).

Mathematical Calculation

The Nkm value is calculated with the following formula:

$$Nkm(t) = \frac{F_x(t)}{F_{xc}} + \frac{M_{OCy}(t)}{M_{yc}}$$

with	F_x	Force at the point of transition from head to neck.
	F_{xc}	Critical force
	M_{OCy}	Total Moment (see *MOC*)
	M_{yc}	Critical moment

Determining Input Values

The measured values of the tension are filtered in accordance with CFC 600. The measured values of the bending moment and the shearing force are also filtered in accordance with CFC 600 (see *CFC Filters*).

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. The following table lists the dependencies between forces and moments.

Table 3-7. Forces and Moments

Criterion N_{km}	**Forces**	**Moments**
N_{fa}	anterior (head backwards, torso forwards) $F_x > 0$	Flexion (bending forwards) $M_y > 0$
N_{ea}		Extension (bending backwards) $M_y < 0$
N_{fp}	posterior (head forwards, torso backwards) $F_x > 0$	Flexion (bending forwards) $M_y > 0$
N_{ep}		Extension (bending backwards) $M_y < 0$

The following table lists the critical forces F_{xc} and moments M_{yc} for the Hybrid III dummy type; male 50%.

Table 3-8. Forces and Moments for Hybrid III

Moment	**Force**
Positive Shear F_{xc}	+845 N
Negative Shear* F_{xc}	-845 N
Flexion M_{yc}	+88.1 Nm
Extension* M_{yc}	-47.5 Nm

*The negative signs of F_{xc} and M_{yc} result in positive Nkm values (signal polarity in accordance with SAE J211 and SAE J1733).

Relevant Laws and Regulations

- Working Group for Accident Mechanics `www.agu.ch`

Publications

- A NEW NECK INJURY CRITERION CANDIDATE FOR REAR-END COLLISIONS TAKING INTO ACCOUNT SHEAR FORCES AND BENDING MOMENTS (Schmitt, Muser, Niederer) ESV Conference 2001, Amsterdam NL

LNL

LNL is the abbreviation for the **L**ower **N**eck **L**oad Index.

Description

The risk of damaging the lower neck vertebrae in a rear-impact crash is highest when the forces and moments impact simultaneously.

Mathematical Calculation

The LNL value is calculated with the following formula:

$$LNL - index(t) = \frac{\sqrt{My_{lower}(t)^2 + Mx_{lower}(t)^2}}{C_{moment}} + \frac{\sqrt{Fx_{lower}(t)^2 + Fy_{lower}(t)^2}}{C_{shear}} + \left|\frac{Fz_{lower}(t)}{C_{tension}}\right|$$

with	My_{lower}	Moment in y-direction
	Mx_{lower}	Moment in x-direction
	C_{moment}	Critical moment
	Fx_{lower}	Force in x-direction
	Fy_{lower}	Force in y-direction
	C_{shear}	Critical force
	Fz_{lower}	Force in z-direction
	$C_{tension}$	Critical force

Note The formula is valid for the Lower Neck Load Cell of the RID2 and Hybrid III.

- The result *My* can be corrected for the Hybrid III with the Denton 1794, FMVSS IF-210, and IF-219, MSC 4894 power cells, with the following formula:

$$My_{lowercorrected} = My_{lower} + (0.028575 * Fx_{lower}) + (0.0508 * Fz_{lower})$$

- The *My* moment must not be corrected for RID2.

Determining Input Values

The measured values for the forces and moments are filtered in accordance with CFC 600 (see *CFC Filters*). This filtering is valid regardless of the filter classes defined in SAEJ211. (Compare FMVSS208 with reference to Legislation and Directives *NIJ*).

The following table lists the critical forces and moments for the dummy type RID2.

Table 3-9. Forces and Moments for RID2

Moment	**Force**
C_{moment}	15 [Nm]
C_{shear}	250 [N]
$C_{tension}$	900 [N]

ISO TS 13499 Code

The ISO code describes the input channels for the LNL as follows:

```
? ? NECKLO 00 H3 FO X B : Neck low H3-50th force X, CFC 600
? ? NECKLO 00 H3 FO Y B : Neck low H3-50th force Y, CFC 600
? ? NECKLO 00 H3 FO Z B : Neck low H3-50th force Z, CFC 600
? ? NECKLO 00 H3 MO X B : Neck low H3-50th moment X, CFC 600
? ? NECKLO 00 H3 MO Y B : Neck low H3-50th moment Y, CFC 600
? ? NECKLO 00 R2 FO X B : Neck low RID2 force X, CFC 600
? ? NECKLO 00 R2 FO Y B : Neck low RID2 force Y, CFC 600
? ? NECKLO 00 R2 FO Z B : Neck low RID2 force Z, CFC 600
? ? NECKLO 00 R2 MO X B : Neck low RID2 moment X, CFC 600
? ? NECKLO 00 R2 MO Y B : Neck low RID2 moment Y, CFC 600
```

Relevant Laws and Regulations

- SAE J1727, 6.9
- SAE J1733
- Denton Sign Convention for Load Cells
- AN EVALUATION OF EXISTING AND PROPOSED INJURY CRITERIA WITH VARIOUS DUMMIES TO DETERMINE THEIR ABILITY TO PREDICT THE LEVELS OF SOFT TISSUE NECK INJURY SEEN IN REAL WORLD ACCIDENTS; Frank Heitplatz et all; ESV Conference 2003

4

Description of the Chest Criteria

The following chest criteria are described in this chapter:

VC — Viscous Criterion (velocity of compression)

THPC — Thorax Performance Criterion

TTI(d) — Thoracic Trauma Index (Thorax Trauma Index)

ThAC — Thorax Acceptability Criterion

CTI — Combined Thoracic Index

ThCC or *TCC* — Thoracic Compression Criterion

RDC — Rib Deflection Criterion

CDR (TWG) — Chest Deflection (Compression) Rate at Side Impact

Chest Deflection — Chest Deflection (Compression) at Frontal Impact

VC

VC is the abbreviation for **V**iscous **C**riterion (velocity of compression), and is also called the Soft Tissue Criterion.

Description

VC is an injury criterion for the chest area. The VC value [m/s] is the maximum crush of the momentary product of the thorax deformation speed and the thorax deformation. Both quantities are determined by measuring the rib deflection (side impact) or the chest deflection (frontal impact).

Note Only the crush is included in the calculation.

Mathematical Calculation

The following formulas calculate the VC value:

In accordance with UN-R94, UN-R95 and Euro NCAP (frontal and side impact)

$$VC = Scaling\ factor * \frac{Y_{CFC180}}{Defconst} * \frac{dY_{CFC180}}{dt}$$

In accordance with SAE J1727: (Frontal impact)

$$VC = Scaling\ factor * \frac{Y_{CFC600}}{Defconst} * \frac{dY_{CFC600}}{dt}$$

with	Y	Thoracic deformation [m]
	$\frac{dY}{dt}$	Deformation speed
	Scaling factor	Scaling factor (see also Determining Input Values)
	Def. const.	Dummy constant, that is depth or width of half the rib cage [mm] (see also Determining Input Values)

The deformation speed is calculated in accordance with UN-R94:

$$\frac{dY[t]}{dt} = V[t] = \frac{8(Y[t+\Delta t] - Y[t-\Delta t]) - (Y[t+2\Delta t] - Y[t-2\Delta t])}{12\Delta t}$$

with	Δt	Time interval between the single measurements in seconds

Note If required, the chest or rib crush/velocity can be calculated with the difference between opposite acceleration signals, using integration. This method is not included in any of the listed laws or guidelines.

Determining Input Values

Refer to the mathematical calculation for details on filtering input values.

The following table contains the scaling factor and the deformation constant (dummy constants) for each dummy type, in accordance with SAE J1727 and H.J. Mertz.

Table 4-1. Scaling Factor and Deformation Constant

Dummy Type	Scaling factor	Deformation Constant [mm]
Hybrid III; male 95%	1.3	254
Hybrid III; male 50%	1.3	229
Hybrid III; female 5%	1.3	187
Hybrid III; 10 years	1.3	166
Hybrid III; 6 years	1.3	143
Hybrid III; 3 years	1.3	122
BioSID	1.0	175
EuroSID-1	1.0	140
ES-2	1.0	140
SID-IIs	1.0	138
WorldSID 50%	1.0	170
WorldSID 5%	1.0	138

ISO TS 13499 Code

The ISO code describes the input channels for the VC as follows:

```
? ? CHST  ?? 00 ?? DS  X ? :Frontal Impact DS, Chest Displacement X
? ? SPIN  ?? 00 ?? AC  X ? :Frontal Impact AC, Spinal Acceleration X
? ? STRN  ?? 00 ?? AC  X ? :Frontal Impact AC; Sternum Acceleration X
? ? RIBS  ?? UP ?? DS  Y ? :Side Impact DS, Upper Ribs Displacement Y
? ? RIBS  ?? MI ?? DS  Y ? :Side Impact DS, Middle Ribs Displacement Y
```

```
? ? RIBS  ?? LO ?? DS  Y ? :Side Impact DS, Lower Ribs Displacement Y
? ? TRRI  ?? 01 ?? DS  Y ? :Side Impact DS, Thorax Rib Displacement Y
? ? TRRI  ?? 02 ?? DS  Y ? :Side Impact DS, Thorax Rib Displacement Y
? ? TRRI  ?? 03 ?? DS  Y ? :Side Impact DS, Thorax Rib Displacement Y
? ? ABRI  ?? 01 ?? DS  Y ? :Side Impact DS, Abdominal Rib Displacement Y
? ? ABRI  ?? 02 ?? DS  Y ? :Side Impact DS, Abdominal Rib Displacement Y
```

Relevant Laws and Regulations

- UN-R94, Directive 96/79/EG, Annex II, 3.2.1.5
- UN-R94, Directive 96/79/EG, Annex II, Appendix 2, 6.1-6.2
- UN-R94, 5.2.1.4
- UN-R94, Annex 4, 3.2
- UN-R94, Annex 4, 6
- UN-R95, 5.2.1.2 b)
- UN-R95, Annex 4, Appendix 1, 2.2
- UN-R95, Annex 4, Appendix 2
- Directive 96/27 EG Annex 2, 3.2.1.2 b)
- Directive 96/27 EG Annex 1, Appendix 1, 2.2
- Directive 96/27 EG Annex 1, Appendix 2
- SAE J211, 9.4.3
- SAE J1727, 6.12.1.3
- SAE J1727, 6.12.2
- Euro NCAP, Frontal Impact, 10.3
- Euro NCAP, Side Impact, 10.3
- H.J. Mertz, Injury Risk Assessments Based on Dummy Responses

THPC

THPC is the abbreviation for **Th**orax **P**erformance **C**riterion

Description

THPC is the criterion for chest strain in a side impact. The two elements of the THPC are the rib deflection criterion (RDC) and the viscous criterion (VC).

Mathematical Calculation

See also *RDC* and *VC*.

Determining Input Values

See also *RDC* and *VC*.

ISO TS 13499 Code

The ISO code describes the input channels for the THPC as follows:

```
? ? VCCR  ?? ?? ?? VE  Y X :Viscous Criterion, Velocity Y
? ? RDCR  ?? ?? ?? DS  Y X : Rib Deflection Criterion, Displacement Y
```

Relevant Laws and Regulations

- UN-R95, 5.2.1.2
- UN-R95, Annex 4, Appendix 1,2
- Directive 96/27 EG Annex 2, 3.2.1.2
- Directive 96/27 EG Annex 1, Appendix 1,2
- Directive 96/27 EG Annex 1, Appendix 2

TTI(d)

TTI(d) is the abbreviation for **T**horacic **T**rauma **I**ndex, used for used for USSID and SIDH3.

Description

The thorax trauma index is an injury criterion for the thorax in the case of a side impact. The TTI(d) is the mean of the lateral maximum acceleration of the abdominal spine (12th spinal segment) and the higher of the two values for the maximum acceleration of the upper (8th) and lower (4th) rib.

Mathematical Calculation

The TTI value is calculated with the following formula:

$$TTI(d) = \frac{A(max.rib) + A(lwr.spine)}{2}$$

$$A(max.rib) = max\{A(upr.rib).A(lwr.rib)\}$$

with	A(upr.rib)	Maximum acceleration of the upper rib; [g]
	A(lwr.rib)	Maximum acceleration of the lower rib; [g]
	A(max.rib)	Maximum of A(upr.rib) and A(lwr.rib); [g]
	A(lwr.spine)	Maximum acceleration of the lower spine; [g]

Determining Input Values

Preprocessing the acceleration data of the single sensors (see also *CFC Filters*):

1. Filtering with CFC 180
2. Reduction of the sampling rate to 1600 Hz
3. Removal of bias
4. Filtering with FIR 100
5. Transferring the reduced sampling rate to the original sampling rate (oversampling, only SAE)

Due to the sign regulations in SAE J1733, the acceleration values have to be positive absolute maximum values. If test data with negative absolute maximum values are to be evaluated, the measurement data must first be inverted.

The calculation must use the original measurement data, not selected data sections, otherwise the digital filters may have differing transient responses.

ISO TS 13499 Code

The ISO code describes the input channels for the TTI(d) as follows:

```
? ? RIBS ?? UP ?? AC Y C :Upper Ribs Acceleration Y, CFC 180
? ? RIBS ?? LO ?? AC Y C :Lower Ribs Acceleration Y, CFC 180
? ? SPIN 12 ?? SI AC Y C :Spinal Acceleration Y, CFC 180
? ? SPIN 12 ?? E1 AC Y C :Spinal Acceleration Y, CFC 180
```

Relevant Laws and Regulations

- FMVSS 214, S5.1
- FMVSS 214, S6.13.5
- SAE J1727, 6.13

ThAC

ThAC is the abbreviation for **Th**orax **A**cceptability **C**riterion.

Description

This criterion is determined via the absolute value of the acceleration expressed in units of earth acceleration and the acceleration duration expressed in milliseconds [ms].

Mathematical Calculation

See also *Xms*.

Determining Input Values

The measurement value is filtered in accordance with CFC 180 (see *CFC Filters*).

ISO TS 13499 Code

The ISO code describes the input channels for the ThAC as follows:

```
? ? CHST ?? ?? ?? AC X C :Chest Acceleration X,CFC 180
? ? CHST ?? ?? ?? AC Y C :Chest Acceleration Y,CFC 180
? ? CHST ?? ?? ?? AC Z C :Chest Acceleration Z,CFC 180
```

Relevant Laws and Regulations

- UN-R80, Annex 1, 1.1.2.1.2
- UN-R80, Annex 4, 2

CTI

CTI is the abbreviation for **C**ombined **T**horacic **I**ndex (not included in the current standard).

Description

The Combined Thoracic Index represents an injury criterion for the chest area in case of a frontal impact. The CTI is the evaluated 3 ms value from the resultant acceleration of the spinal cord and the deflection of the chest.

Mathematical Calculation

The CTI value is calculated with the following formula:

$$CTI = \left(\frac{A_{max}}{A_{int}}\right) + \left(\frac{D_{max}}{D_{int}}\right)$$

with A_{max} 3 ms value (single peak) of the resultant acceleration of the spinal cord [g]

A_{int} Critical 3 ms values [g]

D_{max} Deflection of the chest [mm]

D_{int} Critical deflection [mm]

Determining Input Values

The measured values of the acceleration are filtered in accordance with CFC 180 and those of the displacement in accordance with CFC 600 (see *CFC Filters*).

The following table specifies the critical 3 ms A_{int} and the critical deflection D_{int} for each dummy type.

Table 4-2. Critical 3 ms A_{int} and critical deflection D_{int}

Dummy Type	A_{int} [g]	D_{int} [mm]
Hybrid III; male 50%	85	102
Hybrid III; female 5%	85	83
Hybrid III; 6-year	85	63
Hybrid III; 3-year	70	57
CRABI; 12-month	55	49

ISO TS 13499 Code

The ISO code describes the input channels for the CTI as follows:

```
? ? CHST ?? ?? ?? AC X C :Chest Acceleration X,CFC 180
? ? CHST ?? ?? ?? AC Y C :Chest Acceleration Y,CFC 180
? ? CHST ?? ?? ?? AC Z C :Chest Acceleration Z,CFC 180
? ? CHST ?? ?? ?? DS X B :Chest Displacement X,CFC 600
```

Relevant Laws and Regulations

Note This criterion is not included in the current standard!

- FMVSS 208 proposal (September 1998), S6.6
- FMVSS 208 proposal (September 1998), S15.3
- FMVSS 208 proposal (September 1998), S19.4
- FMVSS 208 proposal (September 1998), S21.5
- FMVSS 208 proposal (September 1998), S23.5

ThCC or TCC

ThCC or TCC is the abbreviation for **Th**oracic **C**ompression **C**riterion.

Description

ThCC is the criterion of the thorax compression between the sternum and the spine and is determined using the absolute value of the thorax compression, expressed in millimeters [mm].

Mathematical Calculation

—

Determining Input Values

The measurement value of the chest deflection is filtered in accordance with CFC 180 (see *CFC Filters*).

ISO TS 13499 Code

The ISO code describes the input channels for the ThCC/ TCC as follows:

```
? ? CHST ?? ?? ?? DS X C :Chest Displacement X,CFC 180
```

Relevant Laws and Regulations

- UN-R94, 5.2.1.4
- UN-R94, Annex 4, 3
- Directive 96/79/EG, Annex II, 3.2.1.4
- Directive 96/79/EG, Annex II, Appendix 2, 3.1

Note In the German directives this criterion was called TCC, but it was called ThCC in the English directives.

RDC

RDC is the abbreviation for **R**ib **D**eflection **C**riterion.

Description

RDC is the criterion for the deflection of the ribs, expressed in millimeters [mm], in a side impact.

Mathematical Calculation

—

Determining Input Values

The measurement value of the deflection of the ribs is filtered in accordance with CFC 180 (see *CFC Filters*).

ISO TS 13499 Code

The ISO code describes the input channels for the RDC as follows:

```
? ? RIBS LE UP E? DS Y C :Upper Left Ribs Displacement Y,CFC 180
? ? RIBS LE MI E? DS Y C :Middle Left Ribs Displacement Y,CFC 180
? ? RIBS LE LO E? DS Y C :Lower Left Ribs Displacement Y,CFC 180
? ? RIBS RI UP E? DS Y C :Upper Right Ribs Displacement Y,CFC 180
? ? RIBS RI MI E? DS Y C :Middle Right Ribs Displacement Y,CFC 180
? ? RIBS RI LO E? DS Y C :Lower Right Ribs Displacement Y,CFC 180
```

Relevant Laws and Regulations

- UN-R95, 5.2.1.2 a)
- UN-R95, Annex 4, Appendix 1,2.1
- Directive 96/27 EG Annex 2, 3.2.1.2. a)
- Directive 96/27 EG Annex 1, Appendix 1,2.1

CDR (TWG)

CDR is the abbreviation for **C**hest **D**eflection (Compression) **R**ate of the Technical Working Group (TWG).

Description

CDR is the criterion of the compression acceleration of the chest which can be specified with two methods:

- With the differentiation of the path of the sternum crush (frontal dummies, crush front and rear) or the ribs (SID IIs, side crush).
- With the integration of the acceleration difference between the sternum (frontal dummies) or the ribs (SID IIs) and the spine.

Theoretically the two methods should result in the same solution. However, tests have shown that the measurement values of the potentiometer, which measures the crush, might deviate from the actual measurement data, and might contain noise signals when used under the above mentioned the conditions. Both conditions can generate errors in the differentiation of the compression rate.

The TWG has agreed that every method can be used to calculate the chest compression rate. However, the recommendation is to check the result with the integration method if the differentiation method is used. The following section describes the recommended integration method for calculating the chest compression.

Mathematical Calculation

1. Calculation of the chest compression as a function of time:

   This method uses the acceleration data of the spine, the ribs, or of the sternum and the data of the potentiometer compression of the ribs or of the sternum.

   a. All data must comply with the SAE prefix rules.

   b. The acceleration data must be filtered in accordance with SAE CFC 1000.

   c. The data of the deflection of chest and rib must be filtered in accordance with SAE CFC 600.

   d. Specifying the moment of impact (Time T_0) – The moment when the dummy first impacts the airbag:

      – Specifying the time ($T_{5\%}$) when the sternum or rib acceleration reaches 5% of the maximum value at the impact with the airbag.

      – Monitoring the falling sternum or rib acceleration signal of $T_{5\%}$ to the moment when the acceleration signal changes the sign. This time is T_0 for all measurements.

   e. Determining the moment of maximum compression T_{maxD}:

The moment of maximum compression must be determined for the sternum and the rib deflection. For signals with several peaks the moment of the peak with the maximum compression must be recorded.

f. Of each time increment the value of the x-direction of the spine acceleration (frontal dummies) or the y-value of the spine acceleration must be subtracted from the y-value of the rib acceleration (SID IIs). The resulting differences of the accelerations over time is AD(t) (acceleration differences in relation to time). If the acceleration is measured in g, the unit in m/s^2 multiplied by 9.81 must be used.

g. Set AD(t)=0 if $t \leq T_0$. The new function is called $AD_{0(t)}$.

h. Define N as the number of time increments between T_{maxD} and T_0. Then $DT = (T_{maxD} - T_0)/N$ is the time increment in seconds. Integrate the difference acceleration ($AD_{0(t)}$), to obtain the compression rate CR(t) in m/s in relation to the time in seconds.

$$CR(t_m) = S\left(\frac{AD_{0(ti)} + AD_{0(ti-1)}}{2}\right)\Delta t$$

with	i	1.2,… m
	m	Integer number between 1 and N
	$CR(t_0)=0$	for m = 0
	$CR(t_N)$	If m = N, $CR(t_N)$ is the value of the compression rate if T_{maxD}.

2. Checking the accuracy of the compression rate:

The compression rate is accurate if CR(t) is null at $t = t_{maxD}$.

a. The compression rate, which corresponds to T_{maxD}, of the integration data of list point 1. h. is searched for. This value is called ValueB.

b. If the absolute value of ValueB is ≤0,1 m/s, the compression rate from list point 1. h. can be used and the maximum compression rate $CR(t)_{max}$ is the maximum value of CR(t). If the absolute value of ValueB is > 0,1m/s, the error in the integration process is to great.

Therefore, use rules 3 and 4 to improve the accuracy of the calculation.

3. Calculation of the correction factor (ValueC):

a. Calculating the time interval between the first impact with the airbag and the maximum compression: This interval is called ValueA.

Then ValueA is = $T_{maxD} - T_0$.

b. Dividing ValueB by ValueA to obtain ValueC. ValueC has the unit m/s^2 and the same sign as ValueB.

4. Using the correction factor for the sternum and rib accelerations:
   a. Subtracting the ValueC from the filtered sternum or rib data at each time increment, starting at T_0 and ending with T_{maxD}. If the acceleration data have the unit g, ValueC must be converted into m/s^2. That means ValueC is divided by 9,81 before an application. The procedure complies with the SAE prefix regulation.
   b. Returning to point 1.f. with a repetition of the calculation of the deflection rate (compression) as the function of the time and the accuracy test.
5. The accuracy test from point 2.b. is implemented after every iteration to ensure that the correction method was executed correctly.

Determining Input Values

The measurement values for chest and rib displacements are filtered in accordance with CFC 600 (see *CFC Filters*).

The measured accelerations for chest, sternum, spine, and rib are filtered in accordance with CFC 1000 (see *CFC Filters*).

ISO TS 13499 Code

The ISO code describes the input channels for the CDR as follows:

```
? ? CHST 00 00 ?? DS X B :Frontal, Chest Displacement X, CFC 600
? ? TRRI ?? ?? S2 DS Y B :Side, Thorax Rib Displacement Y, CFC 600
? ? ABRI ?? ?? S2 DS Y B :Side, Abdominal Rib Displacement Y, CFC 600
? ? CHST 00 00 ?? AC X A :Frontal, Chest Acceleration X, CFC 1000
? ? STRN 00 00 ?? AC X A :Frontal, Sternum Acceleration X, CFC 1000
? ? THSP ?? ?? S2 AC Y A :Side, Thoracic Spine Acceleration Y, CFC 1000
? ? ABSP ?? ?? S2 AC Y A :Side, Abdominal Spine Acceleration Y, CFC 1000
```

Relevant Laws and Regulations

- Side Airbag, Out of Position, Technical Working Group (TWG), First Revision July 2003, Appendix B
- SAE J211, Dec 2003

Chest Deflection

Chest Deflection is the criterion for the deflection of the chest.

Description

Chest Deflection is the criterion for the deflection of the chest expressed in millimeters [mm], in a frontal impact.

Mathematical Calculation

—

Determining Input Values

The measurement value of the deflection of the ribs is filtered in accordance with CFC 180 or CFC 600 respectively (depending on the regulation; see *CFC Filters*).

ISO TS 13499 Code

The ISO code describes the input channels for the Chest Deflection as follows:

```
? ? CHST 00 00 ?? DS  X B/C : Chest displacement X, CFC 600/180
```

Relevant Laws and Regulations

- FMVSS 208, S. 6.4 (a); (H3)
- FMVSS 208, S. 6.4 (b); (HF)
- FMVSS 208, S. 15.3.4; (HF)
- FMVSS 208, S. 21.5.4; (HIII-3-year, SubpartO)
- FMVSS 208, S. 23.5.4; (HIII-6-year, SubpartN)

5

Description of the Criteria for the Lower Extremities

This section describes the following criteria for the lower extremities:

APF — Abdominal Peak Force

PSPF — Pubic Symphysis Peak Force

FFC (ECE) — Femur Force Criterion

FFC (Euro NCAP) — Femur Force Criterion

FFC (IIHS) — Femur Force Criterion

TI —Tibia Index

TCFC — Tibia Compression Force Criterion

APF

APF is the abbreviation for **A**bdominal **P**eak **F**orce. This is a criterion for the European side impact regulations.

Description

APF is the maximum side abdominal strain criterion. It is the highest value of the sum of the three forces [kN] that are measured on the impact side.

Mathematical Calculation

$$APF = max\left|F_{yFront} + F_{yMiddle} + F_{yRear}\right|$$

Determining Input Values

The measurement value of the abdominal strain is filtered in accordance with CFC 600 (see *CFC Filters*).

ISO TS 13499 Code

The ISO code describes the input channels for the APF as follows:

```
? ? ABDO ?? FR ?? FO  Y B :Front Abdomen Force Y, CFC 600
? ? ABDO ?? MI ?? FO  Y B :Middle Abdomen Force Y, CFC 600
? ? ABDO ?? RE ?? FO  Y B :Rear Abdomen Force Y, CFC 600
```

Relevant Laws and Regulations

- UN-R95, 5.2.1.4
- UN-R95, Annex 4, Appendix 1,3
- Directive 96/27 EG Annex 2, 3.2.1.4
- Directive 96/27 EG Annex 1, Appendix 1,3

PSPF

PSPF is the abbreviation for **P**ubic **S**ymphysis **P**eak **F**orce.

Description

PSPF is the criterion for pelvic strain during side impact and is determined by the maximum strain on the pubic symphysis, expressed in kN.

Mathematical Calculation

—

Determining Input Values

The measurement channel of the pelvic strain is filtered in accordance with CFC 600 (see *CFC Filters*).

ISO TS 13499 Code

The ISO code describes the input channels for the PSPF as follows:

```
? ? PUBC ?? ?? ?? FO  Y B :Pubic Force Y, CFC 600
```

Relevant Laws and Regulations

- UN-R95, 5.2.1.3
- UN-R95, Annex 4, Appendix 1,4
- Directive 96/27 EG Annex 2, 3.2.1.3
- Directive 96/27 EG Annex 1, Appendix 1,4

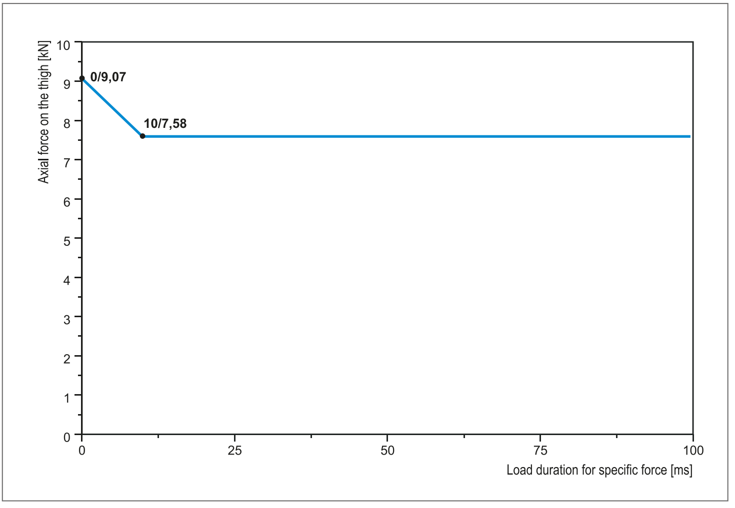
FFC (UN)

FFC is the abbreviation for **F**emur **F**orce **C**riterion

Description

FFC is the criterion of the force acting on the femur $F_z(-)$ and is determined by the compression stress in kN that is transmitted axially on each femur of the dummy as well as the duration of action of the compression force in ms.

Figure 5-1. Duration and strength of the forces acting on the femur.



Mathematical Calculation

See also *Time-dependent loading criterion* .

Note The duration is calculated cumulatively (see *FFC (Euro NCAP)*).

The limit curve is different from *FFC (Euro NCAP)*.

Determining Input Values

The measurement channel of the femur force is filtered in accordance with CFC 600 filtered (see *CFC Filters*).

ISO TS 13499 Code

The ISO code describes the input channels for the FFC (UN) as follows:

```
? ? FEMR LE ?? ?? FO  Z B : Left Femur Force Z, CFC 600
? ? FEMR RI ?? ?? FO  Z B : Right Femur Force Z, CFC 600
```

Relevant Laws and Regulations

- UN-R94, 5.2.1.6
- UN-R94, Annex 4, 4
- Directive 96/79/EG, Annex II, 3.2.1.6
- Directive 96/79/EG, Annex II, Appendix 2, 4.1

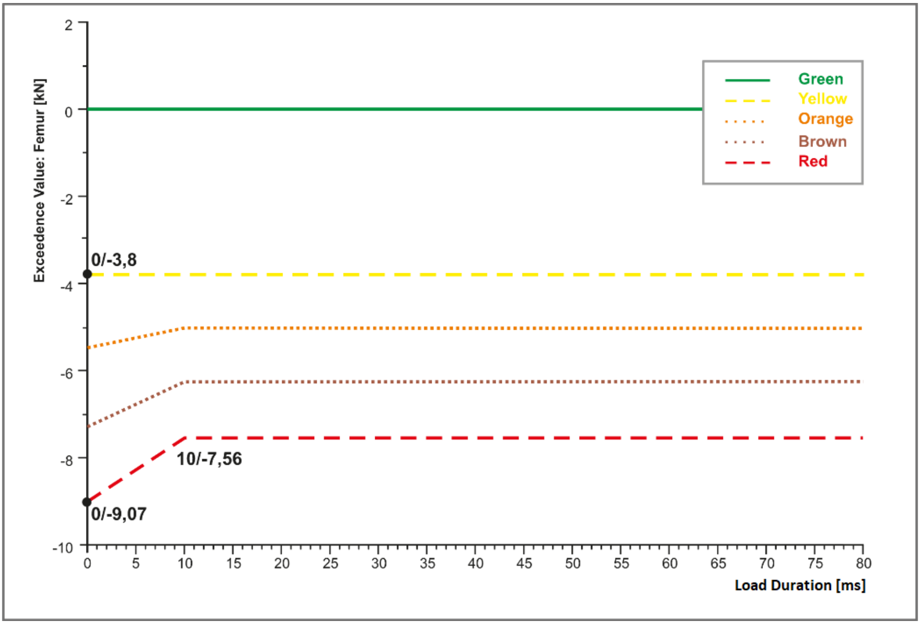
FFC (Euro NCAP)

FFC is the abbreviation for **F**emur **F**orce **C**riterion

Description

FFC is the criterion of the force acting on the femur $F_z(-)$ and is determined by the compression stress in kN that is transmitted axially on each femur of the dummy as well as the duration of action of the compression force in ms.

Figure 5-2. Compression stress and duration of the forces acting on the femur



Note The dotted lines are determined from the *Lower* and *Upper Limit* by linear scaling.

Mathematical Calculation

The duration is calculated cumulatively by sorting channel values in descending order.

See also *Time-dependent loading criterion*.

Note The limit curve is different from *FFC (UN).*

Determining Input Values

The measurement value of the femur force is filtered in accordance with CFC 600 filtered (see *CFC Filters*).

ISO TS 13499 Code

The ISO code describes the input channels for the FFC (Euro NCAP) as follows:

```
? ? FEMR LE ?? ?? FO  Z B : Left Femur Force Z, CFC 600
? ? FEMR RI ?? ?? FO  Z B : Right Femur Force Z, CFC 600
```

Relevant Laws and Regulations

- Euro NCAP, Frontal Impact Testing Protocol, Version 5.0; October 2009

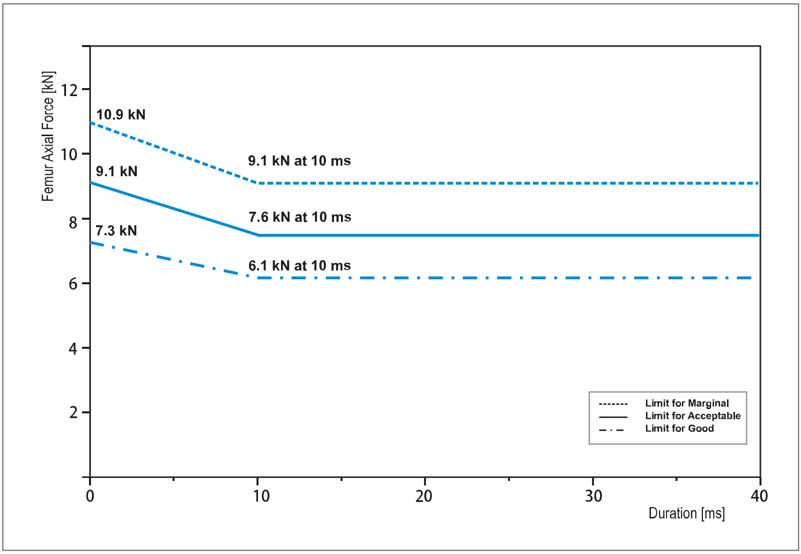
FFC (IIHS)

This description of the **F**emur **F**orce **C**riterion (FFC) is taken from the Guidelines for Rating Injury Measures by the Insurance Institute for Highway Safety (IIHS).

Description

FFC is the criterion of the force acting on the femur $F_z(-)$ and is determined by the compression stress in kN that is transmitted axially on each femur of the dummy as well as the duration of action of the compression force in ms.

Figure 5-3. Compression stress and duration of the forces acting on the femur



Mathematical Calculation

The duration is calculated continually (see *Time-dependent loading criterion*).

Determining Input Values

The measurement value of the femur force is filtered in accordance with CFC 600 filtered (see *CFC Filters*).

ISO TS 13499 Code

The ISO code describes the input channels for the FFC (IIHS) as follows:

```
? ? FEMR LE ?? ?? FO  Z B :Left Femur Force Z, CFC 600
? ? FEMR RI ?? ?? FO  Z B :Right Femur Force Z, CFC 600
```

Relevant Laws and Regulations

- IIHS, Frontal Offset Crashworthiness Evaluation, Figure 4
- SAE J1727

TI

TI is the abbreviation for the **T**ibia **I**ndex.

Description

The Tibia Index (TI) is an injury criterion for the lower leg area. It involves the bending moments around the x-axis and y-axes as well as the axial force of pressure in the z direction at the top or bottom end of the tibia. When a ”single-moment transducer” is used, the absolute measured value is valid for the calculation. If there are two directions, the resultant moment must be calculated and used.

Mathematical Calculation

The calculation of the TI value is based on the equation:

$$TI = \left|\frac{M_R}{(M_c)_R}\right| + \left|\frac{F_z}{(F_c)_z}\right|$$

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

with	M_x	Bending moment [Nm] around the x-axis
	M_y	Bending moment [Nm] around the y-axis
	$(M_c)_R$	Critical bending moment, see the following table
	F_z	Axial compressive force [kN] in z-direction
	$(F_c)_z$	Critical compression force in z-direction; see the following table

Determining Input Values

The measured values of the bending moment and axial compression force are filtered in accordance with CFC 600 (see *CFC Filters*).

Note For the calculation only the axial compression forces are used. The tensile forces must be set to the value 0.

The following table contains the critical bending moment and the critical compression force in relation to the dummy type, in accordance with SAE J1727, 3.11.

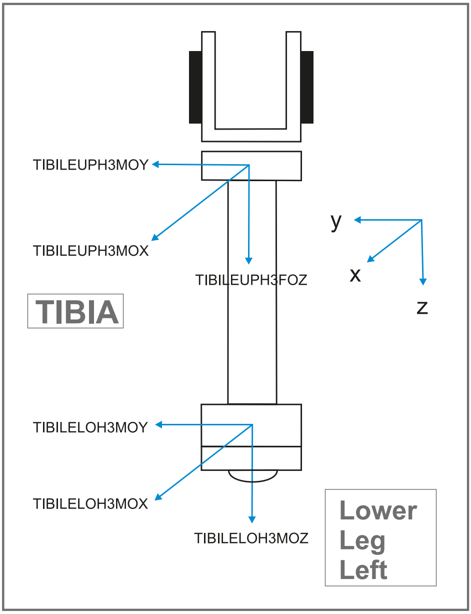
Table 5-1. Critical Bending Moment and Compression Force

Dummy Type	Critical Bending Moment [Nm]	Critical Compression Force [kN]
Hybrid III; male 95%	307,0	44,2
Hybrid III; male 50%	225,0	35,9
Hybrid III; female 5%	115,0	22,9

The following figure shows the possible forces and moments of a lower leg (using the example of a Hybrid III dummy, lower left leg) for calculating the Tibia Index.

Note: The ISO codes given below are for the 50% dummy (H3), but they are also valid for the 95% (HM) and 5% (HF) dummy.

Figure 5-4. Possible Forces and Moments on Lower Leg



with	**TIBILEUPH?MOX**	Bending moment about the x-axis, upper tibia
	TIBILEUPH?MOY	Bending moment about the y-axis, upper tibia
	TIBILEUPH?FOX	Axial shear force in x-direction, upper tibia
	TIBILEUPH?FOY	Axial shear force in y-direction, upper tibia

TIBILEUPH?F0Z	Axial compression force in z-direction, upper tibia
TIBILELOH?M0X	Bending moment about the x-axis, lower tibia
TIBILELOH?M0Y	Bending moment about the y-axis, lower tibia
TIBILELOH?F0X	Axial shear force in x-direction, lower tibia
TIBILELOH?F0Y	Axial shear force in y-direction, lower tibia
TIBILELOH?F0Z	Axial compression force in z-direction, lower tibia

The following table shows the differences in calculation of the upper or lower Tibia Index with a 5-channel and a 6-channel lower leg.

Table 5-2. 5-Channel and 6-Channel Calculation of the Upper and Lower Tibia Index

	5-channel lower leg	**6-channel lower leg**
Measurement channels	**TIBILEUPH?M0X** **TIBILEUPH?M0Y** **TIBILELOH?F0X** or **TIBILELOH?F0Y** **TIBILELOH?F0Z** **TIBILELOH?M0X** or **TIBILELOH?M0Y**	**TIBILEUPH3F0Z** **TIBILEUPH3M0X** **TIBILEUPH3M0Y** **TIBILELOH3F0Z** **TIBILELOH3M0X** **TIBILELOH3M0Y**
Upper tibia		
Resultant bending moment	5-channel: $M_R = \sqrt{(\text{TIBILEUPH3M0X})^2 + (\text{TIBILEUPH3M0Y})^2}$ 6-channel: $M_R = \sqrt{(\text{TIBILEUPH3M0X})^2 + (\text{TIBILEUPH3M0Y})^2}$	
Axial compression force	**Fz=TIBILEUPH?FOZ**	**Fz=TIBILEUPH?FOZ**
Lower tibia		
Resultant bending moment	**M_R=|TIBILELOH?MOX|** or **M_R=|TIBILELOH?MOY|**	$M_R = \sqrt{(\text{TIBILELOH? M0X})^2 + (\text{TIBILELOH? M0Y})^2}$
Axial compression force	**F_z=TIBILELOH?FOZ**	**F_z=TIBILELOH?FOZ**

The following table lists the differences of the calculation of the upper or lower tibia-index with two different 8-channel lower legs.

Table 5-3. 8-Channel Calculation of the Upper and Lower Tibia Index

	8-channel lower leg	**8-channel lower leg**
Measurement channels	**TIBILEUPH?F0X** **TIBILEUPH?F0Z** **TIBILEUPH?M0X** **TIBILEUPH?M0Y** **TIBILELOH?F0X** **TIBILELOH?F0Z** **TIBILELOH?M0X** **TIBILELOH?M0Y**	**TIBILEUPH?F0X** **TIBILEUPH?F0Z** **TIBILEUPH?M0X** **TIBILEUPH?M0Y** **TIBILELOH?F0X** **TIBILELOH?F0Y** **TIBILELOH?M0X** **TIBILELOH?M0Y**
Upper tibia		
Resultant bending moment	$M_R = \sqrt{(TIBILEUPH?\,M0X)^2 + (TIBILEUPH?\,M0Y)^2}$	$M_R = \sqrt{(TIBILEUPH?\,M0X)^2 + (TIBILEUPH?\,M0Y)^2}$
Axial compression force	**F_z=TIBILEUPH?FOZ**	**F_z=TIBILEUPH?FOZ**
Lower tibia		
Resultant bending moment	$M_R = \sqrt{(\mathrm{TIBILELOH?\,M0X})^2 + (\mathrm{TIBILELOH?\,M0Y})^2}$	$M_R = \sqrt{(\mathrm{TIBILELOH?\,M0X})^2 + (\mathrm{TIBILELOH?\,M0Y})^2}$
Axial compression force	**F_z=TIBILELOH?FOZ**	**F_z=TIBILELOH?FOZ**

The axial compression force F_z in the z-direction can be measured in the upper or lower tibia, according to UN-R94, Annex 4, 5.2.

ISO TS 13499 Code

The ISO code describes the input channels for the TI as follows:

```
? ? TIBI ?? ?? ?? FO X B : Tibia Moment X, CFC 600
? ? TIBI ?? ?? ?? FO Y B : Tibia Moment Y, CFC 600
? ? TIBI ?? ?? ?? FO Z B : Tibia Moment Z, CFC 600
```

Relevant Laws and Regulations

- UN-R94, 5.2.1.8
- UN-R94, Annex 4, 5.2
- Directive 96/79/EG, Annex II, 3.2.1.8
- Directive 96/79/EG, Annex II, Appendix 2, 5.2
- SAE J1727, 3.11
- SAE J211, Table 1
- Euro NCAP, Frontal Impact, 10.6

TCFC

TCFC is the abbreviation for **T**ibia **C**ompression **F**orce **C**riterion.

Description

TCFC is the criterion for the tibia strain and is the force of pressure F_z, expressed in kN, that is transferred axially to each tibia on the test dummy (see also *TI*).

Mathematical Calculation

—

Determining Input Values

The measurement value of the pelvic strain is filtered in accordance with CFC 600 filtered (see *CFC Filters*).

ISO TS 13499 Code

The ISO code describes the input channels for the TCFC as follows:

```
? ? TIBI ?? ?? ?? FO Z B : Tibia Force Z, CFC 600
```

Relevant Laws and Regulations

- UN-R94, 5.2.1.7
- UN-R94, Annex 4, 5.1
- Directive 96/79/EG, Annex II, 3.2.1.7
- Directive 96/79/EG, Annex II, Appendix 2, 5.1
- Euro NCAP, Frontal Impact

6

Description of Additional Criteria

The following further criteria are described in this chapter:

Xms — Generalization of the 3ms value

Xg — Time range for an acceleration greater than x_g

Acomp — Average Acceleration during Compression phase

Pulse Test — Deceleration corridor for sled tests

ASI — Acceleration Severity Index

THIV — Theoretical Head Impact Velocity

Gillis Index — Characteristic value for assessing vehicle safety in frontal impact.

NCAP — New Car Assessment Programme

Euro NCAP — European New Car Assessment Programme

SI — Severity Index

Integration — Integration methods used

Differentiation — Differentiation methods used

CFC Filters — Channel Frequency Class filters

FIR 100 Filters — Finite Impulse Response filters

Xms

Xms is a generalization of the 3 ms value.

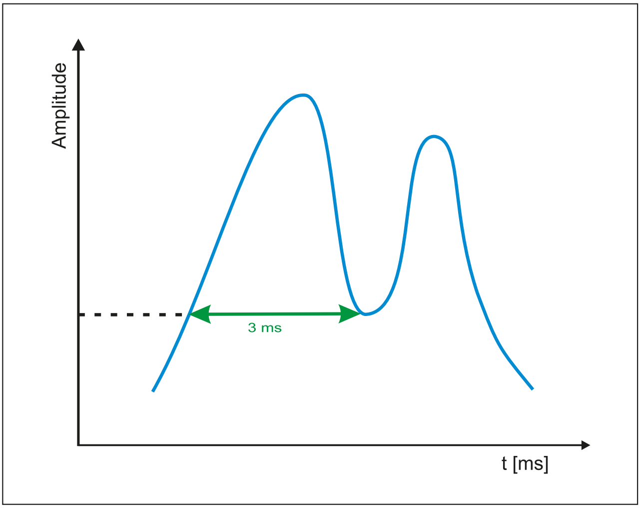
Description

The Xms value is the highest amplitude in a measured signal that lasts x milliseconds. The Xms value is specified either as a single peak (continuously; SAE), or multiple peaks (cumulative; UN-R94, FMVSS). In the cumulative calculation, separate periods of the measurement signal are added, until x milliseconds are reached.

Mathematical Calculation

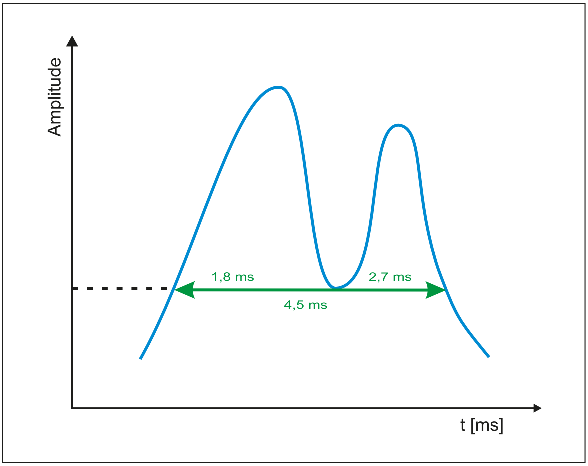
The Xms value can be calculated with one peak, as shown in the first and second figure, or with several peaks, as shown in the third figure.

Figure 6-1. Calculation of the Xms value over a peak



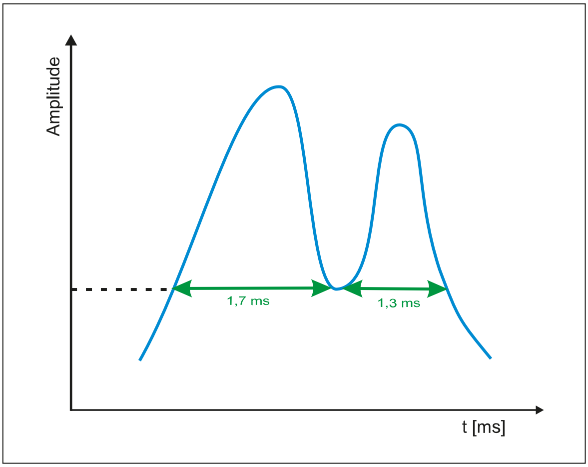
The special case shown in the second figure might have a total time of >x milliseconds.

Figure 6-2. Calculation of the Xms value over a peak



Since the SAE must have a time span of **at least** x ms, the total time (4.5ms) has to be specified, as shown in the third figure.

Figure 6-3. Calculation of the Xms value over several peaks



If the sampling rates are constant, the calculation of the accumulated Xms value shown in the third figure can be based on the following algorithm:

1. Sort the acceleration values in descending order.
2. Acceleration value (sorted) after x ms is the required Xms value.

During calculations in accordance with UN-R94, the rebound movement of the head is not included.

Determining Input Values

The measurement channel must be filtered in accordance with the filter class specified in the regulation.

ISO TS 13499 Code

The ISO code describes the input channels for the Xms as follows:

```
? ? ???? ?? ?? ?? AC ? ? : Acceleration
? ? ???? ?? ?? ?? FO ? ? : Force
```

Relevant Laws and Regulations

- Directive 96/79/EG, Annex 2, 3.2.1.1
- UN-R94, Annex 3, 5.2.1
- UN-R94, Annex 4, 1.3
- UN-R80, Annex 4, 2.1
- UN-R44, 7.1.4.2.1
- UN-R44, 7.1.4.2.2
- UN-R12, 5.3
- UN-R17, 5.1.3.1
- UN-R25, Annex 6, 2
- FMVSS 208 (May 2000), S15.3.3
- FMVSS 208 (May 2000), S19.4.3
- FMVSS 208 (May 2000), S21.5.3
- FMVSS 208 (May 2000), S23.5.3
- SAE J1727, 5.3
- SAE J1727, 6.11
- ADR69/00, 5.3.2
- NHTSA 49 CFR 571[Docket No. 92-28; Notice8], [RIN No. 2127-AG07]; S5.1 (b)
- NHTSA 49 CFR 571,572,589[Docket No. 92-28; Notice7], [RIN No. 2127-AB85]; S5.1 (b)
- EURO NCAP, Frontal Impact, 10, 10.1
- EURO NCAP, Side Impact, 10, 10.1
- EURO NCAP, Pole Side Impact, 10, 10.1
- EURO NCAP, Assessment Protocol, 5
- Formula One Technical Regulation, 16.2

Xg

Description

The Xg value is the time range for an acceleration greater than X[g].

Mathematical Calculation

The Xg-value is determined either individually (single peak) or cumulatively (multiple peaks) and is the time range in which the acceleration was greater than X[g].

In the cumulative calculation, disconnected time ranges for which the head acceleration was greater than X[g], are added up.

Determining Input Values

—

ISO TS 13499 Code

The ISO code describes the input channels for the Xg as follows:

```
? ? ???? ?? ?? ?? AC  ? ? : Acceleration
```

Relevant Laws and Regulations

- UN-R12, 5.3
- UN-R17, 5.1.3.1
- UN–R24
- UN–R96, 3.2.1.1
- ADR69/00, 5.3.2

Acomp

Acomp is the abbreviation for Average **A**cceleration during **Comp**ression phase.

Description

In a frontal impact, the mean acceleration during the deformation phase is calculated for the vehicle acceleration in the x-direction.

Mathematical Calculation

The calculation is completed in the following steps:

1. Integration of the acceleration with the starting speed
2. Defining the first point in time t_1

Figure 6-4. Type 1: Determining an intersection point t_2 of the determined velocity with the abscissa (time axis).

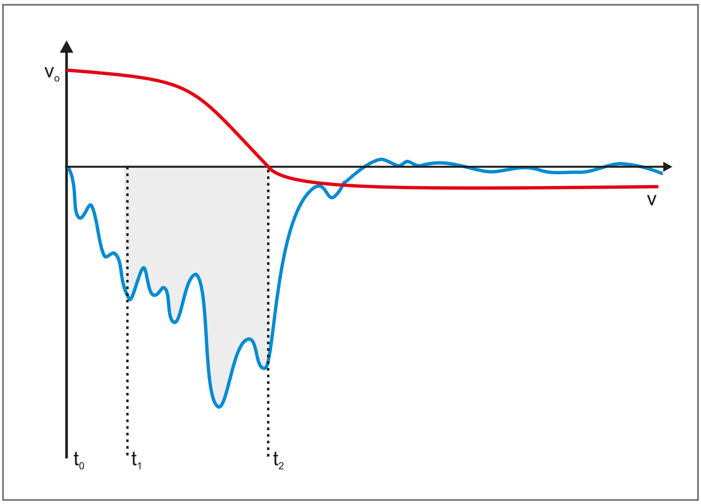
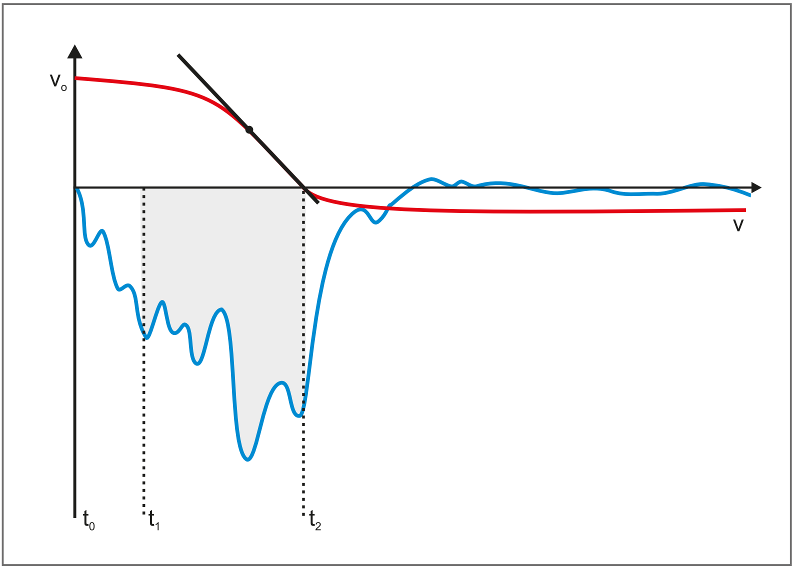


Figure 6-5. Type 2: Determines the point of inflection of the velocity. (The point of inflection is the first maximum of the acceleration). The intersection point t_2 of the tangent with the abscissa (time axis) is determined.



3. The acceleration signal is filtered with CFC 60 (see *CFC Filters*).
4. The mean acceleration of the signal filtered with CFC 60 lies between the specified point in time t_1 and the determined time t_2.

Determining Input Values

The measurement value of the acceleration is filtered in accordance with CFC 60 (see *CFC Filters*).

ISO TS 13499 Code

The ISO code describes the input channels for the Acomp as follows:

```
? ? ???? ?? ?? ?? AC X D :Acceleration, CFC 60
```

Relevant Laws and Regulations

- Company standards

Pulse Test

The pulse test checks the deceleration corridor for sled tests (Deceleration Corridor for Trolley).

Description

In sled tests, you check whether the measured acceleration is within a specific corridor, as shown in the following figures.

Figure 6-6. Corridor for UN-R44; Annex 7; Appendix 1

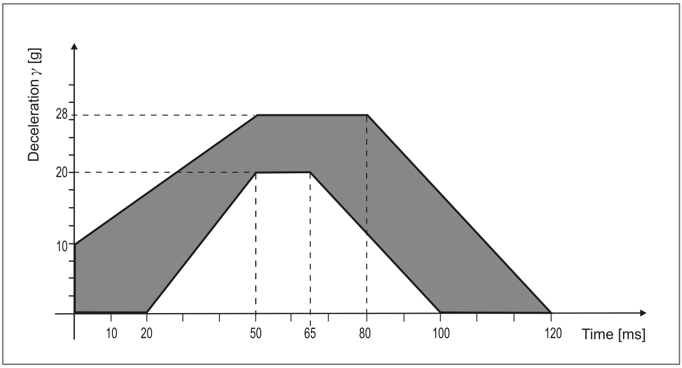


Figure 6-7. Corridor for UN-R44; Annex 7; Appendix 2

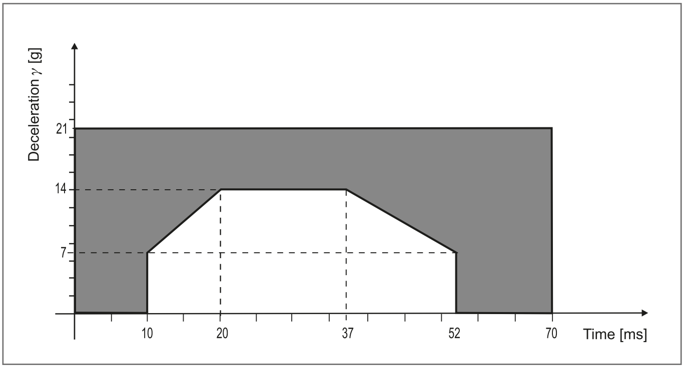


Figure 6-8. Corridor for UN-R16

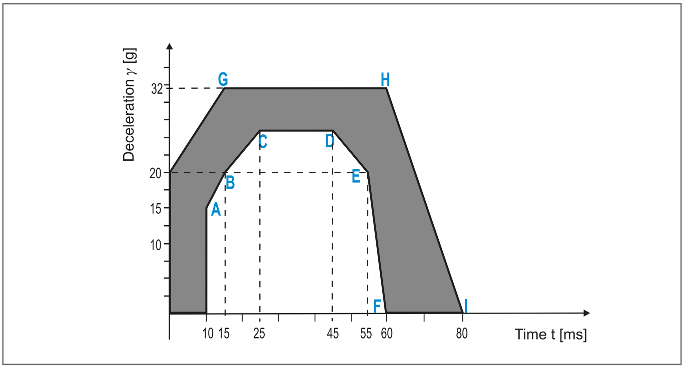


Figure 6-9. Corridor for UN-R16: Description of the delay curve or the acceleration curve of the test sled over time in accordance with UN-R16, Annex 8

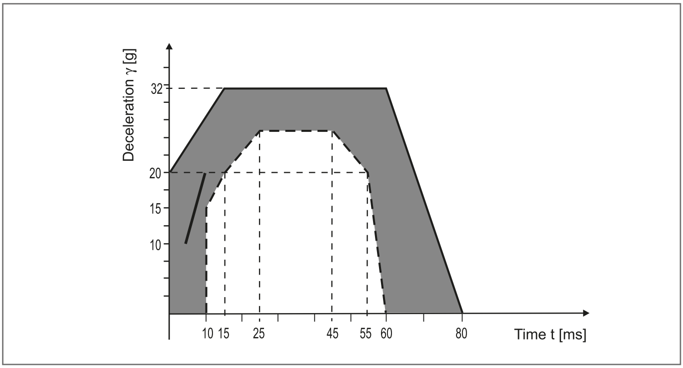


Figure 6-10. Corridor for UN-R17; 6.3.1

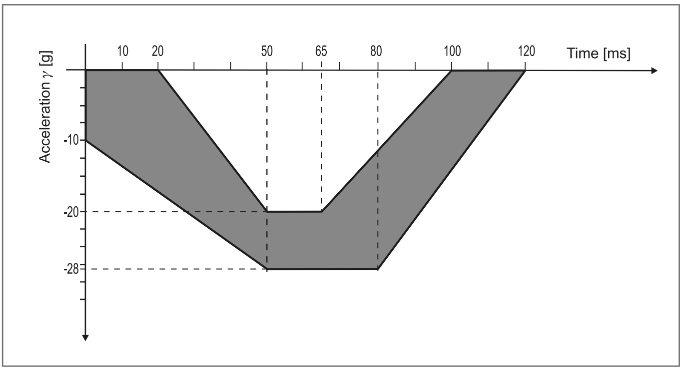


Figure 6-11. Corridor for UN-R80; Annex 4; Figure 1

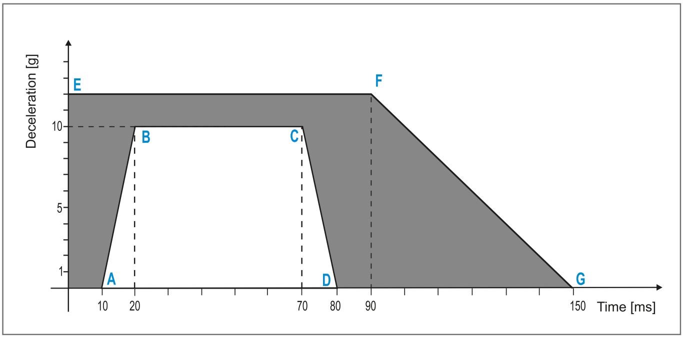


Figure 6-12. Corridor for FMVSS 206; Figure 5

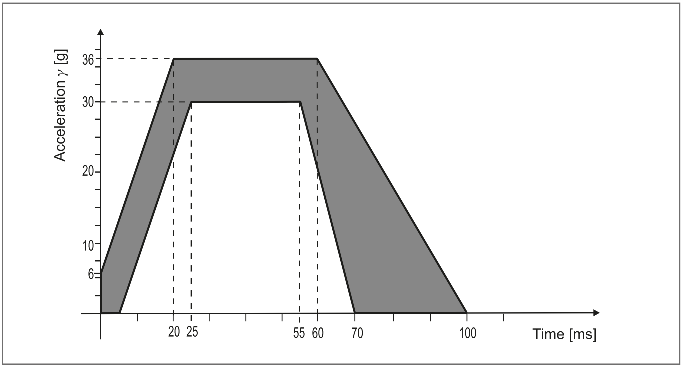


Figure 6-13. Corridor for FMVSS 208; S13.1; Figure 6

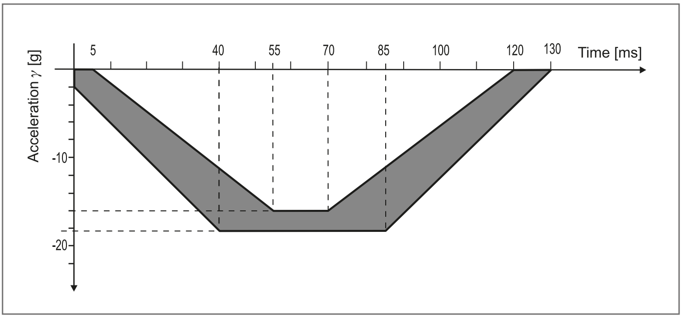
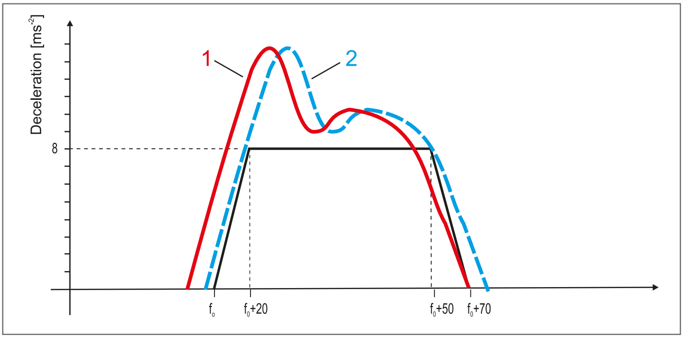


Figure 6-14. Acceleration Impulse of the test sled in accordance with EN 1789 and DIN 75302, figure 4



(1) Measurement curve recorded during the test,
(2) Possibility for moving the curve. The example shows the measurement recording of a valid test.

Figure 6-15. Acceleration impulse in accordance with EN 1789: 1999, Figure 7

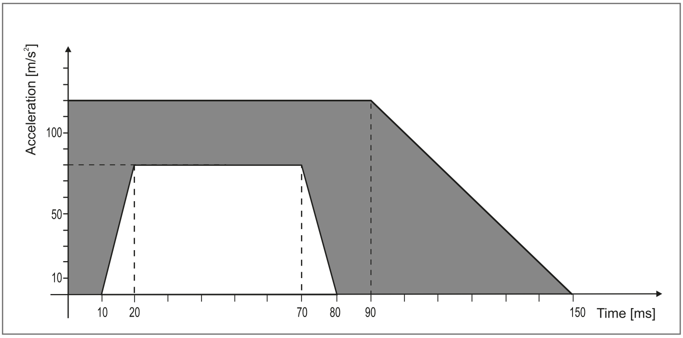


Figure 6-16. Acceleration/ Deceleration requirements for the (48_0^{+2}) km/h delta V impact test in accordance with ISO 7176-19:2001(E)

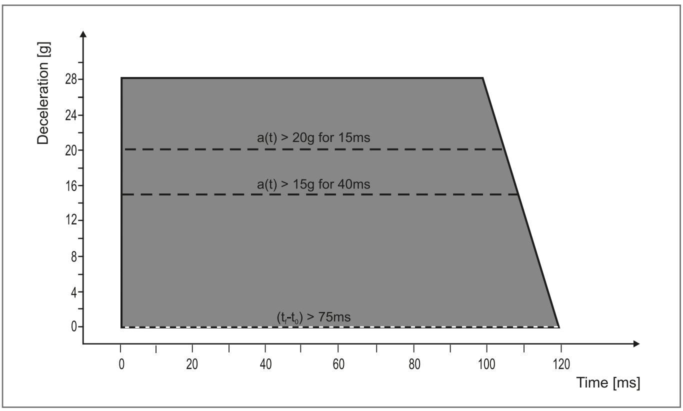


Figure 6-17. Low Severity Pulse corridors for whiplash tests in accordance with Euro NCAP, Appendix IV, Figure 17

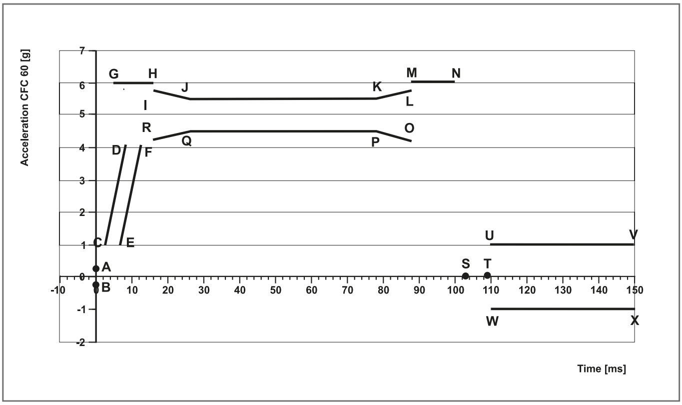


Figure 6-18. Medium Severity Pulse corridors for whiplash tests in accordance with Euro NCAP, Appendix IV, Figure 18

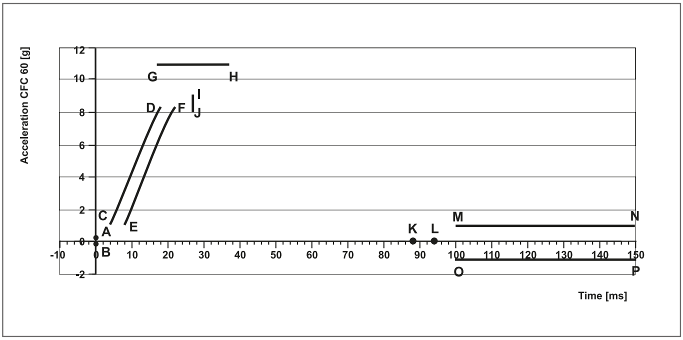
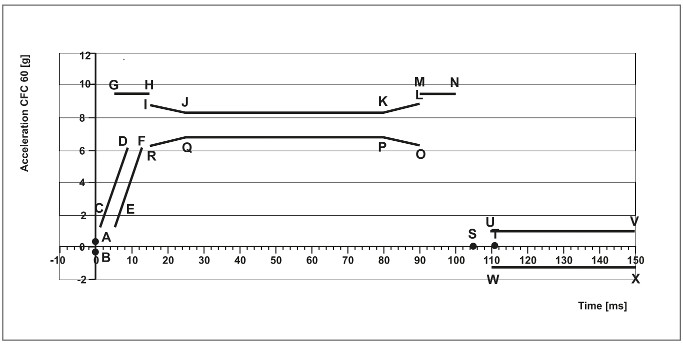


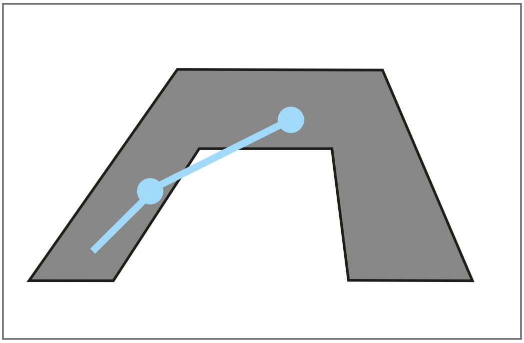
Figure 6-19. High Severity Pulse corridors for whiplash tests in accordance with Euro NCAP, Appendix IV, Figure 19



Mathematical Calculation

The test must determine whether straight lines between two points exceed the specified range and whether the points are within the given range. As the following figure shows points and their connection lines must be within the corridor.

Figure 6-20. Points and connection lines must be inside the corridor



Note In accordance with DIN 75302 the measurement curve (1) can be moved so that the test can be passed.

Determining Input Values

The measurement value of the acceleration is filtered in accordance with CFC 60 (see *CFC Filters*).

Relevant Laws and Regulations

- UN–R11; 3.5.1
- UN–R16; Annex 8
- UN-R17
- UN–R44; Annex 7
- UN–R80; Annex 4; Figure 1
- EN 1789
- DIN 75302
- FMVSS 208; S13.1
- FMVSS 213
- Euro NCAP Whiplash
- SAE AS 8049, Appendix A
- ISO 7862, Annex A– Annex C

ASI

ASI is the abbreviation for the **A**cceleration **S**everity **I**ndex.

Description

The ASI index is a measure for injuries received at the time of impact through the movement of a person in a vehicle with a seat belt system.

Mathematical Calculation

The ASI value is calculated with the following formula:

$$ASI = \left[\left(\frac{\bar{a}_x}{\hat{a}_x}\right)^2 + \left(\frac{\bar{a}_y}{\hat{a}_y}\right)^2 + \left(\frac{\bar{a}_z}{\hat{a}_z}\right)^2\right]^{0.5}$$

Determining Input Values

The measurement value of the acceleration is filtered in accordance with CFC 180 (see *CFC Filters*).

Relevant Laws and Regulations

- DIN-EN 1317-1, 8.1.1

THIV

THIV is the abbreviation of **T**heoretical **H**ead **I**mpact **V**elocity.

Description

The THIV concept was developed to assess injuries of passengers in vehicles with seat belt systems during an impact.

Mathematical Calculation

The THIV value is calculated with the following formula:

$$THIV = \left[v_x^2(t) + v_y^2(t)\right]^{0.5}$$

with $v_x(t) = \dot{x}_b(t)$

and $v_y(t) = \dot{y}_b(t)$

x and y are the position of the vehicle.

Determining Input Values

The measurement value of the acceleration is filtered in accordance with CFC 180 (see *CFC Filters*).

Relevant Laws and Regulations

- DIN-EN 1317-1, 8.1.2

Gillis Index

Description

The Gillis index is a characteristic value for the assessment of the vehicle security during frontal impact. To calculate the Gillis index, the acceleration measurement points of the head and thorax are required as well as the forces on the femur of the driver and the passenger.

Mathematical Calculation

1. Calculate the HIC value and the HIC36 value for the driver and the passenger.
2. Determine the 3 ms values of the resultant thorax acceleration for driver and passenger.
3. Determine the absolute maxima of the forces on the femur of the driver and the passenger.

The Gillis index is calculated with the following formula:

$$G = HIC^D + \frac{D^D}{9.80665} * 16.7 * \frac{3}{4} + \frac{F^{Dl} + F^{Dr}}{4.448232} * 0.44 * \frac{1}{4} + \frac{1}{2} * \left(HIC^P + \frac{D^P}{9.80665} * 16.7 * \frac{3}{4} + \frac{F^{Pl} + F^{Pr}}{4.448232} * 0.44 * \frac{1}{4} \right)$$

The Gillis-Index for 36 milliseconds is calculated with the following formula:

$$G36 = HIC36^D + \frac{D^D}{9.80665} * 16.7 * \frac{3}{4} + \frac{F^{Dl} + F^{Dr}}{4.448232} * 0.44 * \frac{1}{4} + \frac{1}{2} * \left(HIC36^P + \frac{D^P}{9.80665} * 16.7 * \frac{3}{4} + \frac{F^{Pl} + F^{Pr}}{4.448232} * 0.44 * \frac{1}{4} \right)$$

with	*Indices*	*D*—driver, *P*—passenger, *l*—left, *r*—right
	HIC	HIC value
	HIC36	HIC36 value
	F	Absolute maxima of the forces on the femur

Determining Input Values

See also *HIC* and *Xms*.

Relevant Laws and Regulations

—

NCAP

NCAP is the abbreviation for **N**ew **C**ar **A**ssessment **P**rogram.

Description

In order to evaluate the test results, the probabilities of head and thorax injuries according to Mertz (GM) and Prasad (Ford) are used.

Mathematical Calculation

The probability of head injuries is calculated with the following formula:

$$P_{head} = \left(1 + exp\left(5.02 - (0.00351 * HIC36)\right)\right)^{-1}$$

with *HIC36* HIC36 value

The probability of chest injuries is calculated with the following formula:

$$P_{chest} = \left(1 + exp\left(5.55 - (0.0693 * a_{chest.3ms})\right)\right)^{-1}$$

with $a_{chest,\ 3\ ms}$ 3 ms value for chest acceleration

If head and thorax injuries occur simultaneously, a combined probability is calculated with the following formula:

$$P_{combined} = P_{head} + P_{chest} - (P_{head} * P_{chest})$$

The following classification is determined with the determined probability of $P_{combined}$:

Table 6-1. Classifications

$P_{combined} \leq 0,10$	★★★★★
$0,10 < P_{combined} \leq 0,20$	★★★★
$0,20 < P_{combined} \leq 0,35$	★★★
$0,35 < P_{combined} \leq 0,45$	★★
$P_{combined} \geq 0,45$	★

Determining Input Values

—

ISO TS 13499 Code

The ISO code describes the input channels for the NCAP as follows:

```
? ? HEAD ?? ?? ?? AC  X A :Head Acceleration X
? ? HEAD ?? ?? ?? AC  Y A :Head Acceleration Y
? ? HEAD ?? ?? ?? AC  Z A :Head Acceleration Z
? ? CHST ?? ?? ?? AC  X A :Chest Acceleration X
? ? CHST ?? ?? ?? AC  Y A :Chest Acceleration Y
? ? CHST ?? ?? ?? AC  Z A :Chest Acceleration Z
```

Relevant Laws and Regulations

- Refer to the Internet address `www.nhtsa.dot.gov` for more information.

Euro NCAP

Euro NCAP is the abbreviation for **Euro**pean **N**ew **C**ar **A**ssessment **P**rogram

Description

Vehicles are assessed and given stars that indicate the level of safety. The following tests are performed:

- Frontal Impact
- Side Impact
- Pole Side Impact
- Pedestrian Test

Mathematical Calculation

A Euro NCAP spreadsheet shows the test results as points.

Table 6-2. Points evaluation

33 – 40 points	★★★★★
25 – 32 points	★★★★
17 – 24 points	★★★
9 – 16 points	★★
1 – 8 points	★
0 points	

Determining Input Values

—

Relevant Laws and Regulations

- European New Car Assessment Programs
- Refer to the Internet address `www.Euro NCAP.com` for more information.

SI

SI is the abbreviation for the **S**everity **I**ndex.

Description

The SI value assesses the danger of a chest injury (obsolete, similar to HIC {head injury}). This procedure is based on the Wayne-State Curve of Human Tolerance of the human head.

Mathematical Calculation

The incremental SI value is calculated with the following formula:

$$SI_j^{inc} = \frac{1}{1000} N \sum_{i=N(j-1)-1}^{N_j} 0.5 * \left(A_i^{2.5} + A_{i+1}^{2.5}\right)$$

with	*j*	j=1,2, ... T
	T	Length of the data set
	N	Values per ms
	A	i-th value of acceleration signal

The cumulative SI value is calculated with the following formulas:

$$SI_1^{cum} = SI_1^{inc}$$

$$SI_1^{cum} = SI_{j-1}^{cum} + SI_j^{inc}$$

with j = 2,3, ... T

Determining Input Values

—

ISO TS 13499 Code

The ISO code describes the input channels for the SI as follows:

```
? ? CHST ?? ?? ?? AC X :Chest Acceleration X
```

Relevant Laws and Regulations

- SAE J885

Integration

Description

All numeric integration processes (differentiation processes) which return the starting values after an integration followed by differentiation or a differentiation with a subsequent integration are suitable.

Mathematical Calculation

—

Determining Input Values

Note Note that numerical integration routine results are incorrect if there is an offset in the data set.

Relevant Laws and Regulations

- SAE J1727, 5.1.1

Differentiation

Description

All those numeric differentiation processes (integration processes) are suitable, which return the starting values after an integration followed by differentiation or a differentiation with a subsequent integration.

Mathematical Calculation

The differentiation method in accordance with UN-R94 is (see *VC*).

$$\frac{d}{df} * y[t] = V[t] = \frac{8 * (Y[t + \Delta t] - Y[t - \Delta t]) - (Y[t + 2\Delta t] - Y[t - 2\Delta t])}{12\Delta t}$$

with Δt Time interval between the single measurements in seconds

Determining Input Values

—

Relevant Laws and Regulations

- UN-R94, Annex 4, 6.2
- Directive 96/79/EG, Annex II, Appendix 2, 6.2
- SAE J1727, 5.1.2
- SAE J1727, 5.1.3

CFC Filters

CFC is the abbreviation for **C**hannel **F**requency **C**lass

Description

The CFC filters are analog or digital filters. The filters can be phased or un-phased. The following table lists the most common filter types.

Table 6-3. Filter Types

Filter type	Filter parameters	Filter limits
CFC 60	3 dB limit frequency	100 Hz
	Stop damping	–30 dB
	Sampling frequency	At least 600 Hz
CFC 180	3 dB limit frequency	300 Hz
	Stop damping	–30 dB
	Sampling frequency	At least 1800 Hz
CFC 600	3 dB limit frequency	1000 Hz
	Stop damping	–40 dB
	Sampling frequency	At least 6 kHz
CFC 1000	3 dB limit frequency	1650 Hz
	Stop damping	–40 dB
	Sampling frequency	At least 10 kHz

Mathematical Calculation

In accordance with SAE J211, a 4-channel Butterworth low pass with linear phase and special starting conditions is used as a digital filter.

The filter sequence is described by the following difference equation:

$$Y[t] = a_0X[t] + a_1X[t-1] + a_2X[t-2] + b_1Y[t-1] + b_2Y[t-2]$$

with	$X[t]$	Input data sequence
	$Y[t]$	Filtered output data sequence
	a_0, a_1, a_2, b_1, b_2	Filter constants varying with CFC
	T	Sampling interval in seconds

The filter constants are calculated with the following formulas:

$$a_0 = \frac{\omega_a^2}{1 + \sqrt{2}\omega_a + \omega_a^2}$$

$$a_1 = 2a_0$$

$$a_2 = a_0$$

$$b_1 = \frac{-2(\omega_a^2 - 1)}{1 + \sqrt{2}\omega_a + \omega_a^2}$$

$$b_2 = \frac{-1 + \sqrt{2}\omega_a - \omega_a^2}{1 + \sqrt{2}\omega_a + \omega_a^2}$$

with

$$\omega_d = 2\pi * CFC * 2.0775$$

$$\omega_a = \frac{sin\, \omega_d \frac{T}{2}}{cos\, \omega_d \frac{T}{2}}$$

T Sampling interval in seconds

The difference equation describes a two-channel filter: To realize a four-channel filter, the data of the two-channel filter has to run twice: once forwards and once backwards, to prevent phase displacements.

Note The filter constant ω_d is calculated in the ISO 6487 sample code differently to SAE J211:

$$\omega_d = 2\pi * CFC * 1.25 * \frac{5}{3}$$

$$\omega_d = 2\pi * CFC * 2.083\overline{3}$$

Determining Input Values

—

Relevant Laws and Regulations

- SAE J211, 8.4.1
- ISO 6487, 4.5
- ISO 6487, 5.8

FIR 100 Filters

FIR is the abbreviation for **F**inite **I**mpulse **R**esponse

Description

FIR filters are digital filters.

Mathematical Calculation

Filter characteristics in accordance with FMVSS 214, S6.13.5.4

- Passband frequency: 100 Hz
- Stopband frequency: 189 Hz
- Stopband gain: –50 dB
- Passband ripple: 0,0225 dB

NHTSA algorithm for FIR 100:

- CFC 180 phaseless
- Subsampling to 1600 Hz
- Removal of bias
- FIR filters in accordance with filter characteristic FMVSS 214
- Oversampling back to the original sample rate

Determining Input Values

—

Relevant Laws and Regulations

- FMVSS 214, S6.13.5.4
- SAE J1727, 6.13

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Legislation and directives

European Legislation

- UN-R80
- UN-R94
- Regulation 96/79/EG
- UN-R95
- Regulation 96/27/EG
- Regulation 2004/90/EG
- UN-R17
- EEVC AG 17

American Legislation

Federal Motor Vehicle Safety Standard (49 CFR Part 571)

- FMVSS 201
- FMVSS 208
- FMVSS 213
- FMVSS 214

Current American stipulations are also available in the Internet: `www.gpoaccess.gov/cfr`

Japanese Legislation

- TRIAS 47
- TRIAS 63

Standards and Directives

- SAE J1727
- SAE J1733
- SAE J2052
- SAE J211
- ISO 6487
- ISO TS 13499, `standards.iso.org/iso/13499`, `www.iso-mme.org/forum`

- DIN 75302
- EN 1789
- Euro NCAP; European New Car Assessment Programme, `www.Euro NCAP.com/content/test_procedures/introduction.php`
- Robert A. Denton, Sign Conventions for Load Cells (S.A.E. J-211) Rev. 27AUG02

Limit Values

The following table compares the criteria of different test types

Type	America	Europe	Other methods							
	FMVSS208	FMVSS214	NCAP	UN-R94 96/79/EG	UN-R95 96/27/EG	Euro NCAP	Euro NCAP	Euro NCAP	ADAC	AMuS
	Frontal Impact	Side Impact	Front/ Side Impact	Front ODB	Side ODB	Frontal Impact	Side Impact	Side Pole	Front/ Side Impact	Front/ Side Impact
Validity	NPRM 12.5.00	NPRM 18.9.98	1972	From 1998	From 1998	From 2003	From 2003	From 2003		
Speed	56/48 km/h	54 km/h	56/61 km/h	56 km/h	50 km/h	64 km/h	50 km/h	29 km/h carrier	60 km/h	55 km/h
Barrier	Fixed bar.	Mob.Def.Bar	Rigid/ def. bar.	Def. bar.	Mob.Def. Bar.	Def. bar.	Mob.Def. Bar.	Pole		
Overlapping	100%	—	100%/ —	40%		40%	—	—	40%	50%
Impact angle	0×	27×	0×	0×	90×	0×	90×	90×	0º	90º
Test weight	—	1368 kg	— / 1368kg	Addit. weight	950 kg	Addit. weight	950 kg	—	Plus luggage	950 kg
Restraint syst.	Passive		Active	x	x	x	x	x	x	x

PASSENGERS										
Type	America	Europe	Other methods							

	FMVSS208	FMVSS214	NCAP	UN-R94 96/79/EG	UN-R95 96/27/EG	Euro NCAP	Euro NCAP	Euro NCAP	ADAC	AMuS
	Frontal Impact	Side Impact	Front/ Side Impact	Front ODB	Side ODB	Frontal Impact	Side Impact	Side Pole	Front/ Side Impact	Front/ Side Impact
Driver	HIII 5, 50, 95%	US-SID; Spec.	HIII-50% US-SID	HIII-50 %	Euro-SID	HIII-50 %	Euro-SID ES-2 as of 11/02	Euro-SID ES-2 as of 11/02	HIII-50%/Eurosid	50%/ Eurosid
Front seat pass.	HIII 5, 50, 95%	—	—	HIII-50%	—	HIII-50%	—	—	HIII-50%/ Eurosid	50%/ Eurosid
Pos. 4 - behind driver	HIII 12m, 3 year, 6 year	—	—	—	—	P3	P11/2	—	—	—
Pos. 6 - behind passenger	HIII 12m, 3-year, 6-year	—	—	—	—	P11/2	P3	—	—	—
Temperature (measurement time)	20.55-22.22ºC	18.89-25.56ºC	—	19-22ºC	18-26ºC	19-22ºC (>5h)	18-26ºC (>5h)	18-26ºC (>5h)	—	—

SAFETY CRITERIA[1)]										
Type	**America**	**Europe**	**Other methods**							
	FMVSS208	**FMVSS214**	**NCAP**	**UN-R94 96/79/EG**	**UN-R95 96/27/EG**	**Euro NCAP**	**Euro NCAP**	**Euro NCAP**	**ADAC**	**AMuS**
	Frontal Impact	**Side Impact**	**Front/ Side Impact**	**Front ODB**	**Side ODB**	**Frontal Impact**	**Side Impact**	**Side Pole**	**Front/ Side Impact**	**Front/ Side Impact**
HIC, HPC	=<1000 (HIC36) =<700 (HIC15)		=<1000	=<1000	=<1000	=<1000 (HIC36)[2)]	=<1000 (HIC36)	=<1000 (HIC36)	=<1000	=<1000
Head Res 3 ms	—	—	—	=<80g	—	=<80g[1)]	—	=<80g	=<80g	=<80g
Head vert. 3 ms	—	—	—	—	—	=<20g	—	—	—	—
Neck - Flex/Extens.	190/57 Nm	—	—	MOC, Fz	—	MOC, Fz	—	—	—	—
Thorax T1	—	—	—	—	—	—	—	—	—	—
Thorax T12	—	—	—	—	—	—	—	—	—	—
Ribs	—	—	—	—	—	—	—	—	—	—
ChestRes 3 ms	=<60g	—	=<60g/ —	=<60g	—	=<60g	—	—	=<60g	=<60g
Chest vert. 3 ms	—	—	—	—	—	=<30g	—	—	—	—
Chest compression	=<76.2 mm	—	=<76.2 mm	=<50 mm	=<42.0 mm	=<50 mm	=<42.0 mm	—	=<50/ =<42mm	=<50/ =<42mm

SAFETY CRITERIA[1)]										
Type	**America**	**Europe**	**Other methods**							
	FMVSS208	**FMVSS214**	**NCAP**	**UN-R94 96/79/EG**	**UN-R95 96/27/EG**	**Euro NCAP**	**Euro NCAP**	**Euro NCAP**	**ADAC**	**AMuS**
	Frontal Impact	**Side Impact**	**Front/ Side Impact**	**Front ODB**	**Side ODB**	**Frontal Impact**	**Side Impact**	**Side Pole**	**Front/ Side Impact**	**Front/ Side Impact**
VC	=<1.0 ms^{-1}	—	=<1.0 ms^{-1}/ —	=<1.0 ms^{-1}	=<1.0 ms^{-1}	=<1.0 ms^{-1}	=<1.0 ms^{-1}	—	=<1.0 ms^{-1} —	=<1.0 ms^{-1}/—
TTI	—	85/90g	85/90g	—	—	—	—	—	—	—
Abdomen	—	—		—	2.5 kN	—	2.5 kN	—	2.5 kN	2.5 kN
Pelvis	—	130g	130g	—	—	—	—	—	—	—
Pubic Symphysis	—	—	—	—	=<6 kN	—	=<6 kN	—	=<6 kN	=<6 kN
Femur	10 kN	—	=<10 kN	Force/Time	—	Force/Time	—	—	Force/Time	Force/Time
Knee	—	—	—	15 mm	—	15 mm	—	—	15 mm	15 mm
Lower leg	—	—	—	=< 8 kN	—	=< 8 kN	—	—	=< 8 kN	=< 8 kN
Tibia Index	—	—	—	=<1,3	—	=<1,3	—	—	=<1,3	=<1,3

1) Children have different injury criteria.

2) The limit values differ according to vehicle equipment and head contact.

A

Document Change History

V2.4.3:

- 3-2 MOC: In the formula for Mocx the sign for the force component has been corrected from “-“ (V2.4.2) to “+”