Crash Analysis
Criteria Description

Version 2.1.1

**Arbeitskreis
Messdatenverarbeitung
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Crash analysis criteria

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

The description of the criteria contains the name, the mathematical calculation, the input unit, the coding in compliance with ISO TS 13499, and a list of rules and regulations of the algorithm.

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

Explanations to ISO TS 13499

The ISO TS 13499 describes a simple exchange format for multi-medial data from vehicle safety tests.

The ISO TS 13499 describes the data storage structure and the coding of measurement 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.

Document/ Version	Contents	Source	Price
ISO TS 13499	Main Document	www.iso.org	with costs

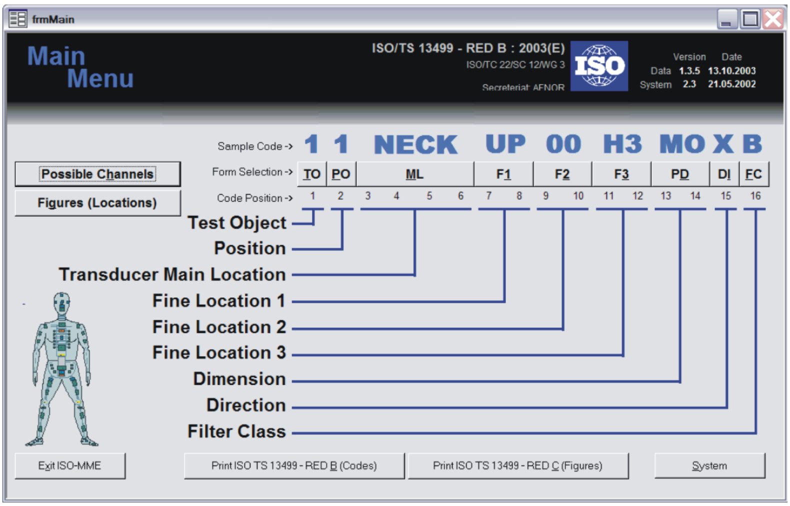
Document/ Version	Contents	Source	Price
RED*A	Examples and hints	standards.iso.org	free of charge
RED B	Channel codes		
RED C	Figures		
RED D	NHTSA Compatibility		
RED E	Calculated Channels		

*RED - Related Electronic Document

Codes

The above 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 standards.iso.org.

The following figure shows the main menu of the ISO TS 13499 data base in the internet.



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Description of the Head Criteria

The following head criteria are described:

- HIC — Head Injury Criterion
- HAC — Head Acceptability Criterion
- HIC(d) — Performance Criterion
- HPC — Head Performance Criterion
- HCD — Head Contact Duration

HIC

HIC is the abbreviation for Head Injury Criterion.

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 of 36 ms
- HIC15: maximum 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 (1 g = 9,80 m/s²). t_1 and t_2 are the moments during an impact for which the HIC value is the maximum value. Measured times are to be specified in seconds.

Determining Input Values

The measured values of the head acceleration (ax, ay, az) are filtered in accordance with CFC 1000.

To specify the input values according to ECE-R80 the measurement values of the head acceleration (ax, ay, az) are filtered in accordance with CFC 600.

ISO TS 13499 Code

The ISO code for the HIC has the following structure.

Output Channel(s)

```
? ? HICR 00  00    ?? 00 R X
             15
             36
```

The following table describes the HIC code.

Part of Code	Code	Description
Test object	`?`	Test object depending
Position	`?`	Position depending
Main location	`HICR`	Head Injury Criterion
Fine location 1	`00`	Without
Fine location 2	`00; 15; 36`	`00` = unlimited `15` = maximum of 15 ms `36` = maximum of 36 ms
Fine location3	`??`	Used for Dummy and Pedestrian Impactor type code
Physical dimension	`00`	Without
Direction	`R`	Resultant
Filter class	`X`	Without

The following table lists the additional channel header attributes for the HIC.

Attribute	Description
.Start time	Start time of the interval belonging to the calculated value (e.g. for the HIC). Only for criteria that uses an interval and not a single point in time.
.End time	End time of the interval belonging to the calculated value (e.g. for the HIC). Only for criteria that uses an interval and not a single point in time.
.Analysis start time	Start of the time interval that has been taken into account for the calculation of the value.
.Analysis end time	End of the time interval that has been taken into account for the calculation of the value.
.Channel 001 .Channel 002 .Channel 003	ISO Code of the first channel used for the calculation. Order of the channels used is arbitrary. Filtering of the channel should be indicated by the right filter class in ISO code at position 16.
.Filter	Filter used: Only if all channels has been filtered with the same channel class! This is redundant to the information given in the ISO codes of each channel but easy to observe in the file.

Input Channel(s)

? ? 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, (ECE R80)

? ? HEAD 00 00 ?? AC Y B : Head Acceleration Y, CFC 600, (ECE R80)

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

Example Codes

`? ? HICR 00 00 ?? 00 R X` : HIC Value (no window limit)

`? ? HICR 00 15 ?? 00 R X` : HIC 15ms Value

`? ? HICR 00 36 ?? 00 R X` : HIC 36ms Value

`? ? HICR 00 15 PA 00 R X` : HIC 15ms Adult Head Impactor

`? ? HICR 00 15 PB 00 R X` : HIC 15ms ACEA Head Impactor

`? ? HICR 00 15 PC 00 R X` : HIC 15ms ACEA Head Impactor

Relevant Laws and Regulations

- FMVSS 208, S6.2
- SAE J2052, 3.2
- SAE J1727,3.6
- ISO/TC22/SC12/WG3 N 282 Issued 1990-03-16
- ADR69/00, 5.3.1
- ECE-R80, Anlage 4, 1
- ECE-R22, 7.3.2.5
- EuroNCAP, Front Impact, 10, 10.1
- EuroNCAP, Side Impact, 10, 10.1
- EuroNCAP, Pole Side Impact, 10, 10.1
- EuroNCAP, Assessment Protocol, 5
- EuroNCAP, Pedestrian Testing Protocol, 10.2
- TRIAS 47, Frontal Impact, 2-6
- TRIAS 63, Pedestrian Impact, 2.4

HAC

HAC is the abbreviation for Head Acceptability Criterion

Caution This calculation instruction is outdated in the ECE-R80. The current version uses the HIC instead.

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). t_1 and t_2 are the points in time during the crash, for which the HAC is at a maximum. Measured times are to be specified in seconds.

Determining Input Values

The measured values of the head acceleration (ax, ay, az) are filtered in accordance with CFC 600..

ISO TS 13499 Code

The ISO code for the HAC has the following structure.

Output Channel(s)

```
? ? HACR 00   00     ?? 00 R X
```

The following table describes the HAC code.

Part of Code	Code	Description
Test object	**?**	Test object depending
Position	**?**	Position depending
Main location	**HACR**	Head Acceptability Criterion
Fine location 1	**00**	Without
Fine location 2	**00**	00 = unlimited
Fine location3	**??**	Dummy type dependent
Physical dimension	**00**	Without
Direction	**R**	Resultant
Filter class	**X**	Without

The following table lists the additional channel header attributes for the HAC.

Attribute	Description
.Start time	Start time of the interval belonging to the calculated value (e.g. for the HIC). Only for criteria that uses an interval and not a single point in time.
.End time	End time of the interval belonging to the calculated value (e.g. for the HIC). Only for criteria that uses an interval and not a single point in time.
.Analysis start time	Start of the time interval that has been taken into account for the calculation of the value.
.Analysis end time	End of the time interval that has been taken into account for the calculation of the value.

Attribute	Description
.Channel 001 .Channel 002 .Channel 003	ISO Code of the first channel used for the calculation. Order of the channels used is arbitrary. Filtering of the channel should be indicated by the right filter class in ISO code at position 16.
.Filter	Filter used: Only if all channels has been filtered with the same channel class! This is redundant to the information given in the ISO codes of each channel but easy to observe in the file.

Input Channel(s)

? ? 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

Example Codes

1 1 HACR 00 00 H3 00 R X : Head Acceptability Criterion 50% Pos11

2 3 HACR 00 00 HM 00 R X : Head Acceptability Criterion 95% Pos23

Relevant Laws and Regulations

- ECE-R80, 5.2.2.1.1
- ECE-R80, Annex 7, 1.1
- Richtlinie 74/408/EWG, Anhang III Anlage 4, 1.1

HIC(d)

HIC(d) is the Performance Criterion

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:

$$HIC(d) = 0.75446 \cdot HIC36 + 166.4$$

with *HIC36* HIC 36 value

Determining Input Values

The measured values of the head acceleration (ax, ay, az) are filtered in accordance with CFC 1000.

ISO TS 13499 Code

The ISO code for the HIC(d) has the following structure:

Output Channel(s)

```
? ? HICR 00  HD   ?? 00 R X
```

The following table describes the HIC(d) code.

Part of Code	Code	Description
Test object	**?**	Test object depending
Position	**?**	Position depending
Main location	**HICR**	Head Injury Criterion
Fine location 1	**00**	Without

Part of Code	Code	Description
Fine location 2	**HD**	Head Performance Criterion
Fine location3	**??**	Dummy type dependent
Physical dimension	**00**	Without
Direction	**R**	Resultant
Filter class	**X**	Without

The following table lists the additional channel header attributes for the HIC(d) .

Attribute	Description
.Start time	Start time of the interval belonging to the calculated value (e.g. for the HIC). Only for criteria that uses an interval and not a single point in time.
.End time	End time of the interval belonging to the calculated value (e.g. for the HIC). Only for criteria that uses an interval and not a single point in time.
.Analysis start time	Start of the time interval that has been taken into account for the calculation of the value.
.Analysis end time	End of the time interval that has been taken into account for the calculation of the value.
.Channel 001 .Channel 002 .Channel 003	ISO Code of the first channel used for the calculation. Order of the channels used is arbitrary. Filtering of the channel should be indicated by the right filter class in ISO code at position 16.
.Filter	Filter used: Only if all channels has been filtered with the same channel class! This is redundant to the information given in the ISO codes of each channel but easy to observe in the file.

Input Channel(s)

`? ? 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

Example Codes

`1 1 HICR 00 HD H3 00 R X` : HIC(d) Free Motion Headform, (FMVSS201)

Relevant Laws and Regulations

- FMVSS 201, S7
- 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

HPC

HPC is the abbreviation for Head Performance Criterion (criterion for the head strain).

Description

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

The HPC value is identical to the HIC value

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, 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, specified 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 at its 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 15ms (HPC15).

Determining Input Values

The measured values of the head acceleration (ax, ay, az) are filtered in accordance with CFC 1000.

ISO TS 13499 Code

The ISO code for the HPC has the following structure.

Output Channel(s)

```
? ? HPCR 00  15    ?? 00 R X

             36
```

The following table describes the HPC code.

Part of Code	Code	Description
Test object	`?`	Test object depending
Position	`?`	Position depending
Main location	`HPCR`	Head Performance Criterion
Fine location 1	`00`	Without
Fine location 2	`15; 36`	`15` = maximum of 15 ms `36` = maximum of 36 ms
Fine location3	`??`	Dummy type dependent
Physical dimension	`00`	Without
Direction	`R`	Resultant
Filter class	`X`	Without

The following table lists the additional channel header attributes for the HPC.

Attribute	Description
.Start time	Start time of the interval belonging to the calculated value (e.g. for the HIC). Only for criteria that uses an interval and not a single point in time.
.End time	End time of the interval belonging to the calculated value (e.g. for the HIC). Only for criteria that uses an interval and not a single point in time.
.Analysis start time	Start of the time interval that has been taken into account for the calculation of the value.
.Analysis end time	End of the time interval that has been taken into account for the calculation of the value.
.Channel 001 .Channel 002 .Channel 003	ISO Code of the first channel used for the calculation. Order of the channels used is arbitrary. Filtering of the channel should be indicated by the right filter class in ISO code at position 16.
.Filter	Filter used: Only if all channels has been filtered with the same channel class! This is redundant to the information given in the ISO codes of each channel but easy to observe in the file.

Input Channel(s)

? ? 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

Example Codes

? ? HPCR 00 15 ?? 00 R X : Head Performance Criterion, Pedestrian

? ? HPCR 00 36 ?? 00 R X : Head Performance Criterion

Relevant Laws and Regulations

- Richtlinie 96/79/EG, Anhang II, 3.2.1.1
- Richtlinie 96/79/EG, Anhang II, Anlage 2, 1.2

- Richtlinie 2003/102/EG
- Richtlinie 2004/90/EG, 2.10
- ECE-R94, Anhang 4, 1.2
- ECE-R95, 5.2.1.1
- ECE-R95, Anhang 4, Anlage 1, 1.
- EuroNCAP Pedestrian Testing Protocol
- EEVC AG 17 Fussgängersicherheit, Terms of Refrence 2002

HCD

HCD is the abbreviation for Head Contact Duration.

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).

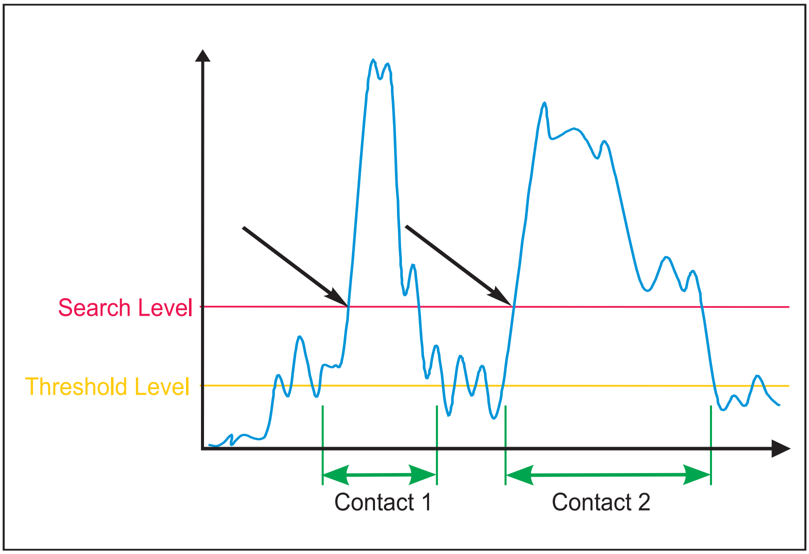
Mathematical Calculation

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

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

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 = 200N) is constantly exceeded and a lower search level (search level = 500N) is exceeded at least once as the following figure shows.



The HIC_j value is calculated for every contact interval Kj

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

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

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 values of the head acceleration (ax, ay, az) and the neck force (Fx, Fy, Fz) are filtered in accordance with CFC 1000.

ISO TS 13499 Code

The ISO code for the HCD has the following structure.

Output Channel(s)

`? ? HECD 00 ?? ?? 00 R X`

The following table describes the HPC code.

Part of Code	Code	Description
Test object	**`?`**	Test object depending
Position	**`?`**	Position depending
Main location	**`HECD`**	Head Contact Duration
Fine location 1	**`00`**	Without
Fine location 2	**`??`**	Fine location 2 dependent
Fine location3	**`??`**	Dummy type dependent
Physical dimension	**`00`**	Without
Direction	**`R`**	Resultant
Filter class	**`X`**	Without

The following table lists the additional channel header attributes for the HCD.

Attribute	Description
.Start time	Start time of the interval belonging to the calculated value (e.g. for the HIC). Only for criteria that uses an interval and not a single point in time.
.End time	End time of the interval belonging to the calculated value (e.g. for the HIC). Only for criteria that uses an interval and not a single point in time.
.Analysis start time	Start of the time interval that has been taken into account for the calculation of the value.

Attribute	Description
.Analysis end time	End of the time interval that has been taken into account for the calculation of the value.
.Channel 001 ... .Channel nnn	ISO Code of the first channel used for the calculation. Order of the channels used is arbitrary. Filtering of the channel should be indicated by the right filter class in ISO code at position 16.
.Filter	Filter used: Only if all channels has been filtered with the same channel class! This is redundant to the information given in the ISO codes of each channel but easy to observe in the file.
.Threshold level	Specific for Head Contact Duration: Threshold level used for the calculation. Maximum of several HIC calculations for time intervals with head contact. Contact Intervals are identified by the ".Threshold level" and the ".Search level"
.Search level	Specific for Head Contact Duration: Search Level used for the calculation. Maximum of several HIC calculations for time intervals with head contact. Contact Intervals are identified by the ".Threshold level" and the ".Search level"
.Mass	Specific for Head Contact Duration: Mass value used for the calculation.

Input Channel(s)

? ? 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

Example Codes

`1 1 HECD 00 00 H3 00 R X :` Head Contact Duration

`2 3 HECD 00 00 HM 00 R X :` Head Contact Duration

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

3

Description of the Neck Criteria

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

Front Impact:

- MOC — Total Moment about Occipital Condyle
- MTO — Total Moment (Lower Neck)
- Time at Level
- NIC (front impact ECE) — Neck Injury Criterion
- NIC (front impact EuroNCAP) — Neck Injury Criterion
- NIC (front impact FMVSS) — Neck Injury Criterion
- Nij — Normalized Neck Injury Criterion

Rear Impact:

- NIC (rear impact) — Neck Injury Criterion
- Nkm — Neck Criterion rear impact
- LNL — Lower Neck Load Index

MOC

MOC is the abbreviation for Total Moment about Occipital Condyle.

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:

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

$$M_{OCx} = M_x + (D \cdot F_y)$$

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

Determining Input Values

The measurement values of the forces and the moments are filtered in accordance with CFC 600. (See also *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 each dummy type.

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	0,00584
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

Dummy type	Load cell type Denton;FTSS;MSC	Axial directions	D[m]
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	W50-1700	6	0,0195

ISO TS 13499 Code

The ISO code for the MOC has the following structure.

Output Channel(s)

```
? ? TMON UP  PO    ?? MO   X X

             NE            Y B
```

The following table describes the MOC code.

Part of Code	Code	Description
Test object	**?**	Test object depending
Position	**?**	Position depending
Main location	**TMON**	Total Moment Neck
Fine location 1	**UP**	UP = Upper position (about occipital condyle)
Fine location 2	**PO; NE**	PO = positive (Flexion) NE = negative (Extension)
Fine location3	**??**	Dummy type dependent

Part of Code	Code	Description
Physical dimension	**MO**	Moment in Nm
Direction	**X; Y**	X = Longitudinal Y = Lateral
Filter class	**X; B**	X = for without B = CFC 600 (if stored as Channel)

The following table lists the additional channel header attributes for the MOC.

Attribute	Description
.Time	The appropriate time where the calculated value occurred.
.Analysis start time	Start of the time interval that has been taken into account for the calculation of the value.
.Analysis end time	End of the time interval that has been taken into account for the calculation of the value.
.Channel 001 ... .Channel nnn	ISO Code of the first channel used for the calculation. Order of the channels used is arbitrary. Filtering of the channel should be indicated by the right filter class in ISO code at position 16.
.Filter	Filter used: Only if all channels has been filtered with the same channel class! This is redundant to the information given in the ISO codes of each channel but easy to observe in the file.

Input Channel(s)

? ? 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

Example Codes

`1 1 TMON UP PO H3 MO X X` : Total Moment Neck X Positive

`1 1 TMON UP NE H3 MO X X` : Total Moment Neck X Negative

`1 1 TMON UP PO H3 MO Y X` : Total Moment Neck Y Positive

`1 1 TMON UP NE H3 MO Y X` : Total Moment Neck Y Negative

Relevant Laws and Regulations

- SAE J1727,3.3 (08/96)
- SAE J1733 (12/94)
- Denton Sign Convention for Load Cells (S.A.E. J-211) (27AUG02)

MTO

MTO is the abbreviation for Total Moment 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 Load Cell is calculated in accordance with SAE J1733 as follows:

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

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

$$M_{TOz} = M_z + (D_x \cdot F_y)$$

with	M_{TOi}	Moment in i-direction [Nm]
	F_i	Neck force in i-direction [N]
	M_i	Neck moment in i-direction [Nm]
	D	Distance between the force sensor axis and the Condyle axis

Determining Input Values

The measurement values of the forces and the moments are filtered in accordance with CFC 600. (See also *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 Dx and Dz in the Lower Load Cell for the calculation in accordance with SAE J1733 in relation to the dummy type.

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

Dummy type	Load cell type Denton; FTSS	D_x[m]	D_z[m]
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 for the MTO has the following structure.

Output Channel(s)

```
? ? TMON LO  PO    ?? MO X X   X X
             NE                Y B
                               Z
```

The following table describes the MTO code.

Part of Code	Code	Description
Test object	`?`	Test object depending
Position	`?`	Position depending
Main location	`TMON`	Total Moment Neck
Fine location 1	`LO`	`LO` = Lower position
Fine location 2	`PO; NE`	`PO` = positive (Flexion) `NE` = negative (Extension)
Fine location3	`??`	Dummy type dependent
Physical dimension	`MO`	Moment

Part of Code	Code	Description
Direction	**X; Y; Z**	X = Longitudinal Y = Lateral Z = Vertical
Filter class	**X; B**	X = for without B = CFC 600 (if stored as Channel)

The following table lists the additional channel header attributes for the MTO.

Attribute	Description
.Time	The appropriate time where the calculated value occurred.
.Analysis start time	Start of the time interval that has been taken into account for the calculation of the value.
.Analysis end time	End of the time interval that has been taken into account for the calculation of the value.
.Channel 001 ... .Channel nnn	ISO Code of the first channel used for the calculation. Order of the channels used is arbitrary. Filtering of the channel should be indicated by the right filter class in ISO code at position 16.
.Filter	Filter used: Only if all channels has been filtered with the same channel class! This is redundant to the information given in the ISO codes of each channel but easy to observe in the file.
.Dx	Distance X between force sensor and joint axis
.Dz	Distance Z between force sensor and joint axis

Input Channel(s)

? ? 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

Example Codes

`1 1 TMON LO PO H3 MO X X` : Total Moment Neck X Positive

`1 1 TMON LO NE H3 MO X X` : Total Moment Neck X Negative

`1 3 TMON LO PO H3 MO Y X` : Total Moment Neck Y Positive

`1 3 TMON LO NE H3 MO Z X` : Total Moment Neck Z Negative

Relevant Laws and Regulations

- SAE J1727,3.3 (08/96)
- SAE J1733 (12/94)
- Denton Sign Convention for Load Cells (SAE J211) (27AUG02)

Time at Level

Time-Dependent Loading Criteria

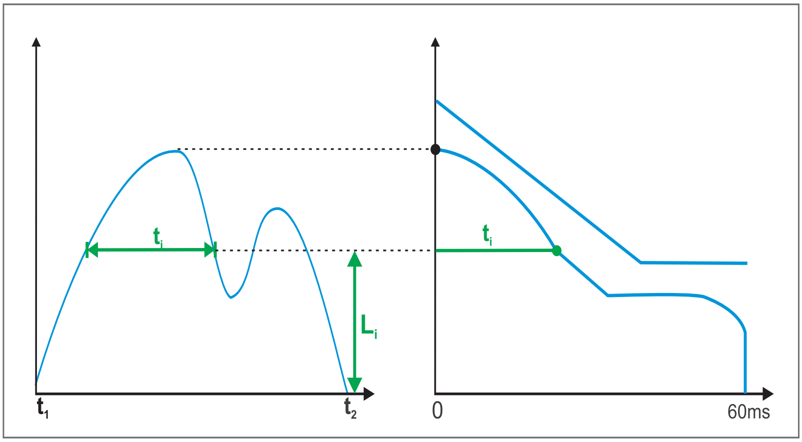
Description

The time-at-level 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 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-related ”load criterion curve” is determined, as the following figure shows.



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 at level – 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 (EuroNCAP)

If the sampling rates are constant, the accumulated values can be calculated with the following algorithm:

1. Values in descending order
2. Value (sorted) after x ms is the y-value.

Determining Input Values

—

Relevant Laws and Regulations

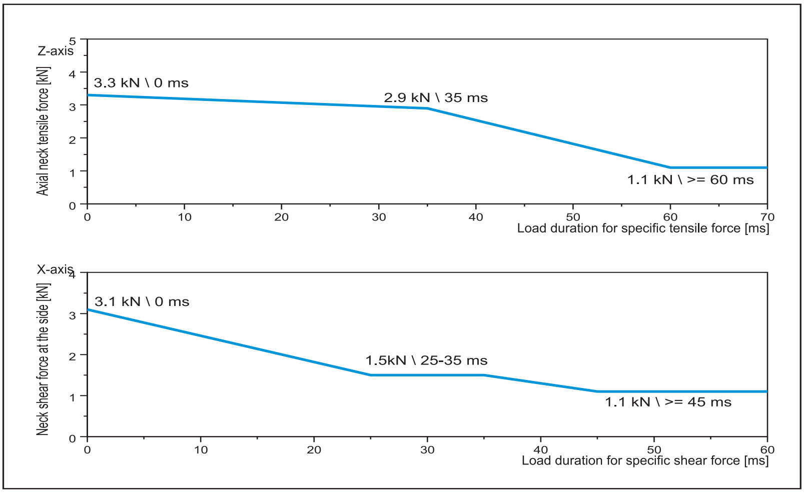
- SAE J1727, 3.9
- EuroNCAP, Front Impact, 10.2.2

NIC (Front Impact ECE)

NIC is the abbreviation for Neck Injury Criterion.

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.



Mathematical Calculation

For all the above-mentioned signals, the time-at-level is calculated and compared to the limit values. (See also).

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 also).

ISO TS 13499 Code

The ISO code for the NIC (front impact ECE) has the following structure.

Output Channel(s)

```
? ? NICF     SP     DP     ?? 00     X X
             ZU     DN               Z
                    DU
```

The following table describes the NIC (front impact ECE) code.

Part of Code	Code	Description
Test object	**?**	Test object depending
Position	**?**	Position depending
Main location	**NICF**	Neck Injury Criterion, Front
Fine location 1	**SP; CU**	SP = Single Peak CU = Cumulative
Fine location 2	**DP; DN; DU**	DP = Duration of loading positive DN = Duration of loading negative DU = Duration of loading
Fine location3	**??**	Dummy type dependent
Physical dimension	**00**	Without
Direction	**X; Z**	X(+) = Shear force Z(+) = Tensile Force Z(-) = Compression Force
Filter class	**X**	Without

The following table lists the additional channel header attributes for the NIC (front impact ECE).

Attribute	Description
.Duration time	For load-duration calculations: Duration for the value closest to the limit line
.Analysis start time	Start of the time interval that has been taken into account for the calculation of the value.
.Analysis end time	End of the time interval that has been taken into account for the calculation of the value.
.Absolute value	For load-duration calculations: Absolute value for the value closest to the limit line.
.Channel 001	ISO Code of the first channel used for the calculation. Order of the channels used is arbitrary. Filtering of the channel should be indicated by the right filter class in ISO code at position 16.
.Filter	Filter used: Only if all channels has been filtered with the same channel class! This is redundant to the information given in the ISO codes of each channel but easy to observe in the file.

Input Channel(s)

? ? 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

Example Codes

1 1 NICF SP DU H3 00 X X : NIC Load Duration X Single Peak

1 1 NICF CU DU H3 00 Z X : NIC Load Duration Z Cummulative

1 1 NICF SP DP H3 00 X X : NIC Load Duration X Pos. Single Peak

1 1 NICF CU DP H3 00 Z X : NIC Load Duration Z Pos. Cummulative

1 1 NICF SP DN H3 00 X X : NIC Load Duration X Neg. Single Peak

1 1 NICF CU DN H3 00 Z X : NIC Load Duration Z Pos. Cummulative

Relevant Laws and Regulations

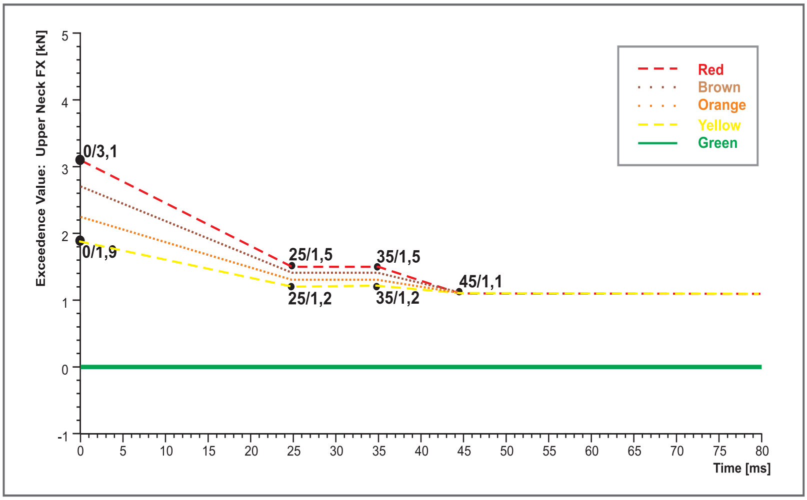
- Richtlinie 96/79/EG, Anhang II, 3.2.1.2
- Richtlinie 96/79/EG, Anhang II, Anlage 2, 2
- ECE-R94, 5.2.1.2
- ECE-R94, Anhang 4, 2
- SAE J1733

NIC (Front Impact EuroNCAP)

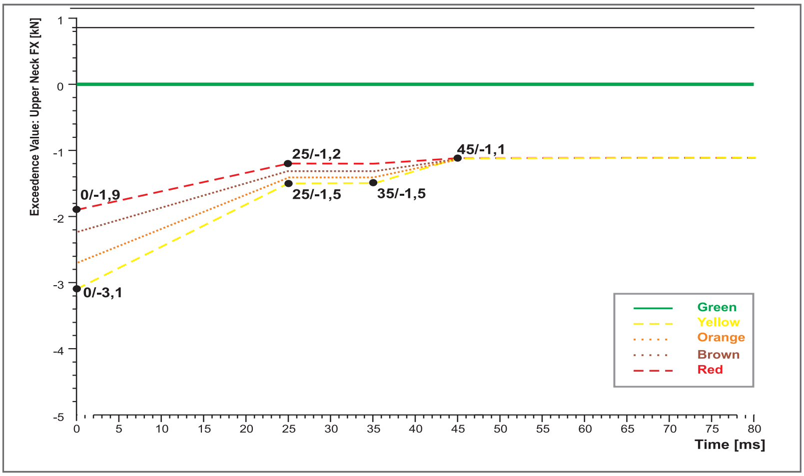
NIC is the abbreviation for Neck Injury Criterion.

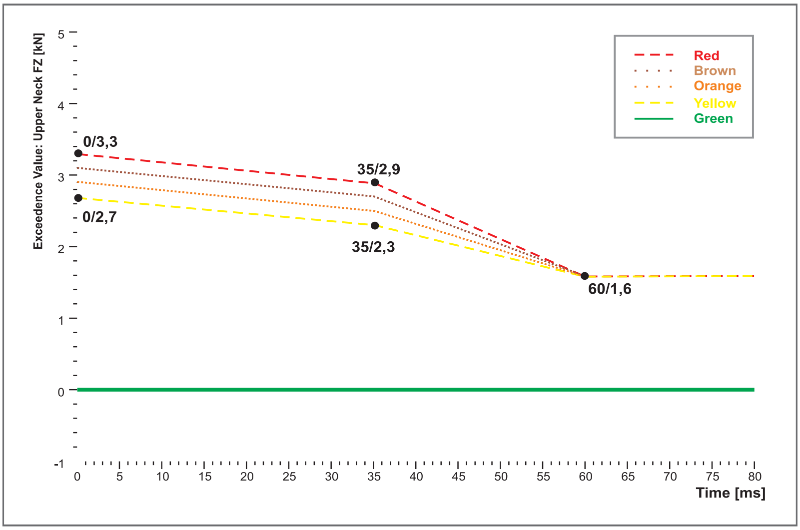
Description

The criteria for neck injuries are determined by the axial tensile force Fz(+), 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.



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





Mathematical Calculation

For all the above-mentioned signals, the cumulative time-at-level is calculated and compared to the limit values. (See also *Time at Level*).

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 also *CFC Filters*).

ISO TS 13499 Code

The ISO code for the NIC (front impact EuroNCAP) has the following structure.

Output Channel(s)

```
? ? NIEF CU   DP    ?? 00    X X
              DN             Z
```

The following table describes the NIC (front impact EuroNCAP) code.

Part of Code	Code	Description
Test object	**?**	Test object depending
Position	**?**	Position depending
Main location	**NIEF**	Neck Injury Criterion, Front
Fine location 1	**CU**	CU = Cumulative
Fine location 2	**DP; DN**	DP = Duration of loading positive DN = Duration of loading negative
Fine location3	**??**	Dummy type dependent
Physical dimension	**00**	Without
Direction	**X; Z**	X = Shear force Z(+) = Tensile Force Z(-) = Compression Force
Filter class	**X**	Without

The following table lists the additional channel header attributes for the NIC (front impact EuroNCAP).

Attribute	Description
.Duration time	For load-duration calculations: Duration for the value closest to the limit line
.Analysis start time	Start of the time interval that has been taken into account for the calculation of the value.
.Analysis end time	End of the time interval that has been taken into account for the calculation of the value.
.Absolute value	For load-duration calculations: Absolute value for the value closest to the limit line.
.Channel 001	ISO Code of the first channel used for the calculation. Order of the channels used is arbitrary. Filtering of the channel should be indicated by the right filter class in ISO code at position 16.
.Filter	Filter used: Only if all channels has been filtered with the same channel class! This is redundant to the information given in the ISO codes of each channel but easy to observe in the file.
.ENCAP Points	.EuroNCAP Points

Input Channel(s)

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

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

Example Codes

1 1 NIEF CU DP H3 00 X X : Neck Injury Criterion, EuroNCAP

1 1 NIEF CU DN H3 00 X X : Neck Injury Criterion, EuroNCAP

1 1 NIEF CU DP H3 00 Z X : Neck Injury Criterion, EuroNCAP

Relevant Laws and Regulations

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

NIC (front impact FMVSS)

NIC is the abbreviation for Neck Injury Criterion.

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

1. See also *NIJ*
2. The following table shows the limit values for each dummy type.

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

Determining Input Values

The measurement values of the limit value monitoring are filtered in accordance with CFC 600. (See also *CFC Filters*).

ISO TS 13499 Code

The ISO code for the NIC (front impact FMVSS) has the following structure.

Output Channel(s)

```
? ? NECK     IP TN     ?? FO Z X
             OP CO
```

The following table describes the NIC (front impact FMVSS) code.

Part of Code	Code	Description
Test object	**?**	Test object depending
Position	**?**	Position depending
Main location	**NECK**	Neck
Fine location 1	**IP; OP**	`IP` = in position `OP` = out of position
Fine location 2	**TN; CO**	`TN` = Tension `CO` = Compression
Fine location3	**??**	Dummy type dependent
Physical dimension	**FO**	Force
Direction	**Z**	`Z(+)` = Tensile Force `Z(-)` = Compression Force
Filter class	**X**	Without

The following table lists the additional channel header attributes for the NIC (front impact FMVSS).

Attribute	Description
.Time	The appropriate time where the calculated value occurred.
.Analysis start time	Start of the time interval that has been taken into account for the calculation of the value.
.Analysis end time	End of the time interval that has been taken into account for the calculation of the value.

Attribute	Description
.Channel 001	ISO Code of the first channel used for the calculation. Order of the channels used is arbitrary. Filtering of the channel should be indicated by the right filter class in ISO code at position 16.
.Filter	Filter used: Only if all channels has been filtered with the same channel class! This is redundant to the information given in the ISO codes of each channel but easy to observe in the file.

Input Channel(s)

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

? ? NECK UP 00 ?? MO Y A : Upper Neck Force Y, CFC 600

Example Codes

1 1 NECK IP CO H3 FO Z X : Neck In Position Compression Force Z

1 3 NECK IP TN H3 FO Z X : Neck In Position Tensile Force Z

1 1 NECK OP CO H3 FO Z X : Neck Out Of Position Comp. Force Z

1 3 NECK OP TN H3 FO Z X : Neck Out Of Position Tensile Force Z

Relevant Laws and Regulations

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

NIJ

Nij is the abbreviation for Normalized Neck Injury Criterion and is the 4 neck criterion (Neck Injury Predictor) NTE (tension-extension), NTF (tension-flexion), NCE (compression-extension), 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:

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

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

Determining Input Values

The measured values of the tensile force and compression force are filtered in accordance with CFC 600. (See also *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.

Criterion Nij	Forces	Moments
N_{CF}	Compression (compression force) F<0	Flexion (forwards bending) M>0
N_{CE}		Extension (backwards extension) M<0
N_{TF}	Tension (tensile force) F>0	Flexion (forwards bending) M>0
N_{TE}		Extension (backwards extension) 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.

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 for Fzc and Myc give 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 ‘in position test‘ according to the dummy types.

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

Dummy Type	F_{zc} [N] Tension	F_{zc} [N]* Compression	M_{yc} [Nm] Flexion	M_{yc} [Nm]* Extension
Hybrid III; 3-year	2120	-2120	68	-27
Hybrid III; 12 months	1460	-1460	43	-17

*The negative signs for Fzc and Myc give positive Nij values (signal polarity in accordance with SAE J211 and SAE J1733).

ISO TS 13499 Code

The ISO code for the NIJ has the following structure.

Output Channel(s)

```
? ? NIJC    IP    CE    ?? 00    X X
            OP    CF             Y B
                  TE
                  TF
                  00
```

The following table describes the NIJ code.

Part of Code	Code	Description
Test object	`?`	Test object depending
Position	`?`	Position depending
Main location	`NIJC`	Normalized Neck Injury Criterion
Fine location 1	`IP; OP`	`IP` = in position `OP` = out of position

Part of Code	Code	Description
Fine location 2	**CE;CF;TE;TF;** **00**	CE = Compression and Extension CF = Compression and Flexion TE = Tension and Extension TF = Tension and Flexion 00 = absolute maximum of CE;CF;TE;TF (optional)
Fine location3	**??**	Dummy type dependent
Physical dimension	**00**	Without
Direction	**X; Y**	X = Longitudinal (Side Impact) Y = Lateral (Frontal Impact)
Filter class	**X; B**	X = for without B = CFC 600 (if stored as Channel)

The following table lists the additional channel header attributes for the NIJ.

Attribute	Description
.Time	The appropriate time where the calculated value occurred.
.Analysis start time	Start of the time interval that has been taken into account for the calculation of the value.
.Analysis end time	End of the time interval that has been taken into account for the calculation of the value.
.Channel 001 ... .Channel nnn	ISO Code of the first channel used for the calculation. Order of the channels used is arbitrary. Filtering of the channel should be indicated by the right filter class in ISO code at position 16.

Attribute	Description
.Filter	Filter used: Only if all channels has been filtered with the same channel class! This is redundant to the information given in the ISO codes of each channel but easy to observe in the file.
.Fzcc	Critical compression force
.Fzct	Critical tension force
.Mycf	Critical flexion moment
.Myce	Critical extension moment

Input Channel(s)

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

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

Example Codes

1 1 NIJC IP CE H3 00 Y X : Neck Injury Criterion Comp./Exte.

1 3 NIJC OP CF Y6 00 Y X : Neck Injury Criterion Comp./Flex.

1 1 NIJC OP TE HF 00 Y X : Neck Injury Criterion Tens./Exte.

1 1 NIJC OP TF H3 00 Y X : Neck Injury Criterion Tens./Flex.

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

Publications:

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

NIC (rear impact)

NIC is the abbreviation for Neck Injury Criterion.

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:

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

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 values of the accelerations are filtered in accordance with CFC 180. (See also *CFC Filters*). 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 a time point within the 150 ms interval after contact with the head rest, this time point limits the NIC interval for determining the NIC_{max} value.

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

ISO TS 13499 Code

The ISO code for the NIC (rear impact) has the following structure.

Output Channel(s)

```
? ? NICR ??  SI    ?? 00 X X
             FI
```

The following table describes the NIC (rear impact) code.

Part of Code	Code	Description
Test object	`?`	Test object depending
Position	`?`	Position depending
Main location	`NICR`	NIC Rear Impact Criterion
Fine location 1	`??`	Fine location 1 dependent
Fine location 2	`SI; FI`	`SI` = selected interval, according to video analysis `FI` = fixed interval (0...150ms)
Fine location3	`??`	Dummy type dependent
Physical dimension	`00`	Without
Direction	`X`	`X` = Longitudinal
Filter class	`X`	Without

The following table lists the additional channel header attributes for the NIC (rear impact).

Attribute	Description
.Time	The appropriate time where the calculated value occurred.
.Analysis start time	Start of the time interval that has been taken into account for the calculation of the value.
.Analysis end time	End of the time interval that has been taken into account for the calculation of the value.
.Factor	Factor used in the calculation: currently for NICR
.Channel 001 ... .Channel nnn	ISO Code of the first channel used for the calculation. Order of the channels used is arbitrary. Filtering of the channel should be indicated by the right filter class in ISO code at position 16.
.Filter	Filter used: Only if all channels has been filtered with the same channel class! This is redundant to the information given in the ISO codes of each channel but easy to observe in the file.

Input Channel(s)

? ? HEAD 00 00 ?? AC X C : Head Acceleration X, CFC 180

? ? SPIN 01 00 ?? AC X C : Spine Acceleration X, CFC 180

Example Codes

1 1 NICR 00 FI BR 00 X X : NIC Rear Impact selected interval

1 3 NICR 00 SI BR 00 X X : NIC Rear Impact fixed interval

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

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 (see also *MOC*) are calculated by adding the standardized shear forces and the standardized corrected bending moment.

Mathematical Calculation

The Nkm value is calculated with the following formula:

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

with	F_x	Force at the point of transition from head to neck.
	F_{int}	Head acceleration in the i direction
	F_i	Critical force
	M_{OCy}	Total Moment (see also *MOC*)
	M_{int}	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 side shearing force are also filtered in accordance with CFC 600. (See also *CFC Filters*.

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.

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

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

Moment	Force
Positive Shear F_{int}	845 N
Negative Shear* F_{int}	-845 N
Flexion M_{int}	88,1 Nm
Extension* M_{int}	-47,5 Nm

*The negative signs of F_{int} and M_{int} make 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 Lower Neck Load 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:

f

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

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.

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

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

Determining Input Values

The measurement values of the forces and the moments are filtered in accordance with CFC 600. (See also *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.

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

Relevant Laws and Regulations

- SAE J1727
- 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

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Description of the chest criteria

The following chest criteria are described:

- 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

VC

VC is the abbreviation for Viscous Criterion (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 ECE-R94, ECE-R95 and EuroNCAP (front and side impact)

$$VC = Scaling\ factor \cdot \frac{Y_{CFC180}}{Defkonst} \cdot \frac{dY_{CFC180}}{dt}$$

In accordance with SAE J1727: (Frontal impact)

$$VC = Scaling\ factor \cdot \frac{Y_{CFC600}}{Defkonst} \cdot \frac{dY_{CFC600}}{dt}$$

with	Y	Thoracic deformation [m]
	dY_{CFCxxx}/dt	Deformation velocity
	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 ECE R94:

$$\frac{dY[t]_{CFC180}}{dt} = V[t] = \frac{8(Y[t+\Delta t] - Y[t-\Delta t]) - (Y[t+2\Delta t] - Y[t-2\Delta t])}{12\Delta t}$$

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, 8/96.

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
BioSID	1,0	175
EuroSID-1	1,0	140
ES-2	1,0	140
SID-IIs	1,0	138

ISO TS 13499 Code

The ISO code for the VC has the following structure.

Output Channel(s)

? ?	**VCCR**	**00**	**00**	**?? VE**	**X**	**X**
	VCAR	**UP**	**01**		**Y**	**B**
		LO	**02**			**C**
		RI	**03**			
		LE	**UP**			
			MI			
			LO			

The following table describes the VC code.

Part of Code	Code	Description
Test object	**?**	Test object depending
Position	**?**	Position depending
Main location	**VCCR; VCAR**	`VCCR` = Viscous Criterion, (Thoracic Ribs) `VCAR` = Viscous Criterion, (Abdominal Ribs)
Fine location 1	**00; LO; UP; LE; RI**	`00` = Not Definied (for V*C calculation of frontal impact dummy like H3 based on rotational potentiometer) `LO` = Lower Position `UP` = Upper Position (determine V*C from acceleration measurement on the sternum and spine) `LE` = Left Position `RI` = Right Position (for side impact dummies)

Part of Code	Code	Description
Fine location 2	**00; 01; 02; 03; UP; MI; LO**	00 = Not Definied UP = Upper MI = Middle LO = Lower (Use 01, 02, 03 or UP, MI, LO according to the coding for the related channel of a side impact dummy (dummy specific). Regardless of the coding for the dummy in FL1 and FL2 here is a strict rule to have LE and RI in FL1 and then UP, MI, LO or 01, 02, 03 in FL2!)
Fine location3	**??**	Dummy type dependent
Physical dimension	**VE**	VE = Velocity
Direction	**X; Y**	X = Longitudinal Y = Lateral (Side)
Filter class	**X; B; C**	X = Without B = CFC 600 (if stored as channel) C = CFC 180 (if stored as channel)

The following table lists the additional channel header attributes for the VC.

Attribute	Description
.Time	The appropriate time where the calculated value occurred.
.Analysis start time	Start of the time interval that has been taken into account for the calculation of the value.
.Analysis end time	End of the time interval that has been taken into account for the calculation of the value.

Attribute	Description
.Factor	Factor used in the calculation: currently for NICR
.Channel 001 ... .Channel nnn	ISO Code of the first channel used for the calculation. Order of the channels used is arbitrary. Filtering of the channel should be indicated by the right filter class in ISO code at position 16.
.Filter	Filter used: Only if all channels has been filtered with the same channel class! This is redundant to the information given in the ISO codes of each channel but easy to observe in the file.
.Scaling factor	Scaling factor in the V*C formula (could alternatively also be described as "factor"; Scaling factor has been taken from the paper describing crash criteria)
.Deformation constant	Deformation constant according to SAE J1727, 8/96

Input Channel(s)

? ? CHST ?? 00 ?? DS X B : Frontal Impact DS, Chest Displacement X, CFC 600

? ? SPIN ?? 00 ?? AC X ? : Frontal Impact AC, Spinal Acceleration X

? ? STRN ?? 00 ?? AC X ? : Frontal Impact AC; Sternum Acceleration X

? ? RIBS ?? UP ?? DS Y C : Side Impact DS, Upper Ribs Displacement Y, CFC 180

? ? RIBS ?? MI ?? DS Y C : Side Impact DS, Middle Ribs Displacement Y, CFC 180

? ? RIBS ?? LO ?? DS Y C : Side Impact DS, Lower Ribs Displacement Y, CFC 180

? ? TRRI ?? 01 ?? DS Y C : Side Impact DS, Thorax Rib Displacement Y, CFC 180

? ? TRRI ?? 02 ?? DS Y C : Side Impact DS, Thorax Rib Displacement Y, CFC 180

? ? TRRI ?? 03 ?? DS Y C : Side Impact DS, Thorax Rib Displacement Y, CFC 180

? ? ABRI ?? 01 ?? DS Y C : Side Impact DS, Abdominal Rib Displacement Y, CFC 180

? ? ABRI ?? 02 ?? DS Y C : Side Impact DS, Abdominal Rib Displacement Y, CFC 180

Example Codes

- VCCR (Viscous Criterion)

1 1 VCCR 00 00 H3 VE X X : Viscous Criterion Driver X

1 1 VCCR LE UP E2 VE Y X : Viscous Criterion upper left rib Y

1 1 VCCR LE MI E2 VE Y X : Viscous Criterion middle left rib Y

1 1 VCCR LE LO E2 VE Y X : Viscous Criterion lower left rib Y

1 1 VCCR RI 01 S2 VE Y X : Viscous Criterion upper right rib Y

1 1 VCCR RI 02 S2 VE Y X : Viscous Criterion middle right rib Y

1 1 VCCR RI 03 S2 VE Y X : Viscous Criterion lower right rib Y

- VCAR (Viscous Criterion Abdomen Rib)

1 1 VCAR LE UP BS VE Y X : Viscous Criterion upper left abdominal rib Y

1 1 VCAR LE LO BS VE Y X : Viscous Criterion lower left abdominal rib Y

1 1 VCAR RI 01 S2 VE Y X : Viscous Criterion upper right abdominal rib Y

1 1 VCAR RI 02 S2 VE Y X : Viscous Criterion lower right abdominal rib Y

Relevant Laws and Regulations

- ECE R94, Directive 96/79/EG, Annex II, 3.2.1.5
- ECE R94, Directive 96/79/EG, Annex II, Appendix 2, 6.1-6.2
- ECE-R94, 5.2.1.4
- ECE R94, Annex 4, 3.2
- ECE R94, Annex 4, 6
- ECE R95, 5.2.1.2 b)
- ECE R95, Annex 4, Appendix 1, 2.2
- ECE 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, 3.8.1
- EuroNCAP, Front Impact, 10.3
- EuroNCAP, Side Impact, 10.3

THPC

THPC is the abbreviation for Thorax Performance Criterion

Description

THPC is the criterion for chest strain with 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 for the THPC has the following structure.

Output Channel(s)

```
? ? THPC  ?? ?? ??  EV 0 X
```

The following table describes the THPC code.

Part of Code	Code	Description
Test object	`?`	Test object depending
Position	`?`	Position depending
Main location	`THPC`	Thoracic Performance Criterion
Fine location 1	`??`	Fine location 1 dependent
Fine location 2	`??`	Fine location 2 dependent
Fine location3	`??`	Dummy type dependent

Part of Code	Code	Description
Physical dimension	**EV**	EV = Event (just pass/fail information based on other criteria (VC and RDC). Used for side impact (ECE-R95)
Direction	**0**	0 = Without
Filter class	**X**	X = Without

Input Channel(s)

? ? VCCR ?? ?? ?? VE Y X : Viscous Criterion, Velocity Y

? ? RDCR ?? ?? ?? DS Y X : Rib Deflection Criterion, Displacement Y

Example Codes

1 1 THPC 00 00 E1 EV 0 X : Thoracic Performance Criterion

Relevant Laws and Regulations

- ECE-R95, 5.2.1.2
- ECE 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 Thoracic Trauma Index (Thorax Trauma Index).

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 for the TTI(d) has the following structure:

Output Channel(s)

```
? ? TTIN   ?? ?? ?? AC Y    X
                            1
```

The following table describes the TTI(d) code.

Part of Code	Code	Description
Test object	**?**	Test object depending
Position	**?**	Position depending
Main location	**TTIN**	Thoracic Trauma Index
Fine location 1	**??**	Fine location 1 dependent
Fine location 2	**??**	Fine location 2 dependent
Fine location3	**??**	Dummy type dependent
Physical dimension	**AC**	Acceleration
Direction	**Y**	`Y` = Lateral
Filter class	**X; 1**	`X` = Without `1` = FIR100 (if stored as channel)

The following table lists the additional channel header attributes for the TTI(d) .

Attribute	Description
.Time rib	The appropriate time where the calculated value occurred.
.Time spine	The appropriate time where the calculated value occurred.
.Analysis start time	Start of the time interval that has been taken into account for the calculation of the value.
.Analysis end time	End of the time interval that has been taken into account for the calculation of the value.
.Channel 001 .Channel 002	ISO Code of the first channel used for the calculation. Order of the channels used is arbitrary. Filtering of the channel should be indicated by the right filter class in ISO code at position 16.
.Filter	Filter used: Only if all channels has been filtered with the same channel class! This is redundant to the information given in the ISO codes of each channel but easy to observe in the file.

Input Channel(s)

? ? 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

Example Codes

1 1 TTIN 00 00 SI AC Y X : Thoracic Trauma Index

Relevant Laws and Regulations

- FMVSS 214, S5.1
- FMVSS 214, S6.13.5
- SAE J1727, 3.5

ThAC

ThAC is the abbreviation for Thorax Acceptability Criterion.

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 of the acceleration is filtered in accordance with CFC 180. (See also *CFC Filters*).

ISO TS 13499 Code

The ISO code for the ThAC has the following structure:

Output Channel(s)

```
? ? THAC ??   3C    ?? AC   X X
              3S            Y C
              5C            Z
              5S            R
```

The following table describes the ThAC code.

Part of Code	Code	Description
Test object	**?**	Test object depending
Position	**?**	Position depending
Main location	**THAC**	Thoracic Acceptability Criterion
Fine location 1	**??**	Fine location 1 dependent

Part of Code	Code	Description
Fine location 2	**3C; 3S; 5C; 5S**	3C = 3 ms Clip cummulative 3S = 3 ms Clip single peak 5C = 5 ms Clip cummulative 5S = 5 ms Clip single peak
Fine location3	**??**	Dummy type dependent
Physical dimension	**AC**	Acceleration
Direction	**X; Y; Z; R**	X = Longitudinal Y = Lateral Z = Vertical R = Resultant
Filter class	**X; C**	X = Without C = CFC 180 (if stored as channel)

The following table lists the additional channel header attributes for the ThAC.

Attribute	Description
.Start time	Start time of the interval belonging to the calculated value (e.g. for the HIC). Only for criteria that uses an interval and not a single point in time.
.End time	End time of the interval belonging to the calculated value (e.g. for the HIC). Only for criteria that uses an interval and not a single point in time.
.Analysis start time	Start of the time interval that has been taken into account for the calculation of the value.
.Analysis end time	End of the time interval that has been taken into account for the calculation of the value.
.Factor	Factor used in the calculation: currently for NICR

Attribute	Description
.Channel 001 .Channel 002 .Channel 003	ISO Code of the first channel used for the calculation. Order of the channels used is arbitrary. Filtering of the channel should be indicated by the right filter class in ISO code at position 16.
.Filter	Filter used: Only if all channels has been filtered with the same channel class! This is redundant to the information given in the ISO codes of each channel but easy to observe in the file.

Input Channel(s)

? ? 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

Example Codes

1 1 THAC 00 3C H2 AC R X : Thorax Acceptability Criterion

1 1 THAC 00 3S H2 AC R X : Thorax Acceptability Criterion

1 1 THAC 00 5C H2 AC R X : Thorax Acceptability Criterion

1 1 THAC 00 5S H2 AC R X : Thorax Acceptability Criterion

Relevant Laws and Regulations

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

CTI

CTI is the abbreviation for Combined Thoracic Index.

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 CIT 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 according to CFC 180 and those of the displacement according to CFC 600 (see also *CFC Filters*).

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

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

Dummy Type	A_{int} [g]	D_{int} [mm]
Hybrid III; 3-year	70	57
CRABI 12 Monate	55	49

ISO TS 13499 Code

The ISO code for the CTI has the following structure.

Output Channel(s)

```
? ? CTIN   ?? ?? ??   00 0 X
```

The following table describes the CTI code.

Part of Code	Code	Description
Test object	`?`	Test object depending
Position	`?`	Position depending
Main location	`CTIN`	Combined Thoracic Index
Fine location 1	`??`	Fine location 1 dependent
Fine location 2	`??`	Fine location 2 dependent
Fine location3	`??`	Dummy type dependent
Physical dimension	`00`	Without
Direction	`0`	Without
Filter class	`X`	Without

The following table lists the additional channel header attributes for the CTI.

Attribute	Description
.Time	The appropriate time where the calculated value occurred.
.Analysis start time	Start of the time interval that has been taken into account for the calculation of the value.
.Analysis end time	End of the time interval that has been taken into account for the calculation of the value.
.Channel 001 ... .Channel nnn	ISO Code of the first channel used for the calculation. Order of the channels used is arbitrary. Filtering of the channel should be indicated by the right filter class in ISO code at position 16.
.Filter 001 ... .Filter nnn	Filter used: Only if all channels has been filtered with the same channel class! This is redundant to the information given in the ISO codes of each channel but easy to observe in the file.
.Aint	Divisor for A3ms part in the formula
.Dint	Divisor for deflection part in the formula

Input Channel(s)

? ? 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

Example Codes

1 1 CTIN 00 00 H3 00 0 X : Combined Thoracic Index

1 3 CTIN 00 00 H3 00 0 X : Combined Thoracic Index

Relevant Laws and Regulations

Note This criterion is not included in the actual 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 Thoracic Compression Criterion.

Description

ThCC is the criterion of the compression of the thorax 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 values of the compression of the thorax are filtered in accordance with CFC 180. (See also *CFC Filters*).

ISO TS 13499 Code

The ISO code for the ThCC/ TCC has the following structure.

Output Channel(s)

```
? ? THCC   ?? ?? ??   DS X X
```

The following table describes the ThCC/TCC code.

Part of Code	Code	Description
Test object	**?**	Test object depending
Position	**?**	Position depending
Main location	**THCC**	Thoracic Compression Criterion
Fine location 1	**??**	Fine location 1 dependent
Fine location 2	**??**	Fine location 2 dependent
Fine location3	**??**	Dummy type dependent
Physical dimension	**DS**	Displacement

Part of Code	Code	Description
Direction	**X**	X = Longitudinal
Filter class	**X**	X = Without

The following table lists the additional channel header attributes for the ThCC/ TCC.

Attribute	Description
.Time	The appropriate time where the calculated value occurred.
.Analysis start time	Start of the time interval that has been taken into account for the calculation of the value.
.Analysis end time	End of the time interval that has been taken into account for the calculation of the value.
.Channel 001	ISO Code of the first channel used for the calculation. Order of the channels used is arbitrary. Filtering of the channel should be indicated by the right filter class in ISO code at position 16.
.Filter	Filter used: Only if all channels has been filtered with the same channel class! This is redundant to the information given in the ISO codes of each channel but easy to observe in the file.

Input Channel(s)

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

Example Codes

1 1 THCC 00 00 H3 DS X X : Thoracic Compression Criterion

Relevant Laws and Regulations

- ECE-R94, 5.2.1.4
- ECE 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 Rib Deflection Criterion.

Description

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

Mathematical Calculation

—

Determining Input Values

The measurement values of the deflection of the ribs are filtered in accordance with CFC 180. (See also *CFC Filters*).

ISO TS 13499 Code

The ISO code for the RDC has the following structure.

Output Channel(s)

```
? ?   RDCR LE   UP   ?? DS Y X
      RDAR RI   MI
                LO
```

The following table describes the RDC code.

Part of Code	Code	Description
Test object	**?**	Test object depending
Position	**?**	Position depending
Main location	**RDCR; RDAR**	RDCR = Chest Rib Deflection Criterion RDAR = Abdominal Rib Deflection Criterion
Fine location 1	**LE; RI**	LE = Left RI = Right

Part of Code	Code	Description
Fine location 2	**UP; MI; LO**	UP = Upper MI = Middle LO = Lower
Fine location3	**??**	Side Impact Dummy type dependent (E1;E2;BS;...)
Physical dimension	**DS**	Displacement
Direction	**Y**	Y = Lateral
Filter class	**X**	X = Without

The following table lists the additional channel header attributes for the RDC.

Attribute	Description
.Time	The appropriate time where the calculated value occurred.
.Analysis start time	Start of the time interval that has been taken into account for the calculation of the value.
.Analysis end time	End of the time interval that has been taken into account for the calculation of the value.
.Channel 001	ISO Code of the first channel used for the calculation. Order of the channels used is arbitrary. Filtering of the channel should be indicated by the right filter class in ISO code at position 16.
.Filter	Filter used: Only if all channels has been filtered with the same channel class! This is redundant to the information given in the ISO codes of each channel but easy to observe in the file.

Input Channel(s)

? ? HEAD 00 00 ?? AC X C : Head Acceleration X, CFC 180

? ? RIBS LE UP ?? DS Y C : Upper Left Ribs Displacement Y, CFC 180

? ? RIBS LE MI ?? DS Y C : Middle Left Ribs Displacement Y, CFC 180

? ? RIBS LE LO ?? DS Y C : Lower Left Ribs Displacement Y, CFC 180

? ? RIBS RI UP ?? DS Y C : Upper Right Ribs Displacement Y, CFC 180

? ? RIBS RI MI ?? DS Y C : Middle Right Ribs Displacement Y, CFC 180

? ? RIBS RI LO ?? DS Y C : Lower Right Ribs Displacement Y, CFC 180

? ? CHRI RI UP ?? DS Y C : Upper Right Chest Rib Displacement Y, CFC 180

? ? CHRI RI MI ?? DS Y C : Middle Right Chest Rib Displacement Y, CFC 180

? ? CHRI RI LO ?? DS Y C : Lower Right Chest Rib Displacement Y, CFC 180

? ? ABRI RI UP ?? DS Y C : Upper Right Abdominal Rib Displacement Y, CFC 180

? ? ABRI RI MI ?? DS Y C : Middle Right Abdominal Rib Displacement Y, CFC 180

? ? ABRI RI LO ?? DS Y C : Lower Right Abdominal Rib Displacement Y, CFC 180

Example Codes

- RDCR (Rib Deflection Criterion)

  1 1 RDCR LE UP E1 DS Y X : Chest Rib Defl. Crit. upper left rib Y

  1 4 RDCR LE MI E1 DS Y X : Chest Rib Defl. Crit. middle left rib Y

  1 6 RDCR RI LO E2 DS Y X : Chest Rib Defl. Crit. lower right rib Y

- RDAR (Rib Deflection Criterion Abdomen)

  `1 1 RDAR LE UP BS DS Y X :` Abdominal Rib Defl. Crit. Upper left Rib Y

  `1 3 RDAR RI 01 S2 DS Y X :` Abdominal Rib Defl. Crit. Upper right Rib Y

Relevant Laws and Regulations

- ECE R95, 5.2.1.2 a)
- ECE 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 Chest Deflection (Compression) Rate 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 decided to use the first method and to check the result with the integration method. 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 according to SAE CFC 1000.

   c. The data of the deflection of chest and rib must be filtered according to 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 point 1.h is searched for. This value is called ValueB.

b. If the absolute value of ValueB is $\leq$0,1 m/s, the compression rate from point I.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 according to CFC 600 (See also *CFC Filters*).

The measured accelerations for chest, sternum, spine, and rib are filtered according to CFC 1000 (See also *CFC Filters*).

ISO TS 13499 Code

The ISO code for the CDR has the following structure.

Output Channel(s)

? ?	**CDRD**	**LE**	**00**	**?? VE**	**X**	**X**
	CDRA	**RI**	**01**		**Y**	**A**
	ADRD	**00**	**02**			**B**
	ADRA		**03**			
			UP			
			MI			
			LO			

The following table describes the CDR code.

Part of Code	Code	Description
Test object	**?**	Test object depending
Position	**?**	Position depending
Main location	**CDRD; CDRA; ADRD; ADRA**	CDRD = Chest Deflection Rate by Displacement (Frontal,Side); CDRA = Chest Deflection Rate by Acceleration (Frontal, Side); ADRD = Abdominal Defl. Rate by Displacement (Side); ADRA = Abdominal Defl. Rate by Acceleration (Side)
Fine location 1	**00; LE; RI**	00 = undefined (Frontal) LE = Left (Side) RI = Right (Side)

Part of Code	Code	Description
Fine location 2	**00; 01; 02; 03; UP; MI; LO**	00 = undefined (Frontal) 01 = Upper (Side) 02 = Middle (Side) 03 = Lower (Side) UP = Upper (Side) MI = Middle (Side) LO = Lower (Side)
Fine location3	**??**	Dummy type dependent Frontal (Y6;Y7; HF;...) Side (S2;...)
Physical dimension	**VE**	Velocity
Direction	**X; Y**	X = Longitudinal (Frontal) Y = Lateral (Side)
Filter class	**X; A; B**	X = Without A = CFC 1000 (channel) B = CFC 600 (channel)

The following table lists the additional channel header attributes for the CDR.

Attribute	Description
.Time	The appropriate time where the calculated value occurred.
.Analysis start time	Start of the time interval that has been taken into account for the calculation of the value.
.Analysis end time	End of the time interval that has been taken into account for the calculation of the value.

Attribute	Description
.Channel 001 ... .Channel nnn	ISO Code of the first channel used for the calculation. Order of the channels used is arbitrary. Filtering of the channel should be indicated by the right filter class in ISO code at position 16.
.Filter	Filter used: Only if all channels has been filtered with the same channel class! This is redundant to the information given in the ISO codes of each channel but easy to observe in the file.

Input Channel(s)

? ? 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

Example Codes

- CDRD (Chest Deflection Rate by Displacement)

  1 1 CDRD 00 00 H3 VE X X : Chest Defl. Rate X (by Displ.)

  1 1 CDRD LE UP E1 VE Y X : Chest Defl. Rate upper left rib Y (by Displ.)

  1 4 CDRD LE MI E1 VE Y X : Chest Defl. Rate middle left rib X (by Displ.)

1 6 CDRD RI UP E2 VE Y X : Chest Defl. Rate upper right rib X (by Displ.)

- CDRA (Chest Deflection Rate by Acceleration)

1 3 CDRA 00 00 HF VE X X : Chest Defl. Rate X (by Accel.)

1 1 CDRA LE 01 S2 VE Y X : Chest Defl. Rate upper left rib Y (by Accel.)

1 3 CDRA RI 01 S2 VE Y X : Chest Defl. Rate upper right rib Y (by Accel.)

- ADRD (Abdominal Reflection Rate by Displacement)

1 1 ADRD LE 01 S2 VE Y X : Abdom. Defl. Rate upper left rib Y (by Displ.)

1 4 ADRD LE 02 S2 VE Y X : Abdom. Defl. Rate lower left rib Y (by Displ.)

- ADRA (Abdominal Reflection Rate by Acceleration)

1 1 ADRA LE 01 S2 VE Y X : Abdom. Defl. Rate upper left rib Y (by Accel.)

1 3 ADRA RI 02 S2 VE Y X : Abdom. Defl. Rate lower right rib Y (by Accel.)

Relevant Laws and Regulations

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

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 (EuroNCAP) — Femur Force Criterion
- TI —Tibia-Index
- TCFC — Tibia Compression Force Criterion

APF

APF is the abbreviation for Abdominal Peak Force. 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

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

Determining Input Values

The measurement values of the abdominal strain are filtered in accordance with CFC 600. (See also *CFC Filters*).

ISO TS 13499 Code

The ISO code for the APF has the following structure.

Output Channel(s)

```
? ? ABPF   LE   SU ?? FO Y X

           RI
```

The following table describes the APF code.

Part of Code	Code	Description
Test object	**?**	Test object depending
Position	**?**	Position depending
Main location	**ABPF**	Abdominal Peak Force
Fine location 1	**LE; RI**	LE = Sum RI = Sum
Fine location 2	**SU**	SU = Sum

Part of Code	Code	Description
Fine location3	`??`	Dummy type dependent
Physical dimension	`FO`	Force
Direction	`Y`	Without
Filter class	`X`	Without

The following table lists the additional channel header attributes for the APF.

Attribute	Description
.Time	The appropriate time where the calculated value occurred.
.Analysis start time	Start of the time interval that has been taken into account for the calculation of the value.
.Analysis end time	End of the time interval that has been taken into account for the calculation of the value.
.Channel 001 ... .Channel nnn	ISO Code of the first channel used for the calculation. Order of the channels used is arbitrary. Filtering of the channel should be indicated by the right filter class in ISO code at position 16.
.Filter	Filter used: Only if all channels has been filtered with the same channel class! This is redundant to the information given in the ISO codes of each channel but easy to observe in the file.

Input Channel(s)

? ? 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

Example Codes

1 1 ABPF LE SU E1 FO Y X : Abdominal Peak Force Left

1 1 ABPF RI SU E2 FO Y X : Abdominal Peak Force Right

Relevant Laws and Regulations

- ECE-R95, 5.2.1.4
- ECE 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 Pubic Symphysis Peak Force.

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 measurements of the pelvic strain are filtered in accordance with CFC 600 (See also *CFC Filters*).

ISO TS 13499 Code

The ISO code for the PSPF has the following structure.

Output Channel(s)

```
? ? PSPF   LE    00 ?? FO Y X

           RI
```

The following table describes the PSPF code.

Part of Code	Code	Description
Test object	**?**	Test object depending
Position	**?**	Position depending
Main location	**PSPF**	Pubic Symphysis Peak Force
Fine location 1	**LE; RI**	Fine location 1 dependent
Fine location 2	**00**	Fine location 2 dependent
Fine location3	**??**	Dummy type dependent
Physical dimension	**FO**	Force

Part of Code	Code	Description
Direction	**Y**	Y = Lateral
Filter class	**X**	Without

The following table lists the additional channel header attributes for the PSPF.

Attribute	Description
.Time	The appropriate time where the calculated value occurred.
.Analysis start time	Start of the time interval that has been taken into account for the calculation of the value.
.Analysis end time	End of the time interval that has been taken into account for the calculation of the value.
.Channel 001	ISO Code of the first channel used for the calculation. Order of the channels used is arbitrary. Filtering of the channel should be indicated by the right filter class in ISO code at position 16.
.Filter	Filter used: Only if all channels has been filtered with the same channel class! This is redundant to the information given in the ISO codes of each channel but easy to observe in the file.

Input Channel(s)

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

Example Codes

1 1 PSPF 00 00 E1 FO Y X : Pubic Symphisis Peak Force

1 4 PSPF 00 00 E2 FO Y X : Pubic Symphisis Peak Force

Relevant Laws and Regulations

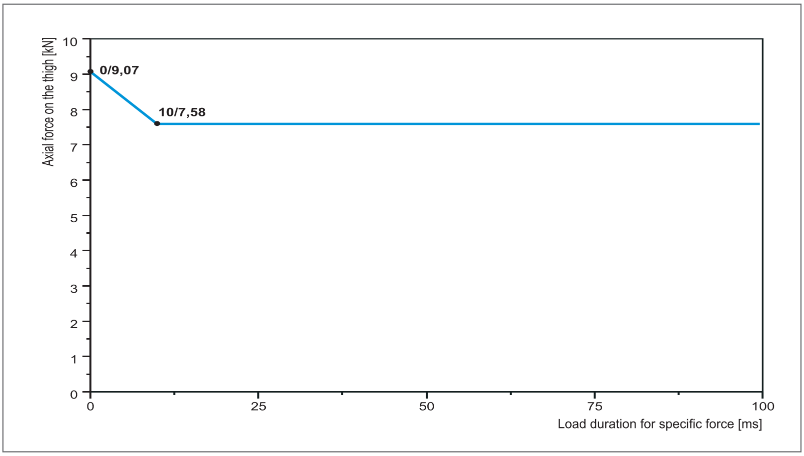
- ECE R95, 5.2.1.3
- ECE R95, Annex 4, Appendix 1, 4
- Directive 96/27 EG Annex 2, 3.2.1.3
- Directive 96/27 EG Annex 1, Appendix 1, 4

FFC (ECE)

FFC is the abbreviation for Femur Force Criterion

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.



Note The pressure is entered as a positive value in the diagram.

Mathematical Calculation

See also *Time at Level* .

Note The time-at-level is calculated cumulatively (see also *FFC (EuroNCAP)*).

Determining Input Values

The measured values of the compression force are filtered in accordance with CFC 600. (See also *CFC Filters*).

ISO TS 13499 Code

The ISO code for the FFC (ECE) has the following structure:

Output Channel(s)

```
? ? FFCR   LE    DN ?? FO Z X
           RI
```

The following table describes the FFC (ECE) code.

Part of Code	Code	Description
Test object	**?**	Test object depending
Position	**?**	Position depending
Main location	**FFCR**	Femur Force Criterion
Fine location 1	**LE; RI**	LE = Left RI = Right
Fine location 2	**DN**	DN = Duration of loading negative
Fine location3	**??**	Dummy type dependent
Physical dimension	**FO**	Force
Direction	**Z**	Z = Vertical
Filter class	**X**	Without

The following table lists the additional channel header attributes for the FFC (ECE) .

Attribute	Description
.Duration time	For load-duration calculations: Duration for the value closest to the limit line
.Absolute value	For load-duration calculations: Absolute value for the value closest to the limit line.
.Analysis start time	Start of the time interval that has been taken into account for the calculation of the value.
.Analysis end time	End of the time interval that has been taken into account for the calculation of the value.

Attribute	Description
.Channel 001	ISO Code of the first channel used for the calculation. Order of the channels used is arbitrary. Filtering of the channel should be indicated by the right filter class in ISO code at position 16.
.Filter	Filter used: Only if all channels has been filtered with the same channel class! This is redundant to the information given in the ISO codes of each channel but easy to observe in the file.

Input Channel(s)

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

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

Example Codes

1 1 FFCR LE DN H3 FO Z X : Femur Force Criterion Left

1 3 FFCR RI DN H3 FO Z X : Femur Force Criterion Right

Relevant Laws and Regulations

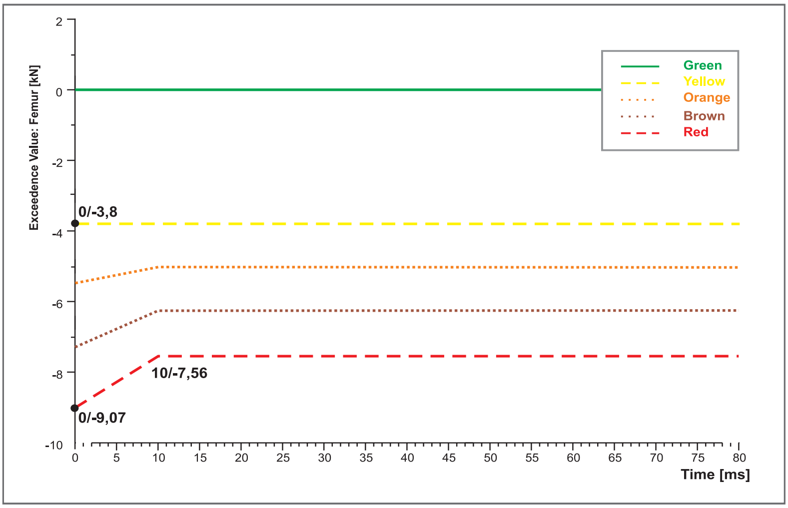
- ECE-R94, 5.2.1.6
- ECE R94, Annex 4, 4
- Directive 96/79/EG, Annex II, 3.2.1.6
- Directive 96/79/EG, Annex II, Appendix 2, 4.1

FFC (EuroNCAP)

FFC is the abbreviation for Femur Force Criterion

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.



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

Mathematical Calculation

See also *Time at Level* .

Note The time-at-level is calculated cumulatively.

Determining Input Values

The measured values of the compression force are filtered in accordance with CFC 600. (See also *CFC Filters*).

ISO TS 13499 Code

The ISO code for the FFC (EuroNCAP) has the following structure:

Output Channel(s)

```
? ? FFCE   LE   DN ?? FO Z X
           RI
```

The following table describes the FFC (EuroNCAP) code.

Part of Code	Code	Description
Test object	**?**	Test object depending
Position	**?**	Position depending
Main location	**FFCE**	Femur Force Criterion
Fine location 1	**LE; RI**	LE = Left RI = Right
Fine location 2	**DN**	DN = Duration of loading negative
Fine location3	**??**	Dummy type dependent
Physical dimension	**FO**	Force
Direction	**Z**	Vertical
Filter class	**X**	Without

The following table lists the additional channel header attributes for the FFC (EuroNCAP).

Attribute	Description
.Duration time	For load-duration calculations: Duration for the value closest to the limit line
.Absolute value	For load-duration calculations: Absolute value for the value closest to the limit line.
.Analysis start time	Start of the time interval that has been taken into account for the calculation of the value.
.Analysis end time	End of the time interval that has been taken into account for the calculation of the value.

Attribute	Description
.Channel 001	ISO Code of the first channel used for the calculation. Order of the channels used is arbitrary. Filtering of the channel should be indicated by the right filter class in ISO code at position 16.
.Filter	Filter used: Only if all channels has been filtered with the same channel class! This is redundant to the information given in the ISO codes of each channel but easy to observe in the file.

Input Channel(s)

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

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

Example Codes

1 1 FFCE LE DN H3 FO Z X : Femur Force Criterion left

1 3 FFCE RI DN H3 FO Z X : Femur Force Criterion right

Relevant Laws and Regulations

- EuroNCAP, Frontal Impact Testing Protocol, Version 4.0; January 2003

TI

TI is the abbreviation for the Tibia Index.

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:

$$TI = \left| \frac{M_R}{(M_C)_R} \right| + \left| \frac{F_Z}{(F_C)_Z} \right|$$

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

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 compression [kN] in z-direction
	$(F_c)_z$	Critical compression force in z-direction; see the following table

Determining Input Values

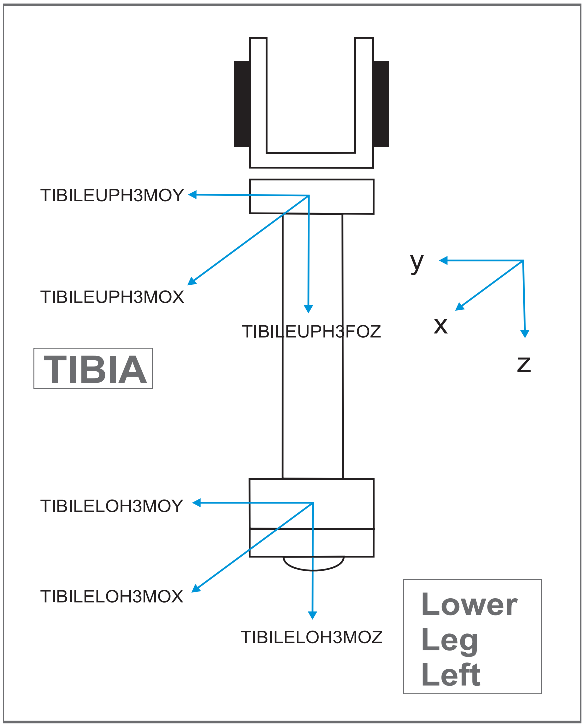
The measured values of the bending moment and the axial compression force are filtered in accordance with CFC 600. (See also *CFC Filters*).

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.

Dummy type	Critical bending moment [Nm]	Crit. 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.



with

TIBILEUPH3M0X	Bending moment about the x-axis, upper tibia
TIBILEUPH3M0Y	Bending moment about the y-axis, upper tibia
TIBILEUPH3F0X	Axial shear force in x-direction, upper tibia
TIBILEUPH3F0Y	Axial shear force in y-direction, upper tibia
TIBILEUPH3F0Z	Axial compression force in z-direction, upper tibia
TIBILELOH3M0X	Bending moment about the x-axis, lower tibia
TIBILELOH3M0Y	Bending moment about the y-axis, lower tibia
TIBILELOH3F0X	Axial shear force in x-direction, lower tibia
TIBILELOH3F0Y	Axial shear force in y-direction, lower tibia
TIBILELOH3F0Z	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.

	5-channel lower leg	**6-channel lower leg**
Measurement values	**TIBILEUPH3M0X TIBILEUPH3M0Y TIBILELOH3F0X** or **TIBILELOH3F0Y TIBILELOH3F0Z TIBILELOH3M0X** or **TIBILELOH3M0Y**	**TIBILEUPH3F0Z TIBILEUPH3M0X TIBILEUPH3M0Y TIBILELOH3F0Z TIBILELOH3M0X TIBILELOH3M0Y**
Upper tibia		
Resultant moment	$M_R=\sqrt{(\mathrm{TIBILEUPH3M0X})^2+(\mathrm{TIBILEUPH3M0Y})^2}$	$M_R=\sqrt{(\mathrm{TIBILEUPH3M0X})^2+(\mathrm{TIBILEUPH3M0Y})^2}$

Axial compression force	**Fz=TIBILELOH3FOZ**	**Fz=TIBILEUPH3FOZ**
Lower tibia		
Resultant moment	**M_R =|TIBILELOH3MOX|** or **M_R=|TIBILELOH3MOY|**	$M_R = \sqrt{(TIBILELOH3M0X)^2 + (TIBILELOH3M0Y)^2}$
Axial compression force	**F_z=TIBILELOH3FOZ**	**F_z=TIBILELOH3FOZ**

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

	8-channel lower leg	**8-channel lower leg**
Measurement values	**TIBILEUPH3F0X TIBILEUPH3F0Z TIBILEUPH3M0X TIBILEUPH3M0Y TIBILELOH3F0X TIBILELOH3F0Z TIBILELOH3M0X TIBILELOH3M0Y**	**TIBILEUPH3F0X TIBILEUPH3F0Z TIBILEUPH3M0X TIBILEUPH3M0Y TIBILELOH3F0X TIBILELOH3F0Y TIBILELOH3M0X TIBILELOH3M0Y**
Upper tibia		
Resultant moment	$M_R = \sqrt{(TIBILEUPH3M0X)^2 + (TIBILEUPH3M0Y)^2}$	$M_R = \sqrt{(TIBILEUPH3M0X)^2 + (TIBILEUPH3M0Y)^2}$
Axial compression force	**F_z=TIBILELOH3FOZ**	**F_z=TIBILELOH3FOZ**
Lower tibia		
Resultant moment	$M_R = \sqrt{(TIBILELOH3M0X)^2 + (TIBILELOH3M0Y)^2}$	$M_R = \sqrt{(TIBILELOH3M0X)^2 + (TIBILELOH3M0Y)^2}$
Axial compression force	**F_z=TIBILELOH3FOZ**	**F_z=TIBILELOH3FOZ**

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

ISO TS 13499 Code

The ISO code for the TI has the following structure:

Output Channel(s)

```
? ? TIIN  LL   00   ?? 00 0 X
          LU   TO
          RL
          RU
```

The following table describes the TI code.

Part of Code	Code	Description
Test object	**?**	Test object depending
Position	**?**	Position depending
Main location	**TIIN**	Tibia Index
Fine location 1	**LL; LU; RL, RU**	LL = Left lower LU = Left upper RL = Right lower RU = Right upper
Fine location 2	**00; TO**	00 = Not defined TO = Total moment
Fine location3	**??**	Dummy type dependent
Physical dimension	**00**	Without
Direction	**0**	Without
Filter class	**X**	Without

The following table lists the additional channel header attributes for the TI.

Attribute	Description
.Time	The appropriate time where the calculated value occurred.
.Analysis start time	Start of the time interval that has been taken into account for the calculation of the value.
.Analysis end time	End of the time interval that has been taken into account for the calculation of the value.

Attribute	Description
.Channel 001 ... .Channel nnn	ISO Code of the first channel used for the calculation. Order of the channels used is arbitrary. Filtering of the channel should be indicated by the right filter class in ISO code at position 16.
.Mrc	For Tibia Index calculation: Divisor for resultant bending moment
.Fzc	For Tibia Index calculation: Divisor for axial force
.Filter	Filter used: Only if all channels has been filtered with the same channel class! This is redundant to the information given in the ISO codes of each channel but easy to observe in the file.

Input Channel(s)

? ? TIBI ?? ?? ?? MO X B : Tibia Moment X, CFC 600

? ? TIBI ?? ?? ?? MO Y B : Tibia Moment Y, CFC 600

? ? TIBI ?? ?? ?? FO Z B : Tibia Moment Z, CFC 600

Example Codes

1 1 TIIN LL 00 H3 00 X : Tibia Index left lower

1 3 TIIN RU 00 H3 00 X : Tibia Index right upper

1 1 TIIN LL TO H3 00 X : Tibia Index left lower total

1 3 TIIN RU TO H3 00 X : Tibia Index right upper total

Relevant Laws and Regulations

- ECE-R94, 5.2.1.8
- ECE 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
- EuroNCAP, Front Impact, 10.6

TCFC

TCFC is the abbreviation for Tibia Compression Force Criterion.

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 measured values of the compression force are filtered in accordance with CFC 600. (See also *CFC Filters*).

ISO TS 13499 Code

The ISO code for the TCFC has the following structure:

Output Channel(s)

```
? ? TCFC   LE UP    ?? FO Z X
           RI LO
```

The following table describes the TCFC code.

Part of Code	Code	Description
Test object	**?**	Test object depending
Position	**?**	Position depending
Main location	**TCFC**	Tibia Compresion Force Criterion
Fine location 1	**LE; RI**	`LE` = Left `RI` = Right
Fine location 2	**UP; LO**	`UP` = Upper `LO` = Lower

Part of Code	Code	Description
Fine location3	**??**	Dummy type dependent
Physical dimension	**FO**	FO = Force
Direction	**Z**	Vertical
Filter class	**X**	Without

The following table lists the additional channel header attributes for the TCFC.

Attribute	Description
.Time	The appropriate time where the calculated value occurred.
.Analysis start time	Start of the time interval that has been taken into account for the calculation of the value.
.Analysis end time	End of the time interval that has been taken into account for the calculation of the value.
.Channel 001	ISO Code of the first channel used for the calculation. Order of the channels used is arbitrary. Filtering of the channel should be indicated by the right filter class in ISO code at position 16.
.Filter	Filter used: Only if all channels has been filtered with the same channel class! This is redundant to the information given in the ISO codes of each channel but easy to observe in the file.

Input Channel(s)

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

Example Codes

1 1 TCFC LE UP H3 FO Z X : Tibia Compr. Crit. left upper

1 3 TCFC RI LO H3 FO Z X : Tibia Compr. Crit. right lower

Relevant Laws and Regulations

- ECE-R94, 5.2.1.7
- ECE 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
- EuroNCAP, Frontal Impact, 5

6

Description of Additional Criteria

The following criteria are described:

- 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 Trolley
- Gillis-Index — Characteristic value for the assessment of the vehicle safety during a frontal crash.
- NCAP — New Car Assessment Program
- EuroNCAP — European New Car Assessment Program
- SI — Severity Index
- Integration — Integration procedure used
- Differentiation — Differentiation procedure used
- CFC Filter — Channel Frequency Class
- FIR100 Filter — Finite Impulse Response

Xms

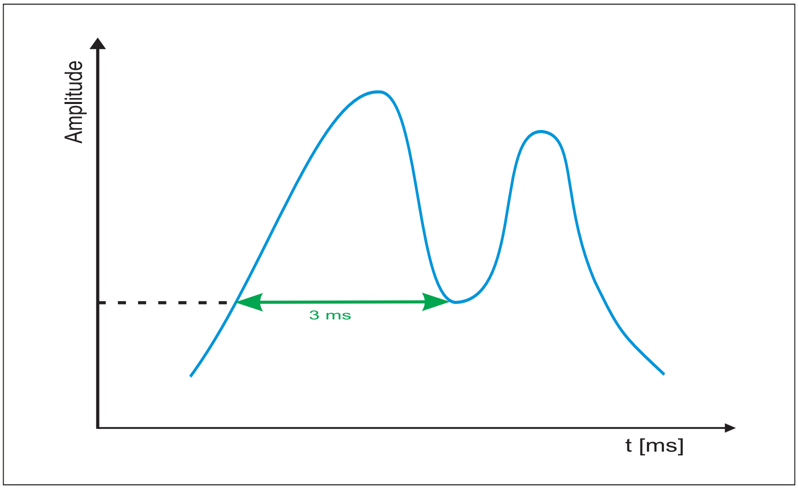
Xms is a generalization of the 3 ms value.

Description

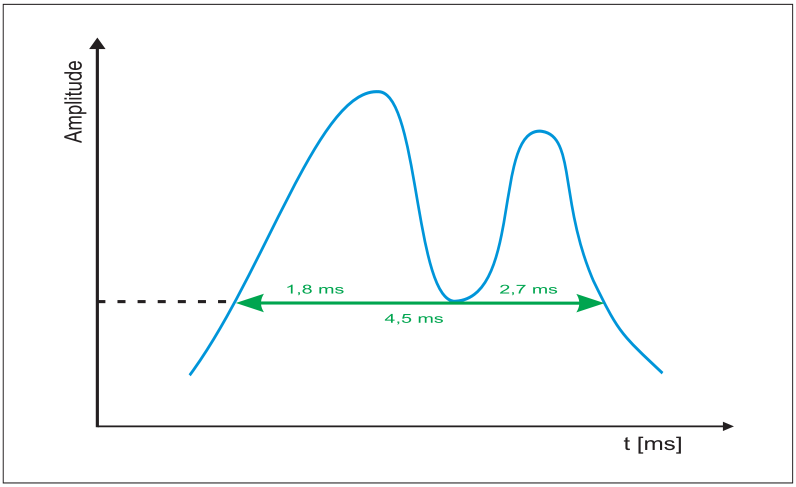
The xms value is the highest amplitude in a measured signal that lasts x milliseconds. The Xms value is specified either as a single peak (SAE), or multiple peaks (ECE-R94, FMVSS). In the cumulative calculation, separate periods of the measurement signal are added, until x milliseconds are reached.

Mathematical Calculation

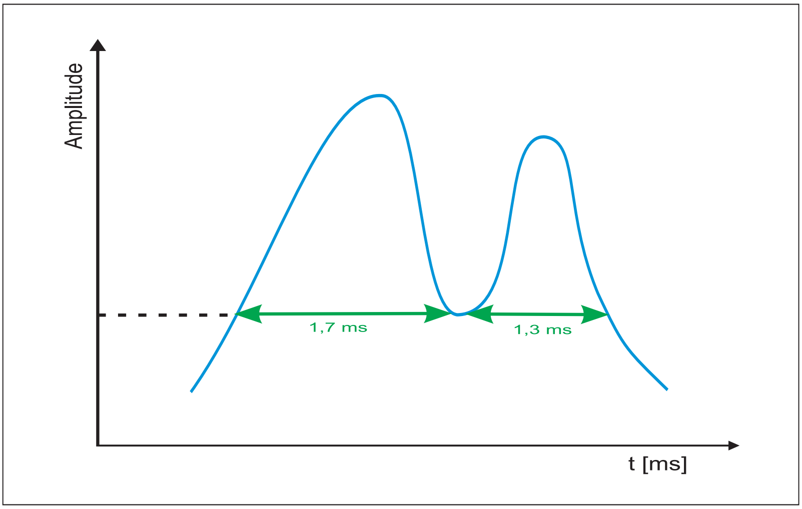
The xms value can be calculated with one peak, as shown in the first and second figure, or with several peaks, as shown in the third figure.



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



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 .



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. Acceleration values in descending order
2. Acceleration value (sorted) after x ms is the required xms value.

During calculations in accordance with ECE R94, the rebound movement of the head is not to be taken into account.

Determining Input Values

The measured values must be filtered in accordance with the stipulated filter classes.

ISO TS 13499 Code

The ISO code for the Xms has the following structure.

Output Channel(s)

```
? ? ???? ??   3C   ?? ?? 0 X
              3S
              5C
              5S
              MC
              MS
```

The following table describes the Xms code.

Part of Code	Code	Description
Test object	?	Test object depending
Position	?	Position depending
Main location	????	Main location dependent CHST = Chest (Xg Value) HEAD = Head (Xg Value)
Fine location 1	??	Fine Location 1 dependent

Part of Code	Code	Description
Fine location 2	**3C; 3S; 5C; 5S; MC; MS**	3C = 3 ms Clip cummulative 3S = 3 ms Clip single peak 5C = 5 ms Clip cummulative 5S = 5 ms Clip single peak MC = other time interval cum. MS = other time interval sp.
Fine location3	**??**	Dummy type dependent
Physical dimension	**TI**	TI = Time
Direction	**0**	Without
Filter class	**X**	Without

The following table lists the additional channel header attributes for the Xms value.

Attribute	Description
.Start time	Start time of the interval belonging to the calculated value (e.g. for the HIC). Only for criteria that uses an interval and not a single point in time.
.End time	End time of the interval belonging to the calculated value (e.g. for the HIC). Only for criteria that uses an interval and not a single point in time.
.Analysis start time	Start of the time interval that has been taken into account for the calculation of the value.
.Time interval	XMS = Value for single peak analysis XMC = Value for cumulative calculation
.Analysis end time	End of the time interval that has been taken into account for the calculation of the value.

Attribute	Description
.Exceedence level	For Xg calculation: Exceedence level used in the calculation
.Channel 001 ... .Channel nnn	ISO Code of the first channel used for the calculation. Order of the channels used is arbitrary. Filtering of the channel should be indicated by the right filter class in ISO code at position 16.
.Filter	Filter used: Only if all channels has been filtered with the same channel class! This is redundant to the information given in the ISO codes of each channel but easy to observe in the file.

Input Channel(s)

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

Example Codes

`1 1 HEAD 00 3C H3 AC R X` **:** Head Resultant Accel. A 3 ms cummulative

`1 1 CHST 00 5S HF AC R X` **:** Chest Resultant Accel. A 5 ms single peak

Relevant Laws and Regulations

- Directive 96/79/EG, Annex 2, 3.2.1.1
- ECE R94, Annex 3, 5.2.1
- ECE R94, Annex 4, 1.3
- ECE-R80, Annex 4, 2.1
- ECE R44, 7.1.4.2.1
- ECE R44, 7.1.4.2.2
- ECE-R12, 5.3
- ECE-R17, 5.1.3.1
- ECE 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, 3.4
- 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, Front Impact, 10, 10.1
- EURO NCAP, Side Impact, 10, 10.1
- EURO NCAP, Pole Side Impact, 10, 10.1
- EURO NCAP, Assessment Protocol , 5

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 resultant head acceleration was greater than X[g].

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

Determining Input Values

—

ISO TS 13499 Code

The ISO code for the Xg has the following structure.

Output Channel(s)

```
? ? ???? ??  XC   ?? TI ? X
             XS
```

The following table describes the Xg code.

Part of Code	Code	Description
Test object	?	Test object depending
Position	?	Position depending
Main location	????	Main location dependent CHST = Chest (Xg Value) HEAD = Head (Xg Value)
Fine location 1	??	Fine Location 1 dependent

Part of Code	Code	Description
Fine location 2	**XC; XS**	XC = Xg value for cumulative calculation XS = Xg value for single peak analysis
Fine location3	**??**	Dummy type dependent
Physical dimension	**TI**	TI = Time
Direction	**0**	Without
Filter class	**X**	Without

The following table lists the additional channel header attributes for the Xg.

Attribute	Description
.Start time	Start time of the interval belonging to the calculated value (e.g. for the HIC). Only for criteria that uses an interval and not a single point in time.
.End time	End time of the interval belonging to the calculated value (e.g. for the HIC). Only for criteria that uses an interval and not a single point in time.
.Analysis start time	Start of the time interval that has been taken into account for the calculation of the value.
.Analysis end time	End of the time interval that has been taken into account for the calculation of the value.
.Exceedence level	For Xg calculation: Exceedence level used in the calculation

Attribute	Description
.Channel 001 ... .Channel nnn	ISO Code of the first channel used for the calculation. Order of the channels used is arbitrary. Filtering of the channel should be indicated by the right filter class in ISO code at position 16.
.Filter	Filter used: Only if all channels has been filtered with the same channel class! This is redundant to the information given in the ISO codes of each channel but easy to observe in the file.

Input Channel(s)

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

Example Codes

1 1 HEAD 00 XC H3 TI R X : Xg Value Head Acceleration Resultant

Relevant Laws and Regulations

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

Acomp

Acomp is the abbreviation for Average Acceleration During Compression Phase.

Description

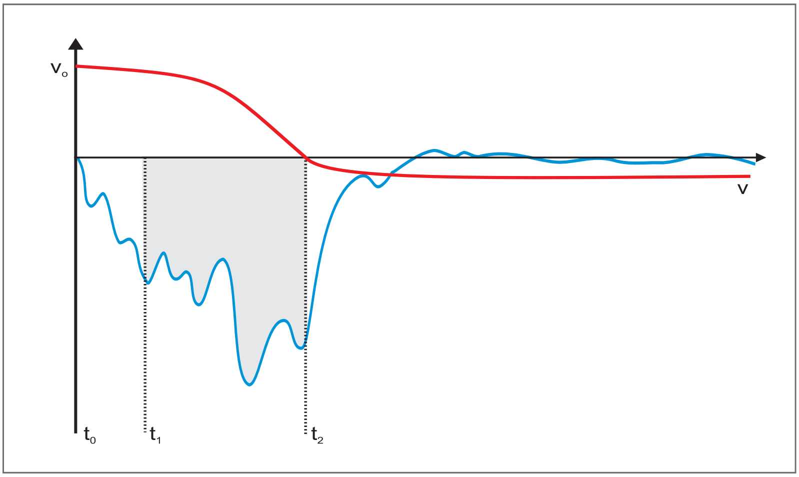
In a frontal crash, the mean acceleration during the deformation phase is calculated for the vehicle acceleration in the x-direction.

Mathematical Calculation

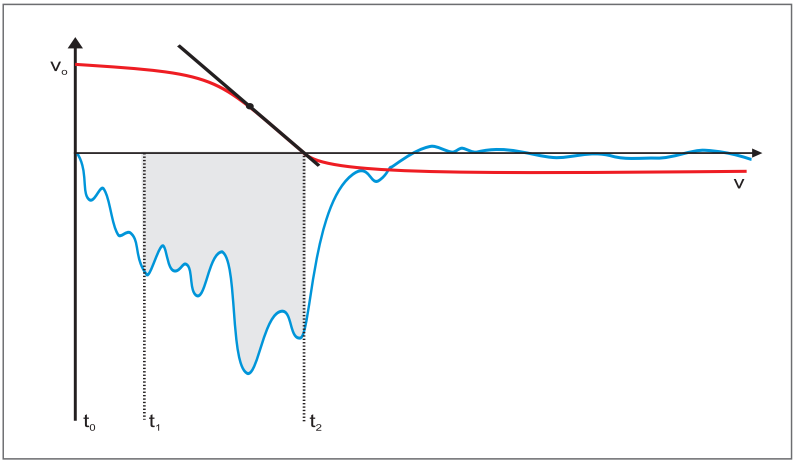
The calculation is completed in the following steps:

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

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



   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 also *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 values of the acceleration are filtered in accordance with CFC 180. (See also *CFC Filters*).

ISO TS 13499 Code

The ISO code for the Acomp has the following structure:

Output Channel(s)

```
? ? AACP ??   ?? ??   AC X X
              01 01
              .. ..
              99 99
```

The following table describes the Acomp code.

Part of Code	Code	Description
Test object	`?`	Test object depending
Position	`?`	Position depending
Main location	`AACP`	Average Acceleration during Compression Phase
Fine location 1	`00; 01; …; 99`	1. bis 99.
Fine location 2	`00; 01; …; 99`	1. bis 99.
Fine location3	`00; 01; …; 99`	1. bis 99.
Physical dimension	`AC`	`AC` = Acceleration
Direction	`X`	Longitudinal
Filter class	`X`	Without

The following table lists the additional channel header attributes for the Acomp.

Attribute	Description
.Start time	Start time of the interval belonging to the calculated value (e.g. for the HIC). Only for criteria that uses an interval and not a single point in time.
.End time	End time of the interval belonging to the calculated value (e.g. for the HIC). Only for criteria that uses an interval and not a single point in time.
.Analysis start time	Start of the time interval that has been taken into account for the calculation of the value.
.Analysis end time	End of the time interval that has been taken into account for the calculation of the value.

Attribute	Description
.Channel 001 ... .Channel nnn	ISO Code of the first channel used for the calculation. Order of the channels used is arbitrary. Filtering of the channel should be indicated by the right filter class in ISO code at position 16.
.Method	For Acomp calculation: valid values are: "Variant 1" or "Variant 2"

Input Channel(s)

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

Example Codes

1 0 AACP 00 00 01 AC X X : Average Acceleration during Compression Phase #001

1 0 AACP 00 01 27 AC X X : Average Acceleration during Compression Phase #127

Relevant Laws and Regulations

- Company standards

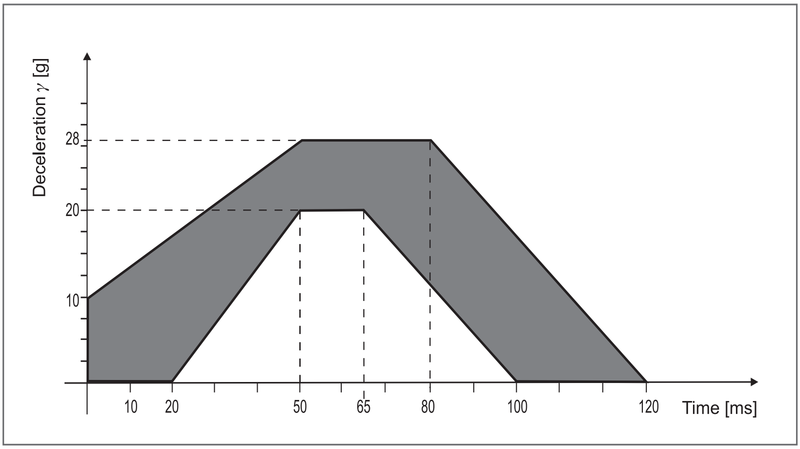
Pulse Test

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

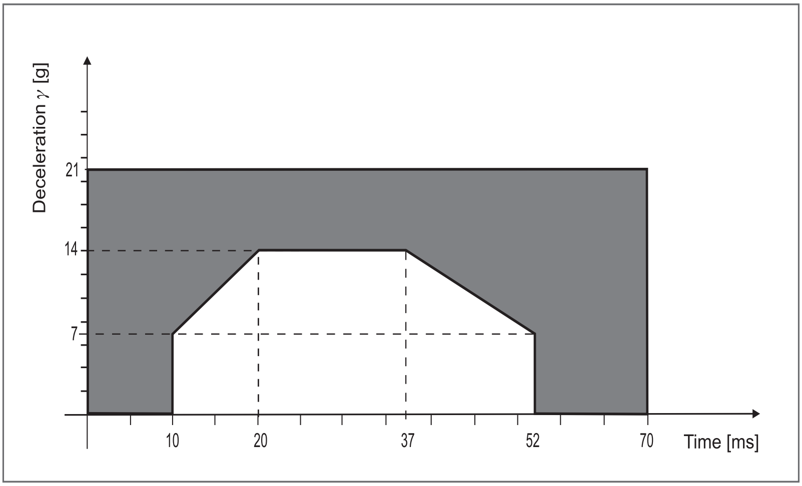
Description

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

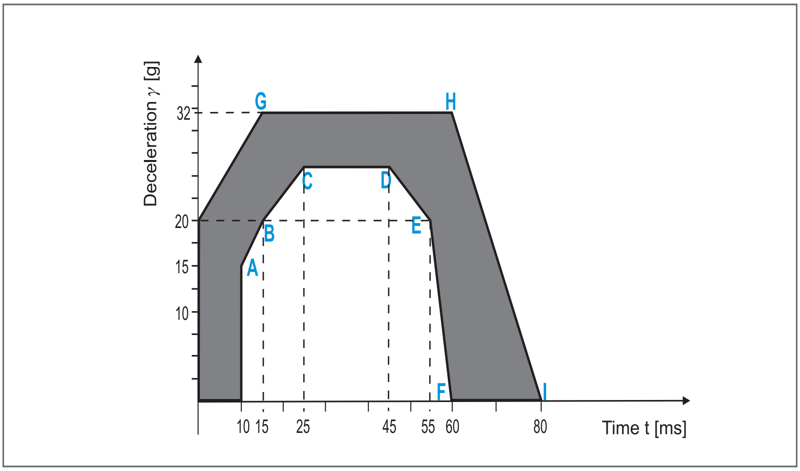
- Corridor for ECE R44; Annex 7; Appendix 1



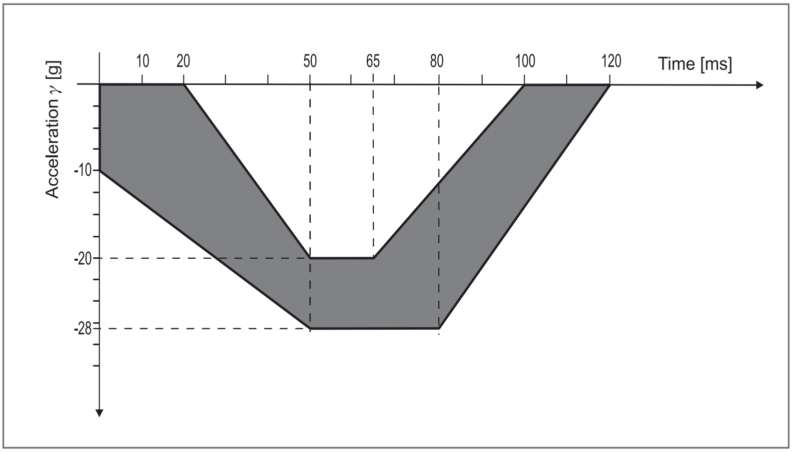
- Corridor for ECE R44; Annex 7; Appendix 2



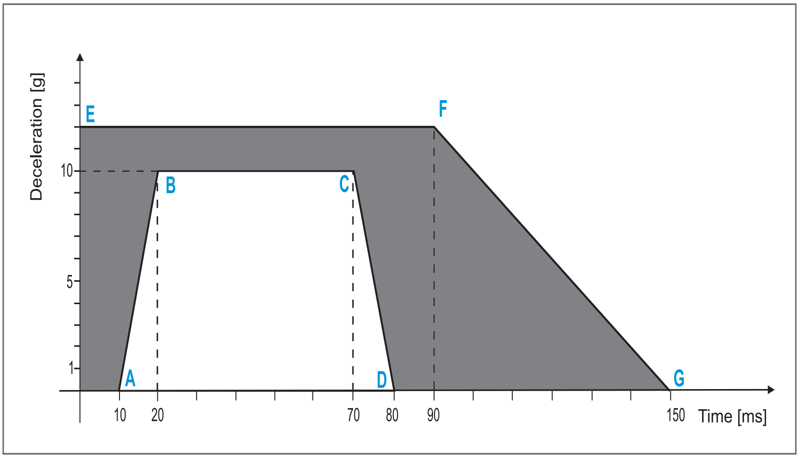
- Corridor for ECE R16



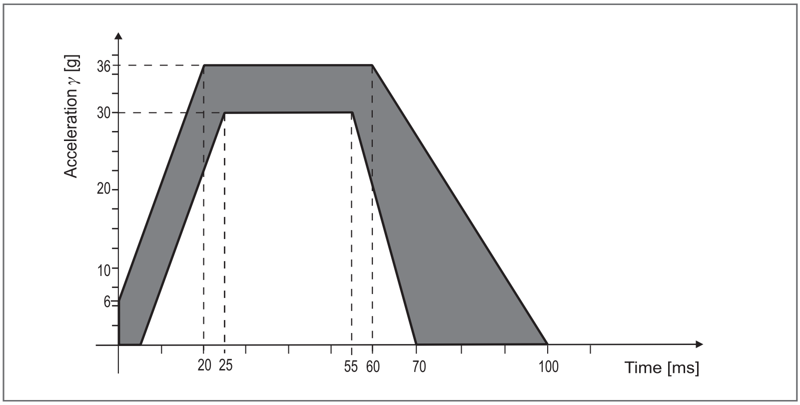
- Corridor for ECE-R17; 6.3.1



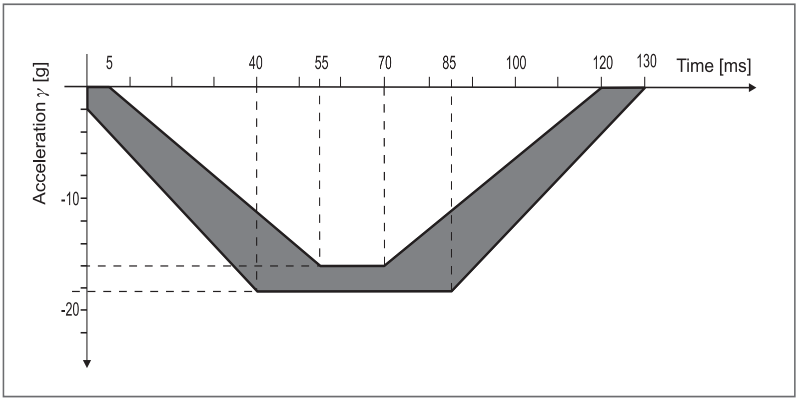
- Corridor for ECE R80; Annex 4; Figure 1



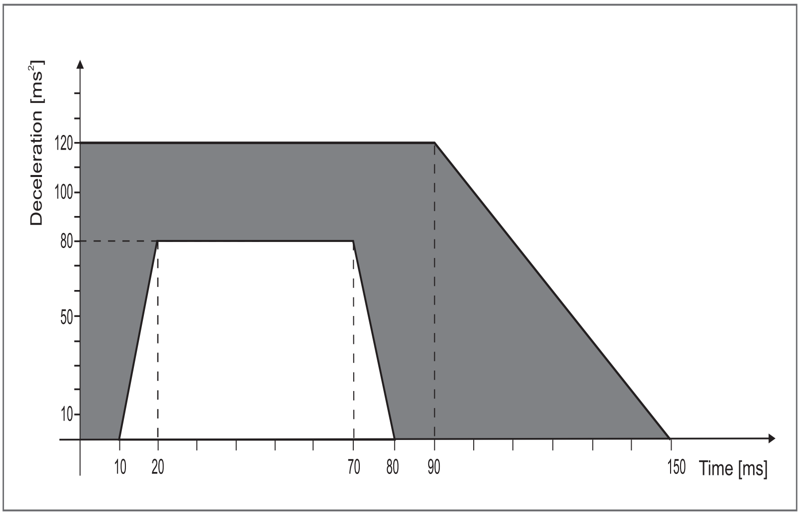
- Corridor for FMVSS 206; Figure 5



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

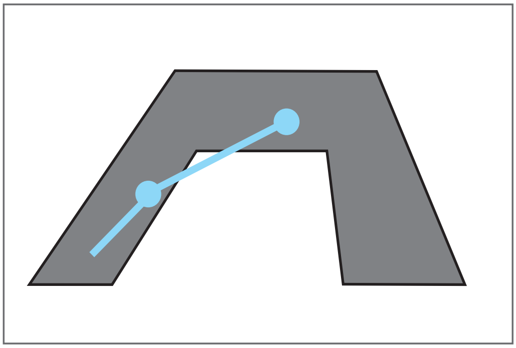


- Acceleration Impulse of the test sled in accordance with EN 1789 and DIN 75302, figure 7



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.



Determining Input Values

The measurement values of the acceleration are filtered in accordance with CFC 60. (See also *CFC Filters*).

Relevant Laws and Regulations

- ECE-R11; 3.5.1
- ECE-R16; Annex 8
- ECE R17
- ECE-R44; Annex 7
- ECE-R80; Annex 4; Figure 1
- EN 1789
- DIN 75302
- FMVSS 208; S13.1
- FMVSS 213

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:

$$G = HIC^F + \frac{D^F}{9.80665} \cdot 16.7 \cdot \frac{3}{4} + \frac{F^{F.l} + F^{F.r}}{4.448232} \cdot 0.44 \cdot \frac{1}{4} + \frac{1}{2} \cdot \left(HIC^B + \frac{D^B}{9.80665} \cdot 16.7 \cdot \frac{3}{4} + \frac{F^{B.l} + F^{B.r}}{4.448232} \cdot 0.44 \cdot \frac{1}{4} \right)$$

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

$$G36 = HIC36^F + \frac{D^F}{9.80665} \cdot 16.7 \cdot \frac{3}{4} + \frac{F^{F.l} + F^{F.r}}{4.448232} \cdot 0.44 \cdot \frac{1}{4} + \frac{1}{2} \cdot \left(HIC36^B + \frac{D^B}{9.80665} \cdot 16.7 \cdot \frac{3}{4} + \frac{F^{B.l} + F^{B.r}}{4.448232} \cdot 0.44 \cdot \frac{1}{4} \right)$$

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 is the abbreviation for New Car Assessment Program.

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:

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

with *HIC36* HIC36 value

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

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

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:

$$P_{combined} = P_{head} + P_{chest} - \left(P_{head} \cdot P_{chest}\right)$$

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

$P_{combined} \leq 0,10$	★★★★★
0,10<Pcombined ≤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 for the NCAP has the following structure.

Output Channel(s)

`? ? NCAP ?? ?? ?? 00 0 X`

The following table describes the NCAP code.

Part of Code	Code	Description
Test object	**?**	Test object depending
Position	**?**	Position depending
Main location	**NCAP**	New Car Accessment Program
Fine location 1	**??**	Fine Location 1 dependent
Fine location 2	**??**	Fine Location 2 dependent
Fine location3	**??**	Dummy type dependent
Physical dimension	**00**	Others
Direction	**0**	Without
Filter class	**X**	Without

The following table lists the additional channel header attributes for NCAP.

Attribute	Description
.Time	The appropriate time where the calculated value occurred.
Analysis start time	Start of the time interval that has been taken into account for the calculation of the value.
.Analysis end time	End of the time interval that has been taken into account for the calculation of the value.
.Channel 001 ... .Channel nnn	ISO Code of the first channel used for the calculation. Order of the channels used is arbitrary. Filtering of the channel should be indicated by the right filter class in ISO code at position 16.
.Stars	For NCAP calculation: Star rating in numerical form 1…5

Input Channel(s)

? ? 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

Example Codes

1 0 NCAP 00 00 00 00 0 X : New Car Assessment Program

1 1 NCAP 00 00 00 00 0 X : New Car Assessment Program

1 3 NCAP 00 00 00 00 0 X : New Car Assessment Program

Relevant Laws and Regulations

- Refer to the Internet address www.nhtsa.dot.gov/cars/testing/ncap for more information.

EuroNCAP

EuroNCAP is the abbreviation for European New Car Assessment Program

Description

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

- Front Impact
- Side Impact
- Pole Side Impact
- Pedestrian Test

Mathematical Calculation

A EuroNCAP spreadsheet shows the test results as points.

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.euroncap.com for more information.

SI

SI is the abbreviation for the Severity Index.

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:

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

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:

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

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

with $j = 2,3, \ldots T$

Determining Input Values

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ISO TS 13499 Code

The ISO code for the SI has the following structure.

Output Channel(s)

`? ? CHSI ?? ?? ?? 00 R X`

The following table describes the SI code.

Part of Code	Code	Description
Test object	`?`	Test object depending
Position	`?`	Position depending
Main location	`CHSI`	Severity Index Chest
Fine location 1	`??`	Fine Location 1 dependent
Fine location 2	`??`	Fine Location 2 dependent
Fine location3	`??`	Dummy type dependent
Physical dimension	`00`	Others
Direction	`R`	Resultant
Filter class	`X`	Without

The following table lists the additional channel header attributes for the SI.

Attribute	Description
.Start time	Start time of the interval belonging to the calculated value (e.g. for the HIC). Only for criteria that uses an interval and not a single point in time.
.End time	End time of the interval belonging to the calculated value (e.g. for the HIC). Only for criteria that uses an interval and not a single point in time.
.Analysis start time	Start of the time interval that has been taken into account for the calculation of the value.
.Analysis end time	End of the time interval that has been taken into account for the calculation of the value.

Attribute	Description
.Channel 001 ... .Channel nnn	ISO Code of the first channel used for the calculation. Order of the channels used is arbitrary. Filtering of the channel should be indicated by the right filter class in ISO code at position 16.
.Filter	Filter used: Only if all channels has been filtered with the same channel class! This is redundant to the information given in the ISO codes of each channel but easy to observe in the file.

Input Channel(s)

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

Example Codes

`1 1 CHSI 00 00 H3 00 R X :` Severity Index Chest

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, 3.1

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 ECE R94 is (see also): *VC*).

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

with Δt Time interval between the single measurements in seconds

Determining Input Values

—

Relevant Laws and Regulations

- ECE R94, Annex 4, 6.2
- Directive 96/79/EG, Annex II, Appendix 2, 6.2
- SAE J1727, 3.1

CFC Filters

CFC is the abbreviation for Channel Frequency Class

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.

Filter type	Filter parameters	
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:

$$Y[t]=a_0 X[t]+a_1 X[t-1]+a_2 X[t-2]+b_1 Y[t-1]+b_2 Y[t-2]$$

The filter constants are calculated with the following formulas:

$$\omega_d = 2\pi \cdot CFC \cdot 2.0775$$
$$\omega_a = \frac{\sin \omega_d \frac{T}{2}}{\cos \omega_d \frac{T}{2}}$$
$$a_0 = \frac{\omega_a^2}{1+\sqrt{2}\omega_a+\omega_a^2}$$
$$a_1 = 2a_0$$
$$a_2 = a_0$$
$$b_1 = \frac{-2(\omega_a^2-1)}{1+\sqrt{2}\omega_a+\omega_a^2}$$
$$b_2 = \frac{-1+\sqrt{2}\omega_a-\omega_a^2}{1+\sqrt{2}\omega_a+\omega_a^2}$$

with	*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 rate 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 constants *wd* is calculated in the ISO 6487 sample code differently to SAE J211:

$$\omega_d = 2\pi \cdot CFC \cdot 1.25 \cdot \frac{5}{3}$$
$$\omega_d = 2\pi \cdot CFC \cdot 2.083\overline{3}$$

Determining Input Values

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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 Finite Impulse Response

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 original sample rate

Determining Input Values

—

Relevant Laws and Regulations

- FMVSS 214, S6.13.5.4
- SAE J1727, 3.5

7

Legislation and directives

European Legislation

- ECE–R80
- ECE–R94
- Directive 96⁄ 79/EG
- ECE–R95
- Directive 96⁄ 27/EG
- Directive 2004⁄ 90⁄ EG
- ECE–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
- DIN 75302
- EN 1789
- EuroNCAP; European New Car Assessment Programme, www.euroncap.com/content/test_procedures/introduction.php
- Robert A. Denton, Sign Conventions for Load Cells (S.A.E. J–211) Rev. 27AUG02

Limits

The following table compares the criteria of different test types.

Type	America	Europe	Other methods							
	FMVSS208	FMVSS214	NCAP	ECE–R94 96/ 79/ EG	ECE–R95 96/ 27/ EG	EuroNCAP	EuroNCAP	EuroNCAP	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		
Velocity	56/ 48 km/ h	54 km/ h	56/ 6 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	—	3.015.92 lb	— / 1368 kg	Addit. weight	2.094.39 lb	Addit. weight	2.094.39 lb	—	Plus luggage	2.094.39 lb
Restraint syst.	Passive		active	x	x	x	x	x	x	x
PASSENGERS										
Driver	HIII 5, 50, 95%	US-SID; Spec.	HIII–50% US–SID	HIII-50 %	Euro-SID	HIII-50 %	Euro–SID ES–2 from 11/ 02	Euro–SID ES–2 from 11/ 02	HIII–50%/ Eurosid	50%/ Euro sid

Type	America	Europe	Other methods							
	FMVSS208	FMVSS214	NCAP	ECE–R94 96/ 79/ EG	ECE–R95 96/ 27/ EG	EuroNCAP	EuroNCAP	EuroNCAP	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
Front seat pass.	HIII 5, 50, 95%	—	—	HIII-50%	—	HIII-50%	—	—	HIII-50%/ Eurosid	50%/ Euro sid
Pos. 4 - behind driver	HIII 12m, 3 year, 6 year	—	—	—	—	P3	P1½	—	—	—
Pos. 6 - behind passenger	HIII 12m, 3–year, 6–year	—	—	—	—	P1½	P3	—	—	—
Temperature (measurement time)	20,55–22, 22°C	18,89–25, 56°C	—	19–22°C	18–26°C	19–22°C (>5h)	18–26°C (>5h)	18–26°C (>5h)	—	—
SAFETY CRITERIA[1]										
HIC, HPC	≤1000 (HIC36) ≤700 (HIC15)		≤1000	≤1000	≤1000	≤900 (HIC36)[2]	≤1000 (HIC36)	≤1000 (HIC36)	≤1000	≤1000
Head Res 3 ms	—	—	—	≤2.82oz	—	≤80g[1]	—	≤2.82oz	≤2.82oz	≤2.82oz
Head vert. 3 ms	—	—	—	—	—	≤0.71oz	—	—	—	—

Type	America	Europe	Other methods							
	FMVSS2 08	FMVSS2 14	NCAP	ECE–R94 96/ 79/ EG	ECE–R95 96/ 27/ EG	EuroNCAP	EuroNCAP	EuroNCAP	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
Neck – Flex/ Extens.	190/ 57 Nm	—	—	MOC, Fz	—	MOC, Fz	—	—	—	—
Thorax T1	—	—	—	—	—	—	—	—	—	—
Thorax T12	—	—	—	—	—	—	—	—	—	—
Ribs	—	—	—	—	—	—	—	—	—	—
ChestRes 3 ms	≤2.12oz	—	≤60g/ —	≤2.12oz	—	≤2.12oz	—	—	≤2.12oz	≤2.12oz
Chest vert. 3 ms	—	—	—	—	—	≤1.06oz	—	—	—	—
Chest compression	≤3.00 in	—	≤3.00 in	≤1.97 in	≤1.65 in	≤1.97 in	≤1.65 in	—	≤50/ ≤42m m	≤50/ ≤42m m
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	—	4.59oz	4.59oz	—	—	—	—	—	—	—
Pubic Symphysis	—	—	—	—	≤6 kN	—	≤6 kN	—	≤6 kN	≤6 kN
Femur	10 kN	—	≤10 kN	Force/ Tim e	—	Force/ Tim e	—	—	Force/ Tim e	Force/ Tim e

Type	America	Europe	Other methods							
	FMVSS208	FMVSS214	NCAP	ECE–R94 96/ 79/ EG	ECE–R95 96/ 27/ EG	EuroNCAP	EuroNCAP	EuroNCAP	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
Knee	—	—	—	0.59 in	—	0.59 in	—	—	0.59 in	0.59 in
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.