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# EUROPEAN NEW CAR ASSESSMENT PROGRAMME (EuroNCAP)

# ASSESSMENT PROTOCOL AND BIOMECHANICAL LIMITS

Version 4.1
March 2004

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## 1 INTRODUCTION

This protocol has been developed jointly by TRL and Vehicle Safety Consultants Ltd., under contract to the UK Department of the Environment Transport and the Regions and International Testing respectively.

## 2 EuroNCAP PRINCIPLES

The EuroNCAP programme is designed to provide a fair, meaningful and objective assessment of the impact performance of cars. It is intended to inform consumers, so providing an incentive to manufacturers as well as giving credit to those who excel at occupant or pedestrian protection. The tests used are based on those developed for legislation by the European Enhanced Vehicle safety Committee (EEVC), for frontal and side impact protection of car occupants and for the protection of pedestrians hit by the front of cars.

No stylised test procedure fully reflects the protection provided by a car in the wide variety of accidents which occur on the roads. However, cars that perform well in these tests should provide better protection in accidents than cars which perform less well.

No anthropometric dummies are available which can measure all the potential risks of injury to humans or assess protection for different sizes of occupant in different seating positions. To compensate for this, the assessment procedure takes account of other information related to occupant kinematics, interior contact points and vehicle structure.

Economic constraints prevent the tests from being repeated, so to take account of vehicle and test variations a number of actions have been taken:

1 Manufacturers have been asked to compare the results from these tests with those from tests they may have conducted and to draw our attention to any anomalies they may find. They have also been requested to supply data from their own tests to us for comparison. Several manufacturers have supplied data for this purpose. Apart from considering the effects of test variation and identifying anomalies, no account of such data is taken in rating the cars and it is kept confidential.

2 The overall assessments are based on the combination of multiple results. Variations in any one of these will only have a limited effect on the overall rating.

The least demanding performance boundaries for the frontal and side impact parameters have been set to be equivalent to the limits proposed in the EEVC test procedures. The EEVC limits were set to provide a basic minimum level of protection and only protect in a moderate proportion of accidents. For car occupants, these limits are too lenient to adequately identify best practice in current production cars and to provide a goal for further improvement. Additional, more demanding, protection boundaries have been set, to identify aspects of a car's performance which offer significantly greater protection.

Most parts of most cars fare relatively badly in the pedestrian impact tests. With so few examples where the proposed EEVC limits are met, the need for a less demanding lower level limit has been recognised. This will separate those cars which more nearly reach the EEVC limit from those well away from it.

## 3 SUMMARY

The starting point for the assessment is the dummy response data. Initially, each body area is given a rating based on the measured dummy parameters. For frontal impact, consideration is given to whether this assessment should be adjusted to reflect occupant kinematics or sensitivity to small changes in contact location, which might influence the protection of different sized occupants in different seating positions. The assessment also considers the structural performance of the car by taking account of such aspects as steering wheel displacement, pedal movement, footwell distortion and displacement of the A pillar. The adjustments based on both inspection and geometrical considerations are applied to the body area assessments to which they are most relevant. These adjustments are conservative but they should be sufficient to warrant consideration by manufacturers.

The adjusted rating for the different body regions is presented, in a visual format of coloured segments within a human body outline. This is presented for the driver and front seat passenger in frontal impact and for the driver in side and pole impact. For the pedestrian impact tests, it is presented in the form of coloured dots on the outline of a car front.

From this information, an overall rating for the car is computed for frontal and side impact protection and separately for pedestrian impact. For occupant protection, the overall rating is based on the driver data, unless part of the passenger fared less well. It is stated that the judgement relates primarily to the driver.

No attempt is made to rate the risk of life threatening injury any differently from the risk of disabling injury. Similarly, no attempt is made to rate the risk of the more serious but less

frequent injury any differently from the risk of less serious but more frequent injury. Care has been taken to try to avoid encouraging manufacturers to concentrate their attention on areas which would provide little benefit in accidents.
In addition to the basic Euro NCAP assessment, additional information is recorded and may be reported. In future, some of these additional aspects may be added to the Euro NCAP assessment. In the first series of tests, a three year old child in a child restraint was fitted on the rear seat, in the frontal and side impact tests. In subsequent series, an 18 month old child dummy has been added.

## 4 SLIDING SCALES

From Phase 3, a sliding scale system of points scoring has been used. This involves two limits for each parameter, a more demanding limit (higher performance), beyond which a maximum score is obtained and a less demanding limit (lower performance), below which no points are scored. In frontal and side impact, the maximum score for each body region is four points. In the pole impact, 2 additional points are available if certain conditions are met. For each impact site in the pedestrian tests, a maximum of two points are available. Where a value falls between the two limits, the score is calculated by linear interpolation.

## 5 FRONTAL IMPACT ASSESSMENT CRITERIA AND LIMIT VALUES

The basic assessment criteria used for frontal impact, with the upper and lower performance limits for each parameter, are summarised below. Where multiple criteria exist for an individual body region, the lowest scoring parameter is used to determine the performance of that region.

**Head**
**Drivers with steering wheel airbags and Passengers**

If a steering wheel airbag is fitted the following criteria are used to assess the protection of the head for the driver. These criteria are always used for the passenger.

Note: $HIC_{36}$ levels above 1000 have been recorded with airbags, where there is no hard contact and no established risk of internal head injury. A hard contact is assumed, if the peak resultant head acceleration exceeds 80 g, or if there is other evidence of hard contact.

If there is no hard contact a score of 4 points is awarded.
If there is hard contact, the following limits are used:

*Higher performance limit*

| | | |
|---|---|---|
| $HIC_{36}$ | 650 | (5% risk of injury ≥ AIS3 [1,2]) |
| Resultant Acc. 3 msec exceedence | 72 g | |

*Lower performance limit*

| | | |
|---|---|---|
| $HIC_{36}$ | 1000* | (20% risk of injury ≥ AIS3 [1,2]) |
| Resultant Acc. 3 msec exceedence | 88 g | *(*EEVC limit)* |

**Drivers with no steering wheel airbag**

If no steering wheel airbag is fitted, and the following requirements are met in the frontal impact test:

| | |
|---|---|
| $HIC_{36}$ | <1000 |
| Resultant Acc. 3 msec exceedence | <88 g |

then, deformable honeycomb faceform tests are carried out on the steering wheel. The tester attempts to choose the most aggressive sites to test and it is expected that two tests will be required, one aimed at the hub and spoke junction and one at the rim and spoke junction. The assessment is then based on the following criteria.

*Higher performance limit*

| | |
|---|---|
| Resultant peak Acc. | 80 g |
| Resultant Acc. 3 msec exceedence | 65 g |

*Lower performance limit*

| | |
|---|---|
| Honeycomb crush | 1 mm |
| $HIC_{36}$ | 1000 |
| Resultant peak Acc. | 120 g |
| Resultant Acc. 3 msec exceedence | 80 g |

From the faceform tests, a maximum of 2 points are awarded for performance better than the lower limits. For values worse than the lower performance limit, no points are awarded. The results from the worst performing test are used for the assessment. This means that for cars, not equipped with a steering wheel airbag, the maximum score obtainable for the driver's head is 2 points.

**Neck**

*Higher performance limit*

| | | | |
|---|---|---|---|
| Shear | 1.9 kN @ 0 msec, | 1.2 kN @ 25 - 35 msec, | 1.1 kN @ 45 msec |
| Tension | 2.7 kN @ 0 msec, | 2.3 kN @ 35 msec, | 1.1 kN @ 60 msec |
| Extension | 42 Nm | | |

*Lower performance limit*

| | | | |
|---|---|---|---|
| Shear | 3.1 kN @ 0 msec, | 1.5 kN @ 25 - 35 msec, | 1.1 kN @ 45 msec* |
| Tension | 3.3 kN @ 0 msec, | 2.9 kN @ 35 msec, | 1.1 kN @ 60 msec* |
| Extension | 57 Nm* | | (Significant risk of injury [3]) |

*(*EEVC Limits)*

Note: Neck Shear and Tension are assessed from cumulative exceedence plots, with the limits being functions of time. By interpolation, a plot of points against time is computed. The minimum point on this plot gives the score. Plots of the limits and colour rating boundaries are given in Appendix I.

**Chest**

*Higher performance limit*

| | | |
|---|---|---|
| Compression | 22 mm | (5% risk of injury ≥ AIS3 [4]) |
| Viscous Criterion | 0.5 m/sec | (5% risk of injury ≥ AIS4) |

*Lower performance limit*

| | | |
|---|---|---|
| Compression | 50 mm* | (50% risk of injury ≥ AIS3 [4]) |
| Viscous Criterion | 1.0 m/sec* | (25% risk of injury ≥ AIS4) |

*(*EEVC Limits)*

**Knee, Femur and Pelvis**

*Higher performance limit*
Femur compression 3.8 kN (5% risk of pelvis injury [5])
Knee slider compressive displacement 6 mm

*Lower performance limit*
Femur Compression 9.07 kN @ 0 msec, 7.56 kN @ ≥ 10 msec* (Femur fracture limit [3])
Knee slider compressive displacement 15 mm* (Cruciate ligament failure limit [3,6])
*(*EEVC Limit)*

Note: Femur compression is assessed from a cumulative exceedence plot, with the limits being functions of time. By interpolation, a plot of points against time is computed. The minimum point on this plot gives the score. Plots of the limits and colour rating boundaries are given in Appendix I.

**Lower Leg**

*Higher performance limit*
Tibia Index 0.4
Tibia Compression 2 kN

*Lower performance limit*
Tibia Index 1.3*
Tibia Compression 8 kN* (10 % risk of fracture [3,7])
*(*EEVC Limits)*

**Foot/Ankle**

*Higher performance limit*
Pedal rearward displacement 100 mm

*Lower performance limit*
Pedal rearward displacement 200 mm

Notes:
1 Pedal displacement is measured for all pedals with no load applied to them.
2 If any of the pedals are designed to completely release from their mountings during the impact, no account is taken of the pedal displacement, provided that release occurred in the test and that the pedal retains no significant resistance to movement.
3 If a mechanism is present to move the pedal forwards in an impact, the resulting position of the pedal is used in the assessment.
4 The passenger's foot/ankle protection is not currently assessed.

5 Footwell intrusion is currently being measured. It is expected that requirements for footwell intrusion will be added in the near future.

## 6 FRONTAL IMPACT MODIFIERS

### Driver

The score generated from driver dummy data may be modified where the protection for different sized occupants or occupants in different seating positions, or accidents of slightly different severity, can be expected to be worse than that indicated by the dummy readings or deformation data alone. In any single body region, the score may reduce by up to a maximum of two points. The concepts behind the modifiers are explained in a later section.

### Head

*Unstable Contact on the airbag*
If during the forward movement of the head its centre of gravity moves further than the outside edge of the airbag, head contact is deemed to be unstable. The score is reduced by one point. If for any other reason head protection by the airbag is compromised, such as by detachment of the steering wheel from the column, or bottoming-out of the airbag by the dummy head, the modifier is also applied.

*Head bottoming-out is defined as:*
*There is a definite rapid increase in the slope of one or more of the head acceleration traces, at a time when the dummy head is deep within the airbag. The acceleration spike associated with the bottoming out should last for more than 3ms.*
*The acceleration spike associated with the bottoming out should generate a peak value more than 5 g above the likely level to have been reached if the spike had not occurred. This level will be established by smooth extrapolation of the curve between the start and end of the bottoming out spike.*

*Unstable Contact on a Steering Wheel without an Air Bag*
If, during the forward movement of the head, its centre of gravity moves radially outwards further than the outside edge of the steering wheel rim, head contact is deemed to be unstable. The score is reduced by one point. If for any other reason head contact on the steering wheel is unstable, such as detachment of the steering wheel from the column, the modifier is also applied.

*Displacement of the steering column*
The score is reduced for excessive rearward, lateral or upward static displacement of the top end of the steering column. Up to 90 percent of the EEVC limits, there is no penalty. Beyond 110 percent of the EEVC limits, there is a penalty of one point. Between these limits, the penalty is generated by linear interpolation. The EEVC recommended limits are: 100 mm rearwards, 80 mm upwards and 100mm lateral movement. The modifier used in the assessment is based on the worst of the rearward, lateral and upward penalties.

**Chest**

*Displacement of the A Pillar*
The score is reduced for excessive rearward displacement of the driver's front door pillar, at a height of 100 mm below the lowest level of the side window aperture. Up to 100 mm displacement there is no penalty. Above 200 mm there is a penalty of two points. Between these limits, the penalty is generated by linear interpolation.

*Integrity of the passenger compartment*
Where the structural integrity of the passenger compartment is deemed to have been compromised, a penalty of one point is applied. The loss of structural integrity may be indicated by characteristics such as:

- Door latch or hinge failure, unless the door is adequately retained by the door frame.
- Buckling or other failure of the door resulting in severe loss of fore/aft compressive strength.
- Separation or near separation of the cross facia rail to A pillar joint.
- Severe loss of strength of the door aperture.

*Steering Wheel Contact*
Where there is obvious direct loading of the chest from the steering wheel, a one point penalty is applied.

**Knee, Femur & Pelvis**

*Variable Contact*
The position of the dummy's knees are specified by the test protocol. Consequently, their point of contact on the facia is pre-determined. This is not the case with human drivers, who may have their knees in a variety of positions prior to impact. Different sized occupant and those seated in different positions may also have different knee contact locations on the facia and their knees may penetrate into the facia to a greater extent. In order to take some account of this, a larger area of potential knee contact is considered. If contact at other points, within this greater area, would be more aggressive penalties are applied.

The area considered extends vertically 50 mm above and below the maximum height of the actual knee impact location [10]. Vertically upwards, consideration is given to the region up to 50 mm above the maximum height of knee contact in the test. If the steering column has risen during the test it may be repositioned to its lowest setting if possible. Horizontally, for the outboard leg, it extends from the centre of the steering column to the end of the facia. For the inboard leg, it extends from the centre of the steering column the same distance inboard, unless knee contact would be prevented by some structure such as a centre console. Over the whole area, an additional penetration depth of 20 mm is considered, beyond that identified as the maximum knee penetration in the test. The region considered for each knee is generated independently. Where, over these areas and this depth, femur loads greater that 3.8kN and/or knee slider displacements greater than 6mm would be expected, a one point penalty is applied to the relevant leg.

*Concentrated Loading*
The biomechanical tests, which provided the injury tolerance data, were carried out using a padded impactor which spread the load over the knee. Where there are structures in the knee impact area which could concentrate forces on part of the knee, a one point penalty is applied to the relevant leg.

Where a manufacturer is able to show, by means of acceptable test data, that the Variable Contact and/or Concentrated Loading modifiers should not be applied, the penalties may be removed.

**Lower Leg**

*Upward Displacement of the worst performing Pedal*
The score is reduced for excessive upward static displacement of the pedals. Up to 90 percent of the limit considered by EEVC, there is no penalty. Beyond 110 percent of the limit, there is a penalty of one point. Between these limits, the penalty is generated by linear interpolation. The limit agreed by EEVC was 80 mm.

**Foot & Ankle**

*Footwell Rupture*
The score is reduced if there is significant rupture of the footwell area. This is usually due to separation of spot welded seams. A one point penalty is applied for footwell rupture. The footwell rupture may either pose a direct threat to the driver's feet, or be sufficiently extensive to threaten the stability of footwell response.

*Pedal Blocking*
Where the rearward displacement of a 'blocked' pedal exceeds 175mm, a one point penalty is applied to the driver's foot and ankle assessment. A pedal is blocked when the forward movement of the intruded pedal under a load of 200N is <25mm. Between 50mm and 175mm of rearward displacement the penalty is calculated using a sliding scale between 0 to 1 points.

**Passenger**

Currently, the only modifiers applied to the front seat passenger are those related to airbag stability and head bottoming-out (where present) and the knee impact areas. The assessment is the same as for drivers. For the outboard knee, the lateral range of the knee impact area extends from the centre line of the passenger seat to the outboard end of the facia. For the inboard knee, the area extends the same distance inboard of the seat centre line, unless knee contact is prevented by the presence of some structure such as the centre console.

**Door Opening during the Impact**

When a door opens in a frontal test, a minus one-point modifier will be applied to the score for that test. A one-point modifier will be applied for every door (including the tailgate) that opens.

Concept: The intention is to ensure that the structural integrity is maintained. The underlying principle is to minimize the risks of occupant ejection occurring.
The "door opening" modifier will be applied if any of the following have occurred:

- the latch has fully released or shows significant partial release, either by release of its components from one another, or effective separation of one part of the latch from its supporting structure
- the latch has moved away from the fully latched condition
- if any hinge has released either from the door or bodyshell or due to internal hinge failure
- if there is a loss of structure between the hinges and latches
- if door or hinges fail whilst the door opening tests are being conducted post impact, as loading from an occupant could have a similar effect.

**Door Opening Forces after the Impact**

The force required to unlatch and open each side door to an angle of 45 degrees is measured after the impact. A record is also made of any doors which unlatch or open in the impact. Currently, this information is not used in the assessment but it may be referred to in the text of the published reports.

Door opening forces are categorised as follows:

| | |
|---|---|
| Opens normally | Normal hand force is sufficient |
| Limited force | ≤ 100 N |
| Moderate force | > 100 N to < 500 N |
| Extreme hand force | ≥ 500 N |
| Tools had to be used | Tools necessary |

## 7 SIDE IMPACT ASSESSMENT CRITERIA AND LIMIT VALUES

The basic assessment criteria used for side impact, with the upper and lower performance limits for each parameter, are summarised below. Where multiple criteria exist for an individual body region, the lowest scoring parameter is used to determine the performance of that region.

**Head**
**Cars Fitted with Head Protecting Side Impact Airbags**

If there is no evidence of hard contact, four points are awarded. If there is evidence of hard contact the criteria given for cars without a head protecting airbag are applied.

Note: $HIC_{36}$ levels above 1000 have been recorded with airbags, where there is no hard contact and no established risk of internal head injury. A hard contact is assumed, if the peak resultant head acceleration exceeds 80 g, or if there is other evidence of hard contact.

Provided that four points are scored for head protection in the distributed deformable face barrier side impact test, the manufacturer has the option to fund a side impact pole test. If, in this test, the following criteria are met, the car will be awarded two additional points.

| | |
|---|---|
| $HIC_{36}$ | <1000 |
| Peak Resultant Acc | <80 g |
| No direct head contact with the pole | |

**Cars not Fitted with Head Protecting Side Impact Airbags**

| | | |
|---|---|---|
| *Higher performance limit* | | |
| $HIC_{36}$ | 650 | (5% risk of injury ≥ AIS3 [1,2]) |
| Resultant Acc. 3 msec exceedence | 72 g | |
| *Lower performance limit* | | |
| $HIC_{36}$ | 1000* | (20% risk of injury ≥ AIS3 [1,2]) |
| Resultant Acc. 3 msec exceedence | 88 g | *(*EEVC Limit)* |

**Chest**

The assessment is based on the worst performing individual rib

| | | |
|---|---|---|
| *Higher performance limit* | | |
| Compression | 22 mm | (5% risk of injury ≥ AIS3 [8]) |
| Viscous Criterion | 0.32 | (5% risk of injury ≥ AIS3 [8]) |
| *Lower performance limit* | | |
| Compression | 42 mm* | (30% risk of injury ≥ AIS3 [8]) |
| Viscous Criterion | 1.0* | (50% risk of injury ≥ AIS3 [8]) |
| | | *(*EEVC Limits)* |

**Abdomen**

| | | |
|---|---|---|
| *Higher performance limit* | | |
| Total Abdominal Force | 1.0 kN | |
| *Lower performance limit* | | |
| Total Abdominal Force | 2.5 kN* | *(*EEVC Limit)* |

**Pelvis**

| | | |
|---|---|---|
| *Higher performance limit* | | |
| Pubic Symphysis Force | 3.0 kN | |
| *Lower performance limit* | | |
| Pubic Symphysis Force | 6.0 kN* | (Pelvic fracture in young adults) |
| | | *(*EEVC Limit)* |

## 8 SIDE IMPACT MODIFIERS

### Backplate

Where the backplate load Fy exceeds 4.0kN, a two point penalty is applied to the driver's chest assessment. Between 1.0kN and 4.0kN the penalty is calculated using a sliding scale from 0 to 2 points.

| | |
|---|---|
| Higher performance limit | |
| Fy | 1.0 kN |
| | |
| Lower performance limit | |
| Fy | 4.0 kN |

### *T12 Modifier*

Where the T12 loads Fy and Mx exceed 2.0kN or 200Nm respectively, a two point penalty is applied to the driver's chest assessment. Between 1.5kN – 2.0kN or 150Nm – 200Nm the penalty is calculated using a sliding scale from 0 to 2 points. The assessment is based upon the worst performing parameter.

| | | | |
|---|---|---|---|
| Higher performance limit | | | |
| Fy | 1.5 kN | Mx | 150 Nm |
| | | | |
| Lower performance limit | | | |
| Fy | 2.0 kN | Mx | 200 Nm |

### Door Opening during the Impact

When a door opens in a side barrier test or a pole test, a minus one-point modifier will be applied to the score for that test. A one-point modifier will be applied for every door (including the tailgate) that opens.

Concept: The intention is to ensure that the structural integrity is maintained. The underlying principle is to minimize the risks of occupant ejection occurring.
The "door opening" modifier will be applied if any of the following have occurred:

- the latch has fully released or shows significant partial release, either by release of its components from one another, or effective separation of one part of the latch from its supporting structure
- the latch has moved away from the fully latched condition
- if any hinge has released either from the door or bodyshell or due to internal hinge failure
- if there is a loss of structure between the hinges and latches

- if door or hinges fail whilst the door opening tests are being conducted post impact, as loading from an occupant could have a similar effect.

**Door Opening Forces after the Impact**

A check is made to ensure that the doors on the non-struck side can be opened. The doors on the struck side are not opened.

**Pole Test**

A one point modifier is applied if the head protection airbag does not deploy fully in the designed manner.

## 9 PEDESTRIAN IMPACT ASSESSMENT CRITERIA AND LIMIT VALUES

The basic assessment criteria used for the pedestrian impact tests, with the upper and lower performance limits for each parameter, are summarised below. Where multiple criteria exist for an individual test, the lowest scoring parameter is used to determine the performance of that test.

### Headform

*Higher performance limit*

| | | |
|---|---|---|
| $HIC_{15}$ | 1000* | (20% risk of injury ≥ AIS3 [1,2]) |
| | | *(*EEVC Limit)* |

*Lower performance limit*

| | | |
|---|---|---|
| $HIC_{15}$ | 1350 | |

### Upper Legform

*Higher performance limit*

| | | |
|---|---|---|
| Bending Moment | 300 Nm* | (18% risk of femur/pelvis fracture) |
| Sum of forces | 5.0 kN* | (20% risk of femur/pelvis fracture) |
| | | *(*EEVC Limits)* |

*Lower performance limit*

| | | |
|---|---|---|
| Bending Moment | 380 Nm | (33% risk of femur/pelvis fracture) |
| Sum of forces | 6.0 kN | (36% risk of femur/pelvis fracture) |

### Legform

*Higher performance limit*

| | | |
|---|---|---|
| Tibia deceleration | 150 g* | (27% risk of lower leg fracture) [9] |
| Knee shear displacement | 6 mm* | [9] |
| Knee bending angle | 15º * | [9] |
| | | *(*EEVC Limits)* |

*Lower performance limit*

| | | |
|---|---|---|
| Tibia deceleration | 200 g | (46% risk of lower leg fracture) |
| Knee shear displacement | 7 mm | |
| Knee bending angle | 20º | |

## 10 VISUAL PRESENTATION

For frontal and side impact, the protection provided for adults for each body region are presented visually, using coloured segments within body outlines. The colour used is based on the points awarded for that body region (rounded to two decimal places), as follows:

| | | |
|---|---|---|
| Green | 4.00 | points |
| Yellow | 2.67 - 3.99 | points |
| Orange | 1.33 - 2.66 | points |
| Brown | 0.01 - 1.32 | points |
| Red | 0.00 | points |

The method of presenting the pole impact results are as follows:

- A passed pole test gives a green star overlaying the side impact driver's head.
- A marginal pass is shown as a yellow star overlaying the side impact driver's head.
- A failed pole test is shown as an empty star overlaying the side impact driver's head.
- A car that has not been subjected to a pole test has nothing added to the graphic.

For pedestrians, the protection provided by each test site is illustrated by a coloured area, on an outline of the front of the car. The colour used is based on the points awarded for that test site (rounded to two decimal places), as follows:

| | | |
|---|---|---|
| Green | 2 | points |
| Yellow | 0.01 – 1.99 | points |
| Red | 0 | points |

## 11 OVERALL ASSESSMENTS

An overall assessment is presented for frontal and side impact protection. This is normally based on the driver scores, unless any body region for the passenger receives a lower score. In this case the score for the passenger is used for that body region. A separate overall assessment is currently made for pedestrian protection. The overall assessments are computed as follows:

For frontal impact, the body regions are grouped together, with the rating for the grouped body region being that of the worst performing region or limb. The grouped regions are:

- Head and Neck
- Chest
- Knee, Femur, Pelvis (i.e. left and right femur and knee slider)
- Leg and Foot (i.e. left and right lower leg and foot and ankle)

For the distributed barrier side impact and for the pedestrian tests, all the individual regions are used. For the pole test, only the head is considered at present.

To obtain the overall ratings, the points gained by each region are added together. Frontal and distributed barrier side impact each have four regions which can each be awarded up to four points. The pole test potentially contributes a further 2 points. This gives a possible maximum overall score of 34 points.

For pedestrian impact, each of the potential 18 test sites can be awarded up to two points, giving a possible overall score of 36 points. However, If the vehicle manufacturer chooses to fund additional tests either in the legform, upper legform or headform test area the score would be calculated as follows:

Example:

Headform testing:
EuroNCAP test produces a HIC of 1300 = 0.07 points/quarter
Additional test produces a HIC of 1050 = 0.43 points/quarter

| **EuroNCAP test Score** | **Extra Test Score** | **Number of manufacturer nominated quarters** | **Area Score** | |
|---|---|---|---|---|
| 0.07 | | 0 | (0.07 x 4) | = 0.29 |
| 0.07 | 0.43 | 1 | (0.07 x 3)+(0.43 x 1) | = 0.64 |
| 0.07 | 0.43 | 2 | (0.07 x 2)+(0.43 x 2) | = 1.00 |
| 0.07 | 0.43 | 3 | (0.07 x 1)+(0.43 x 3) | = 1.36 |

Legform/upper legform testing (based upon the worst result):
EuroNCAP test produces a knee bending angle of 19° = 0.2 points/half
Additional test produces a knee bending angle of 16° = 0.8 points/half

| **EuroNCAP test Score** | **Extra Test Score** | **Number of manufacturer nominated halves** | **Area Score** |
|---|---|---|---|
| 0.20 | | 0 | 0.20 x 2 = 0.40 |
| 0.20 | 0.80 | 1 | 0.20+0.80 = 1.00 |

Where a manufacturer has nominated additional test zone(s) and those zone(s) perform worse than the EuroNCAP nominated test zone, the test zone(s) which have not been tested will have the best result applied to them regardless of manufacturer nomination.

In each case, the overall score is rounded to the nearest integer only after the front, side and pole impact scores have been added.
For example:

| | |
|---|---|
| Front impact score = | 7.51 |
| Side impact score = | 10.87 |
| Total score = | 18.38 |
| Final score = | 18 points |

**Relationship between Points and Stars for Frontal and Side Tests**

The overall scores and the balance between side and front scores are then used to generate star ratings. Vehicles which perform very poorly in the frontal or side tests have their star rating restricted to show that they do not provide good all-round protection.

There will be a minimum number of points required in both the frontal and side impact (includes pole test) assessments to achieve a star rating. The following limits are applied after the individual test scores have been rounded:

**Total Points and Balance Applied to Star Values**

Provided there is a balance between the Frontal and Side Impacts the following applies:

| | | |
|---|---|---|
| 33 - 40 | points | 5 stars |
| 25 - 32 | points | 4 stars |
| 17 - 24 | points | 3 stars |
| 9 - 16 | points | 2 stars |
| 1 - 8 | points | 1 star |
| 0 | points | 0 stars |

However if the balance is lacking then the following hurdles are applied:

| Minimum points required in each test: | Star rating: |
|---|---|
| 13 points | 5 |
| 9 points | 4 |
| 5 points | 3 |
| 2 points | 2 |

Pedestrian Impact

| | | |
|---|---|---|
| 28 - 36 | points | 4 stars |
| 19 - 27 | points | 3 stars |
| 10 - 18 | points | 2 stars |
| 1 - 9 | points | 1 star |
| 0 | points | 0 stars |

**Struck Through Stars**

Concerns have been expressed that some cars were being “recommended” by the media, on the basis of their star rating, even when some important body region was poorly protected. Where this problem might occur, the final star for occupant protection is struck through with a single diagonal red line.

The final star is struck through when zero points are scored, on the basis of dummy response alone, for any body region where there is **“an unacceptably high risk of life-threatening injury.”** In frontal impact, body regions which could give rise to a struck through star are: head, neck and chest. In the distributed barrier side impact they are: head, chest, abdomen and pelvis.

## 12 CONCEPTS BEHIND THE ASSESSMENTS

### Frontal Impact

### Head

***CONCEPT****: The driver's head should be predictably restrained by the airbag, and should remain protected by the airbag during the dummy's forward movement. There should be no bottoming out of the airbag.*

***CONCEPT****: Geometric control of steering wheel movement is needed to ensure that the airbag launch platform remains as close as possible to the design position, to protect a full range of occupant sizes****.***

### Neck

***CONCEPT:*** *Neck injuries are frequent, but relatively little is known about appropriate injury criteria. The neck criteria recommended by EEVC are used to identify poorly designed restraint systems. It is not expected that many cars will fail these requirements****.***

In addition to the EEVC recommended limits, additional ones have been added, at the request of the car manufacturers. It is assumed that good restraint systems will have no problems meeting these criteria.

### Chest

***CONCEPT****: Rib compression is used as the main guide to injury risk. It is expected that the Viscous Criterion will only identify cars with poorly performing restraint systems.*

The injury risk data is relevant for seat belt only loading rather than combined seat belt and airbag loading. No change is made in the event of combined seat belt and airbag restraint. This avoids value judgements about the extent of airbag restraint on the chest and is in line with the EEVC recommendation.

***CONCEPT:*** *There is an interrelationship between chest loading, as measured by the above dummy criteria, and intrusion. To ensure that a good balance is struck, a geometric criterion on waist level intrusion, as measured by door pillar movement at waist level, is used.*

***CONCEPT:*** *When the passenger compartment becomes unstable, any additional load can result in unpredictable excessive further collapse of the passenger compartment. When the passenger compartment becomes unstable the repeatability of the car's response in the test becomes poor and confidence in the car's performance is reduced.*

***CONCEPT:*** *The chest performance criteria are developed for loads applied by a seat belt. The more concentrated loading from a "stiff" steering wheel exposes the chest to direct loading injury.*

**Abdomen**

Protection of the abdomen is important, but no criteria or assessment techniques are available at present.

**Knee, Femur & Pelvis**

***CONCEPT****: Transmitting loads through the knee joint from the upper part of the tibia to the femur can lead to cruciate ligament failure.*

Zero knee slider displacement is both desirable and possible. The higher performance limit allows for some possible movement due to forces transmitted axially up the tibia.

***CONCEPT:*** *The knee impact area should have uniformly good properties over a wide area of potential impact sites. This is to account for people sitting with their knees in different positions and slight variations in impact angle. The characteristics of the area should not change markedly if knee penetration is slightly greater than that observed with the 50 percentile dummy in this test. This takes into account the protection of different sized occupants or occupants in different seating positions.*

***CONCEPT****: Loading on the knee should be well distributed and avoid concentration that could result in localised damage to the knee.*

The injury tolerance work that supports the legislative femur criterion was conducted with padded impactors that spread the load over the knee.

**Lower Leg**

***CONCEPT:*** *Loads resulting in fracture of the tibia produce bending moments and forces measurable at the upper and lower ends of the tibia. These measurements on the tibia relate to risk of tibia fracture.*

At the request of the car manufacturers, further limits were added to those proposed for lower leg protection. These limits can be expected to help protect the ankle joint.

### Foot and Ankle

***CONCEPT***: *Expert opinion suggests that a Tibia Index of less than 0.2 would be necessary to prevent ankle joint failure. Until a biofidelic ankle and foot become available, the assessment will be based on intrusion. Intrusion is highly correlated with the risk of injury.*
***CONCEPT***: *Rupture of the footwell exposes the occupant to additional dangers. Objects outside the passenger compartment may enter, parts of the occupant may contact items outside the passenger compartment, there is a risk from exposed edges and the structure may become unstable.*

## 13 SEATING POSITION IN SIDE IMPACT

***CONCEPT:*** *Effective side impact protection needs to consider all sizes of occupants. This concept is included in the EU Directive. Currently, side impact tests are conducted with the seat in the design position. In future, consideration will be given to the level of protection in other seating positions.*

### POLE TEST

The pole test is included as a test of systems designed to provide head protection in a wide range of side impact situations. It is necessary as the current distributed barrier side impact test presents no threat to the head from outside the vehicle. Reliance on the distributed barrier side impact test alone tends to give false assurance of the protection offered to the head in side impact.

## 14 CHILD DUMMY ASSESSMENT CRITERIA AND LIMIT VALUES

### Cars Fitted with Passenger Side Frontal Protection Airbags

Children in rearward facing child restraints face a serious risk of fatal injury, if they are positioned on a front seat that is equipped with a functioning frontal protection airbag. Euro NCAP will apply a penalty (yet to be decided) to cars where adequate steps are not taken to avoid this risk. When devices are developed to safely disable the airbag, they will be required, if the penalty is to be avoided. At that time, a lesser penalty will be applied if the car is equipped with labels which meet the Euro NCAP minimum requirements.

In the absence of airbag disabling devices, the assessment is based on the labelling provided. Currently, the quality of the labelling is reported in the text. In the future, it is proposed that a penalty will be applied to the car's rating, where the labelling does not meet the minimum requirements. A check is also made to ensure that the labelling meets the less stringent legislative requirements.

### Minimum Airbag Warning Label Requirements

1 A warning label shall be visible to someone about to put a rearward facing child restraint into the seat in question.

2 The warning label shall be easily readable, must contain a pictogram and explicit text, in at least one language of the country in which the vehicle is sold. This must warn, using an attention grabbing design, of the risk of death or serious injury to children in rearward facing child restraints. The label must include:
   - Instructions not to use a rear facing CRS on the airbag equipped seat
   - The warning label must be permanently attached to the vehicle so that it is likely to remain with it during its entire service life.

3 There must be a permanent warning, easily visible from the driver and passenger seats, even when the passenger door is closed

The following criteria are used to assess the performance of the child restraints (CRS) that the vehicle manufacturer recommends the public to use in the model in question.

| Dummy | P1½ | P3 |
|---|---|---|
| **Head** | | |
| *Higher performance limit* | | |
| Vertical Acc. 3 msec exceedence[1] | 20 g | n/a |
| *Lower performance limit* | | |
| Forward excursion[2,3] | 550 mm[4,5] | 550 mm[4,5] |
| **Chest** | | |
| *Higher performance limit* | | |
| Resultant Acc. 3 msec exceedence[6] | 41 g | 41 g |
| Vertical Acc. 3 msec exceedence[6] | 23 g | 23 g |
| *Lower performance limit* | | |
| Resultant Acc. 3 msec exceedence[7] | 55 g | 55 g |
| Vertical Acc. 3 msec exceedence[7] | 30 g | 30 g |

Notes:

1 To control axial neck loads
2 Relative to the Cr point
3 No contact with vehicle interior
4 No compressive force to the top of the head
5 Not applied to a rearward facing CRS, provided that the head remains within the CRS shell, there is no risk of head contact with the vehicle interior or intruding objects and the dummy’s trajectory is well controlled.
6 75 percent of the ECE 44.03 limit
7 ECE 44.03 limit

**Forward facing child restraints (Groups I, II and III)**

***Concept:*** *The head forward movement criterion is based on ECE Regulation 44.03. By adding a no contact with the vehicle interior requirement, Euro NCAP aims to encourage compatibility between child restraint performance and the space available in the vehicle. Contact between the head and the interior may result in injury to the head or neck. With no dummy capability to* *monitor the risk of shear induced injuries in the neck, the only safe course is to avoid contact.*

**Rearward facing child restraints (Groups 0+, I and II not supported by the facia)**

***Concept:*** *The head should not be exposed to avoidable risk of injury by being exposed outside the protection of the CRS shell. The dimensional requirement is relaxed provided the risk is controlled. The compression load requirement prevents the top of the head being used to restrain the dummy.*

***Concept:*** *Euro NCAP uses the vertical chest acceleration requirement to cover both directions. ECE Regulation 44.03 specifies this acceleration as being measured "from abdomen towards the head."*

Note:

1 Child restraints are inspected for compliance with the marking and labelling requirements of UN ECE Regulation 44.03, taking into account the situation where the seat is fitted in the vehicle.

2 Child restraints are inspected for compatibility with the system used to mount them to the vehicle.

3 Any significant damage sustained in the impact is recorded.

4 The provision of ALR/ELR switchable seat belts is recorded. The protocol requires that a label, explaining their use, be permanently visible to the user. Unless this is the case, the ALR feature will not be used.

## 15 SIDE IMPACT

In the absence of satisfactory child dummies and bio-mechanical criteria for side impact, the criteria chosen have been kept simple. At present, the child dummies are only used in the distributed barrier side impact.

For both sized dummies:

1 CRS should contain the dummy head during the impact[1]

2 Head Resultant Acc. 3 msec exceedence <80g

Note:

1 No part of the head shall pass outside the forward projected exterior surface of the child restraint.

## 16 PEDESTRIAN TESTS

With the current level of pedestrian protection provided by car fronts, it would be optimistic to expect protection levels to exceed those proposed by the EEVC. In order to discriminate between cars which more nearly meet the EEVC requirements from those which greatly exceed them, a lower limit has been set. This has been derived from experience gained in the early phases of Euro NCAP.

## 17 REFERENCES


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10 Schneider, L.W., Vogel, M. and Bosio, C.A. Locations of driver knees relative to knee bolster design. The University of Michigan Transportation Research Institute, Ann Arbor, Michigan. UMTRI-88-40. September 1988.

## APPENDIX I

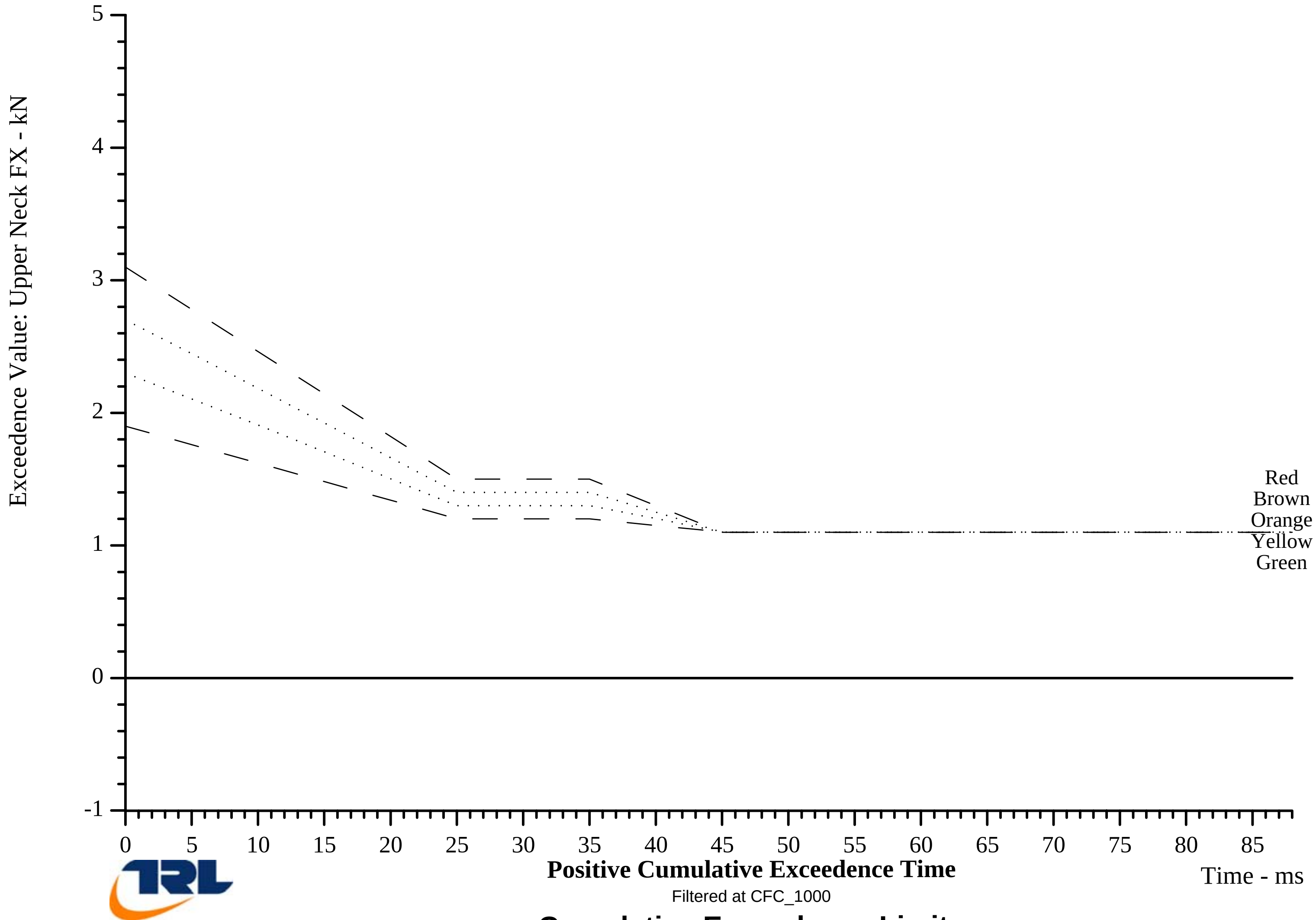
## GRAPHICAL LIMITS FOR CUMULATIVE EXCEEDENCE PARAMETERS

1 Upper Neck Shear FX - Positive

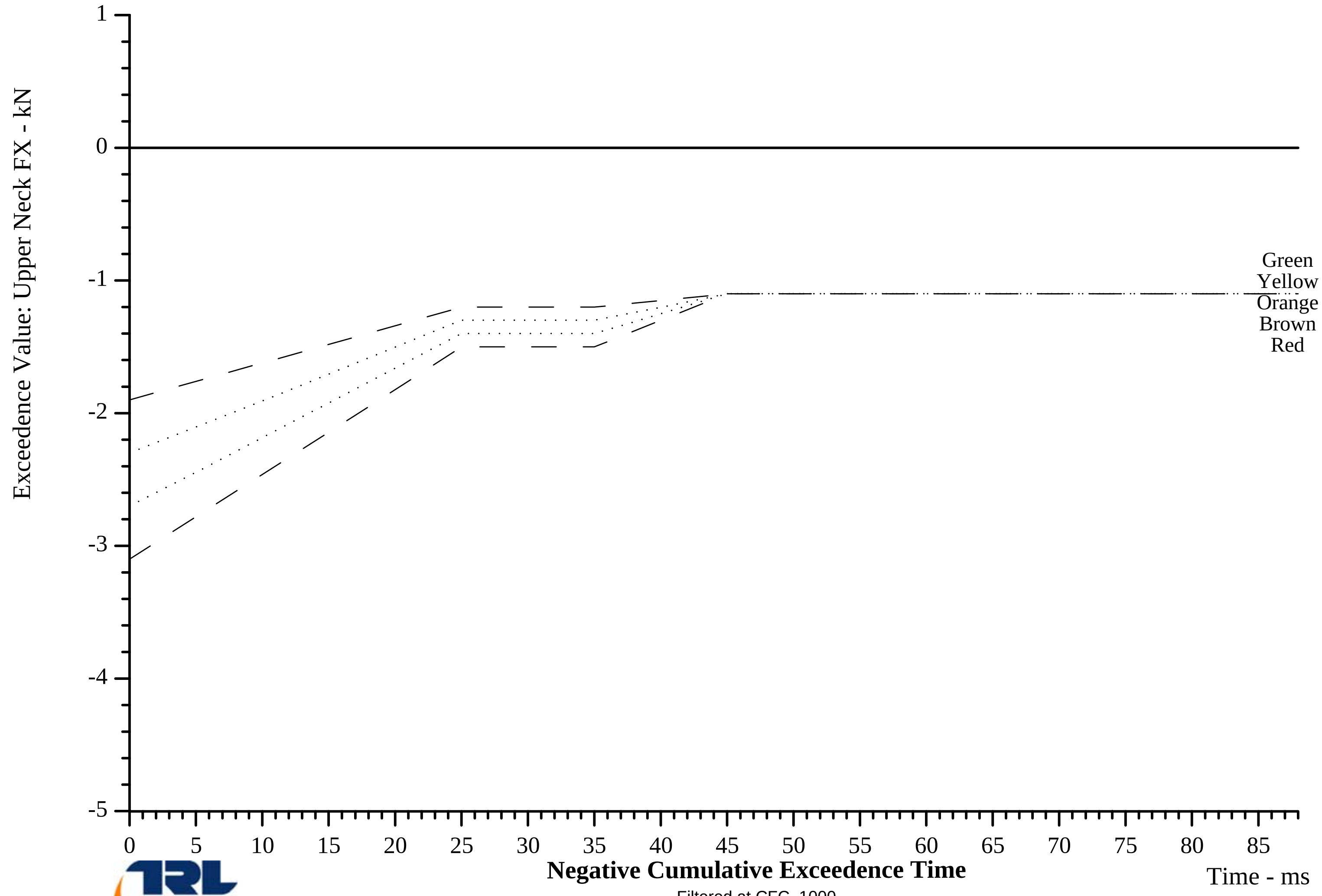
2 Upper Neck Shear FX - Negative

3 Upper Neck Tension FZ

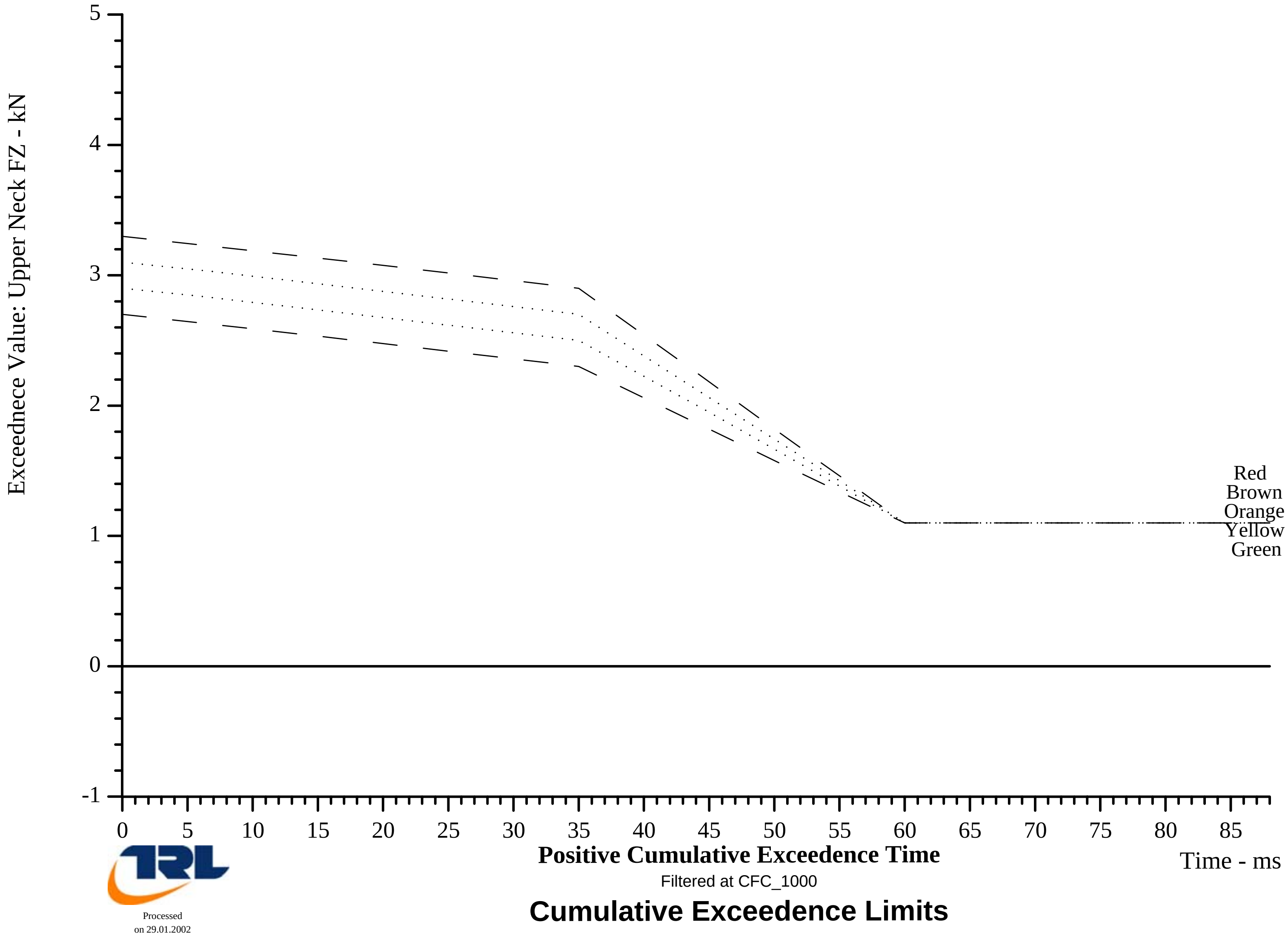
4 Femur Compression

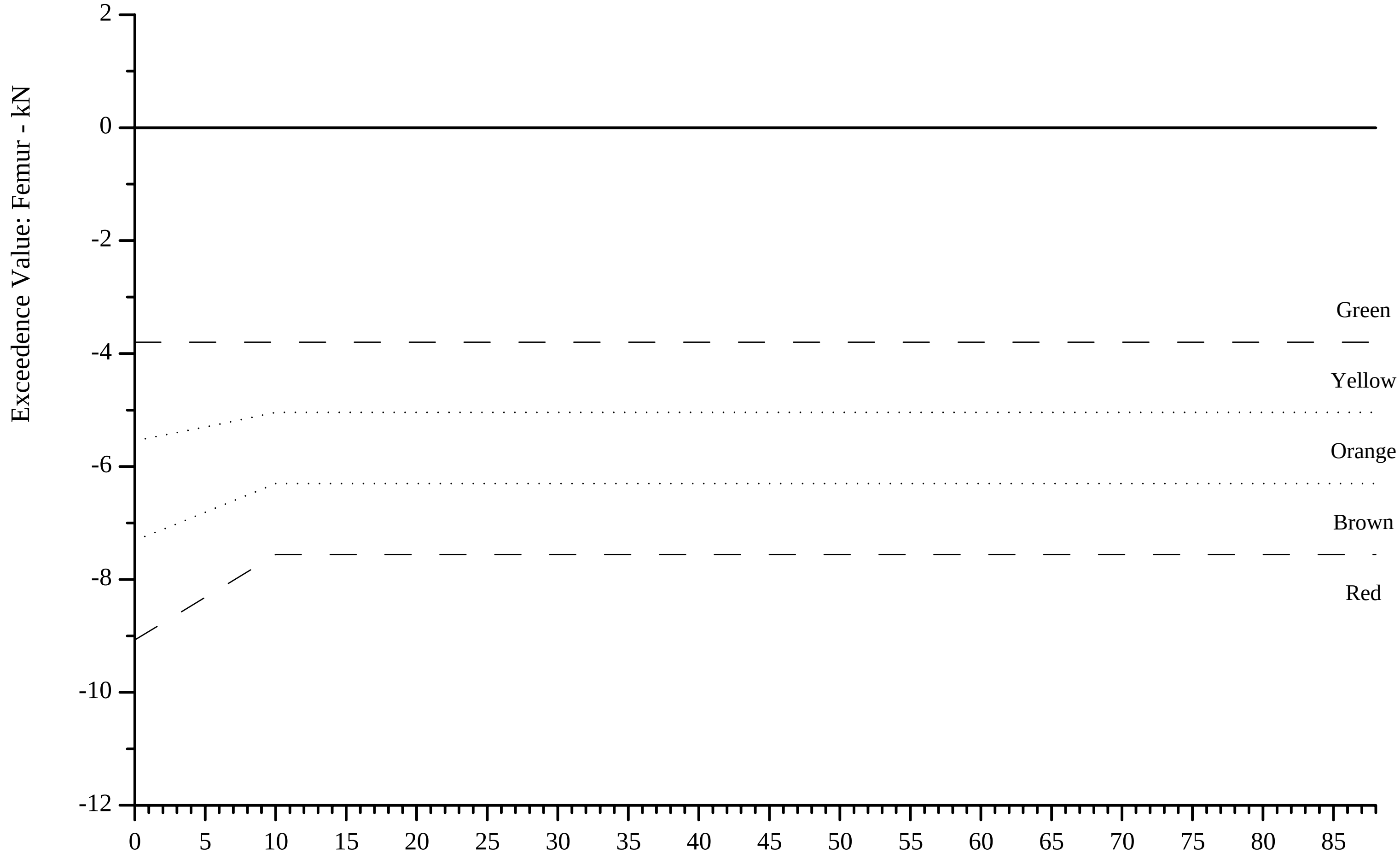



**Cumulative Exceedence Limits**




**Cumulative Exceedence Limits**


Exceednece Value: Upper Neck FZ - kN
5
4
3
2
1
0
-1
Red
Brown
Orange
Yellow
Green
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
Positive Cumulative Exceedence Time
Time - ms
Filtered at CFC_1000
Cumulative Exceedence Limits
Processed
on 29.01.2002




Time - ms

**Negative Cumulative Exceedence Time**

Filtered at CFC_600

## Cumulative Exceedence Limits

Processed
on 01.02.2002