# INTERNATIONAL STANDARD

# ISO 13232-5

Second edition
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## Motorcycles — Test and analysis procedures for research evaluation of rider crash protective devices fitted to motorcycles —

## Part 5:
## Injury indices and risk/benefit analysis

*Motocycles — Méthodes d'essai et d'analyse de l'évaluation par la recherche des dispositifs, montés sur les motocycles, visant à la protection des motocyclistes contre les collisions —*

*Partie 5: Indices de blessure et analyse risque/bénéfice*

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# Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

ISO 13232-5 was prepared by Technical Committee ISO/TC 22, *Road vehicles*, Subcommittee SC 22, *Motorcycles*.

This second edition cancels and replaces the first version (ISO 13232-5:1996), which has been technically revised.

ISO 13232 consists of the following parts, under the general title *Motorcycles — Test and analysis procedures for research evaluation of rider crash protective devices fitted to motorcycles*:

— *Part 1: Definitions, symbols and general considerations*

— *Part 2: Definition of impact conditions in relation to accident data*

— *Part 3: Motorcyclist anthropometric impact dummy*

— *Part 4: Variables to be measured, instrumentation and measurement procedures*

— *Part 5: Injury indices and risk/benefit analysis*

— *Part 6: Full-scale impact-test procedures*

— *Part 7: Standardized procedures for performing computer simulations of motorcycle impact tests*

— *Part 8: Documentation and reports*

# Introduction

ISO 13232 has been prepared on the basis of existing technology. Its purpose is to define common research methods and a means for making an overall evaluation of the effect that devices which are fitted to motorcycles and intended for the crash protection of riders, have on injuries, when assessed over a range of impact conditions which are based on accident data.

It is intended that all of the methods and recommendations contained in ISO 13232 should be used in all basic feasibility research. However, researchers should also consider variations in the specified conditions (for example, rider size) when evaluating the overall feasibility of any protective device. In addition, researchers may wish to vary or extend elements of the methodology in order to research issues which are of particular interest to them. In all such cases which go beyond the basic research, if reference is to be made to ISO 13232, a clear explanation of how the used procedures differ from the basic methodology should be provided.

ISO 13232 was prepared by ISO/TC 22/SC 22 at the request of the United Nations Economic Commission for Europe Group for Road Vehicle General Safety (UN/ECE/TRANS/SCI/WP29/GRSG), based on original working documents submitted by the International Motorcycle Manufacturers Association (IMMA), and comprising eight interrelated parts.

This revision of ISO 13232 incorporates extensive technical amendments throughout all the parts, resulting from extensive experience with the standard and the development of improved research methods.

In order to apply ISO 13232 properly, it is strongly recommended that all eight parts be used together, particularly if the results are to be published.

# Motorcycles — Test and analysis procedures for research evaluation of rider crash protective devices fitted to motorcycles —

# Part 5:
# Injury indices and risk/benefit analysis

## 1 Scope

This part of ISO 13232 provides:

- performance indices which can be correlated with human injuries;
- formulae which relate injury indices to probable injury cost;
- a consistent means of interpreting impact test results;
- a means of relating the results obtained from film analysis and instrumentation of the dummy to injuries sustained in accidents;
- a means of assessing both the combined and relative effects of multiple injuries;
- an objective means of quantifying injury cost using a single index;
- a means of verifying the analysis; and
- a means of doing risk/benefit analysis of protective devices fitted to motorcycles, based upon the population of impact conditions identified in ISO 13232-2.

ISO 13232 specifies the minimum requirements for research into the feasibility of protective devices fitted to motorcycles, which are intended to protect the rider in the event of a collision.

ISO 13232 is applicable to impact tests involving:

- two-wheeled motorcycles;
- the specified type of opposing vehicle;
- either a stationary and a moving vehicle or two moving vehicles;
- for any moving vehicle, a steady speed and straight-line motion immediately prior to impact;
- one helmeted dummy in a normal seating position on an upright motorcycle;
- the measurement of the potential for specified types of injury, by body region;
- evaluation of the results of paired impact tests (i.e. comparisons between motorcycles fitted and not fitted with the proposed devices).

ISO 13232 does not apply to testing for regulatory or legislative purposes.

## 2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 13232-1, *Motorcycles — Test and analysis procedures for research evaluation of rider crash protective devices fitted to motorcycles — Part 1: Definitions, symbols and general considerations*

ISO 13232-2, *Motorcycles — Test and analysis procedures for research evaluation of rider crash protective devices fitted to motorcycles — Part 2: Definition of impact conditions in relation to accident data*

ISO 13232-4, *Motorcycles — Test and analysis procedures for research evaluation of rider crash protective devices fitted to motorcycles — Part 4: Variables to be measured, instrumentation, and measurement procedures*

ISO 13232-7, *Motorcycles — Test and analysis procedures for research evaluation of rider crash protective devices fitted to motorcycles — Part 7: Standardized procedures for performing computer simulations of motorcycle impact tests*

ISO 13232-8, *Motorcycles — Test and analysis procedures for research evaluation of rider crash protective devices fitted to motorcycles — Part 8: Documentation and reports*

AIS-90, Association for the Advancement of Automotive Medicine (AAAM), Des Plaines, IL, USA, *The abbreviated injury scale. 1990 revision*

SAE J211, *Instrumentation for impact tests*, Warrendale, Pennsylvania, USA

SAE J885, *Human tolerance to impact conditions as related to motor vehicle design*, Warrendale, Pennsylvania, USA

## 3 Definitions and abbreviations

The following terms are defined in ISO 13232-1. For the purposes of this part of ISO 13232, those definitions apply. Additional definitions which could apply to this part of ISO 13232 are also listed in ISO 13232-1:

— abbreviated injury scale (AIS);

— abdomen maximum residual penetration ($p_{A,max}$);

— ancillary costs ($AC$);

— cost of fatality ($CF$);

— entire impact sequence;

— generalized acceleration model for brain injury tolerance (GAMBIT, $G$);

— head injury criterion ($HIC$);

— injury assessment function;

— injury assessment variable;

— injury costs ($IC$);

— injury index;

— injury potential variable;

— injury severity probability ($ISP$);

— lower extremities ($lE$);

— maximum PAIS;

— medical costs ($MDC$);

— normalized injury cost ($IC_{norm}$);

— permanent partial incapacity ($PPI$);

— primary impact period;

— probability of fatality ($PF$);

— probable AIS ($PAIS$);

— secondary impact period;

— total PAIS;

— upper (or lower) sternum maximum normalized compression ($C_{us,max,norm}$ or $Cl_{s,max,norm}$);

— upper (or lower) sternum maximum velocity-compression ($VC_{us,max}$ or $VCl_{s,max}$);

— upper (or lower) sternum velocity ($V_{us}$ or $V_{ls}$).

# 4 Requirements

## 4.1 Injury variables

### 4.1.1 Injury assessment variables

The following injury assessment variables shall be evaluated over the primary impact period and also over the entire impact sequence using the calculations presented in 5.1 and the measurement methods given in 5.2.1 and 5.2.3.3 of ISO 13232-4:

— head maximum GAMBIT ($G_{max}$);

— head injury criterion ($HIC$);

— head maximum resultant linear acceleration ($a_{r,H,max}$);

— neck injury index ($NII$);

— upper sternum maximum normalized compression ($C_{us,max,norm}$);

— lower sternum maximum normalized compression ($C_{ls,max,norm}$);

— upper sternum maximum velocity-compression ($VC_{us,max}$) for $V_{us}$ ≥ 3 m/s;

— lower sternum maximum velocity-compression ($VC_{ls,max}$) for $V_{ls}$ ≥ 3 m/s;

— abdomen maximum residual penetration ($p_{A,max}$).

#### 4.1.2 Injury potential variables

The following injury potential variables shall be determined by evaluating them using the methods described in 5.2.4.2 of ISO 13232-4. The variables shall be evaluated over the interval from 0,050 s before first MC/OV contact until first helmet/OV contact, or until the helmet leaves the field of view, whichever occurs sooner, unless otherwise stated. In order to calculate velocities, the results shall be differentiated according to 5.1.7 of this part of ISO 13232, over this same time interval. The specific values listed below shall be identified from the velocity time histories:

— helmet trajectory in initial longitudinal-vertical plane of MC travel ($z_h$ versus $x_h$);

— helmet resultant velocity at first helmet/OV contact ($V_{r,h,fc}$);

— helmet longitudinal velocity at first helmet/OV contact ($V_{x,h,fc}$);

— helmet lateral velocity at first helmet/OV contact ($V_{y,h,fc}$);

— helmet vertical velocity at first helmet/OV contact ($V_{z,h,fc}$).

### 4.2 Lower extremity injuries

The following lower extremity injuries shall be evaluated, based on observations and measurements of the frangible components, as described in 5.2.3 of ISO 13232-4:

— non-displaced bone fractures;

— displaced bone fractures;

— knee partial dislocations;

— knee complete dislocations.

### 4.3 Injury severity probabilities

The following injury severity probabilities ($ISP$) shall be determined for each severity level, AIS ≥ 1 through the highest level, using the methods described in 5.3:

closed head $ISP_H$;

upper neck combined loading $ISP_n$;

upper sternum compression $ISP_{C,us}$;

lower sternum compression $ISP_{C,ls}$;

upper sternum velocity-compression $ISP_{VC,us}$;

lower sternum velocity-compression $ISP_{VC,ls}$;

intra-abdominal penetration $ISP_A$.

### 4.4 Injury indices

The probability of each discrete AIS injury severity level shall be calculated for each of the five body regions: the head, upper neck, thorax, abdomen, and lower extremities, using the procedures described in 5.4.

The medical and ancillary costs associated with injuries to each of the five body regions shall be calculated using the procedures described in 5.5.1 and 5.5.2, respectively. The cost of fatality shall be determined as defined in Annex A.

The probability of fatality shall be calculated using the procedures described in 5.6.

The risk of life threatening brain injury shall be calculated from $HIC$ using the procedures described in 5.6.4.

The probable AIS ($PAIS$) shall be determined by body region, using the procedures described in 5.7.1. The maximum PAIS and total PAIS shall be determined across all body regions using the procedures described in 5.7.2 and 5.7.3, respectively.

The normalized injury costs of survival and fatality and the total normalized injury cost shall be determined using the procedures described in 5.8.

NOTE The term "cost" is used in this subclause in a specific and limited sense, and for test comparison purposes only (see def 3.5.7 of ISO 13232-1 for specific cost definitions). The "costs," as used here, represent average costs based on a simplified model of samples of bioeconomic data; collected over a particular time period and region; and for a limited range of specific injury types, severities, and body regions, which are able to be monitored in crash tests, and which can exclude the majority of the types, severities, and locations of human body injuries, and some types of cost components. In no way do such injury costs consider, nor are they intended to consider, the market level costs of a proposed protective device. The "costs" described herein are only intended to provided a convenient, common basis for combining and comparing across body regions and crash tests and on a relative basis, different types, locations, and severities of injuries. For the foregoing reasons, such costs have limited applicability and are not intended nor appropriate for calculating, for example, the actual cost of a specific real accident, or the total societal or economic cost of a given device or design.

### 4.5 Risk/benefit analysis

Any risk/benefit analysis of a proposed rider crash protective device fitted to a motorcycle, which forms a part of the overall evaluation described in ISO 13232-2 or which may be used to identify potential failure modes of a proposed device for purposes of further testing, shall use the methods described in 5.10.

## 5 Procedures

### 5.1 Injury variables

Compute the maximum values of the variables over time, for example, $G_{max\ (t)}$.

#### 5.1.1 Resultants

Calculate the head resultant linear and angular accelerations, using the time histories of the linear and angular accelerations as calculated in 5.2.1 of ISO 13232-4, and shown in the example for the resultant linear acceleration, given below:

$$a_r = \left(a_x^2 + a_y^2 + a_z^2\right)^{1/2}$$

where

$a_r$ is the resultant linear acceleration, in g units;

$a_x$ is the linear acceleration in the $x$ direction, in g units;

$a_y$ is the linear acceleration in the $y$ direction, in g units;

$a_z$ is the linear acceleration in the $z$ direction, in g units.

Where only two components are included in a resultant, calculate the resultant of those two components, as shown in the example for the resultant shear force, given below:

$$F_{xy} = \left(F_x^2 + F_y^2\right)^{1/2}$$

where

$F_{xy}$ is the resultant force, in kilonewtons;

$F_x$ is the force in the $x$ direction, in kilonewtons;

$F_y$ is the force in the $y$ direction, in kilonewtons.

### 5.1.2 GAMBIT

Calculate GAMBIT using the equation given below:

$$G = \left(\left(\frac{a_{r,H}}{250}\right)^2 + \left(\frac{a_{r,H}}{25000}\right)^2\right)^{1/2}$$

where

— $G$ is GAMBIT

— $a_{r,H}$ is the head resultant linear acceleration, in g units;

— $\alpha_{r,H}$ is the head resultant angular acceleration, in radians per second squared.

— 250 is the normalization factor for linear acceleration in GAMBIT, in g units;

— 25 000 is the normalization factor for angular acceleration in GAMBIT, in radians per second squared.

— Identify the maximum value of GAMBIT, $G_{max}$

### 5.1.3 HIC

Calculate $HIC$ using the equation given below[1]:

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1) SAE J885, July 1986.

$$HIC = \max\left( \left(t_2 - t_1\right) \left( \frac{1}{t_2 - t_1} \int_{t_2}^{t_1} a_{r,H}\left(t\right) dt \right)^{2,5} \right)$$

where

$HIC$ is the head injury criterion;

$a_{r,H}$ is the head resultant linear acceleration, in g units;

$HIC$ values are only calculated during periods of head contact as defined by head engagement ($t_e$) and head disengagement ($t_d$) times determined according to ISO Technical Report TR 12351.

$t_1$ and $t_2$ (in seconds) are all possible initial and final times for each contact interval which are separated by not more than 0,015 s, and where $t_1$ > = $\tau_\varepsilon$ and $t_2$ < = $t_d$.

An example computer code for the calculation of head contacts is found in Annex I.

### 5.1.4 Upper and lower sternum compression

Use the upper and lower sternum displacement time histories recorded and reduced as described in 4.4.1.3 and 5.2.1 of ISO 13232-4. Calculate the upper and lower sternum deflections and compressions, as shown in the example equations for the upper sternum, given below and referring to Figure 1:

$$D_{y,us} = \frac{\left(l_{uL} + \Delta l_{uL}\right)^2 - \left(l_{uR} + \Delta l_{uR}\right)^2}{2W_{L,R}}$$

$$D_{x,us} = \left( \left(l_{uR} + \Delta l_{uR}\right)^2 - \left( \frac{W_{L,R}}{2} - D_{y,us} \right)^2 \right)^{1/2} - d_{us}$$

$$C_{us,norm} = \frac{-D_{x,us}}{187,5} \times 100$$

where

$D_{y,us}$ is the upper sternum deflection in the *y* direction, in millimetres;

$l_{uL}$ is the cable length of the upper left string pot, in millimetres;

$\Delta l_{uL}$ is the change in cable length of the upper left string pot (positive is longer), in millimetres;

$l_{uR}$ is the cable length of the upper right string pot, in millimetres;

$\Delta l_{uR}$ is the change in cable length of the upper right string pot (positive is longer), in millimetres;

$W_{L,R}$ is the lateral distance between the left and right string pots, in millimetres;

$D_{x,us}$ is the upper sternum deflection in the $x$ direction, in millimetres;

$d_{us}$ is the undeformed perpendicular distance from the plane containing the string pot pivot axes to the upper sternum, at the centre of rib 2 where the strings are attached, in millimetres;

187,5 is the dimensional factor used to normalize compression of the Hybrid III chest, in millimetres;

$C_{us,norm}$ is the normalized upper sternum compression for a Hybrid III dummy, expressed as a percentage.

Identify the maximum normalized upper and lower sternum compressions, $C_{us,max}$ and $Cl_{s,max}$, respectively.

If at any time $D_{x,us}$ or $D_{x,ls}$ exceeds 75 mm, document this result in accordance with ISO 13232-8.

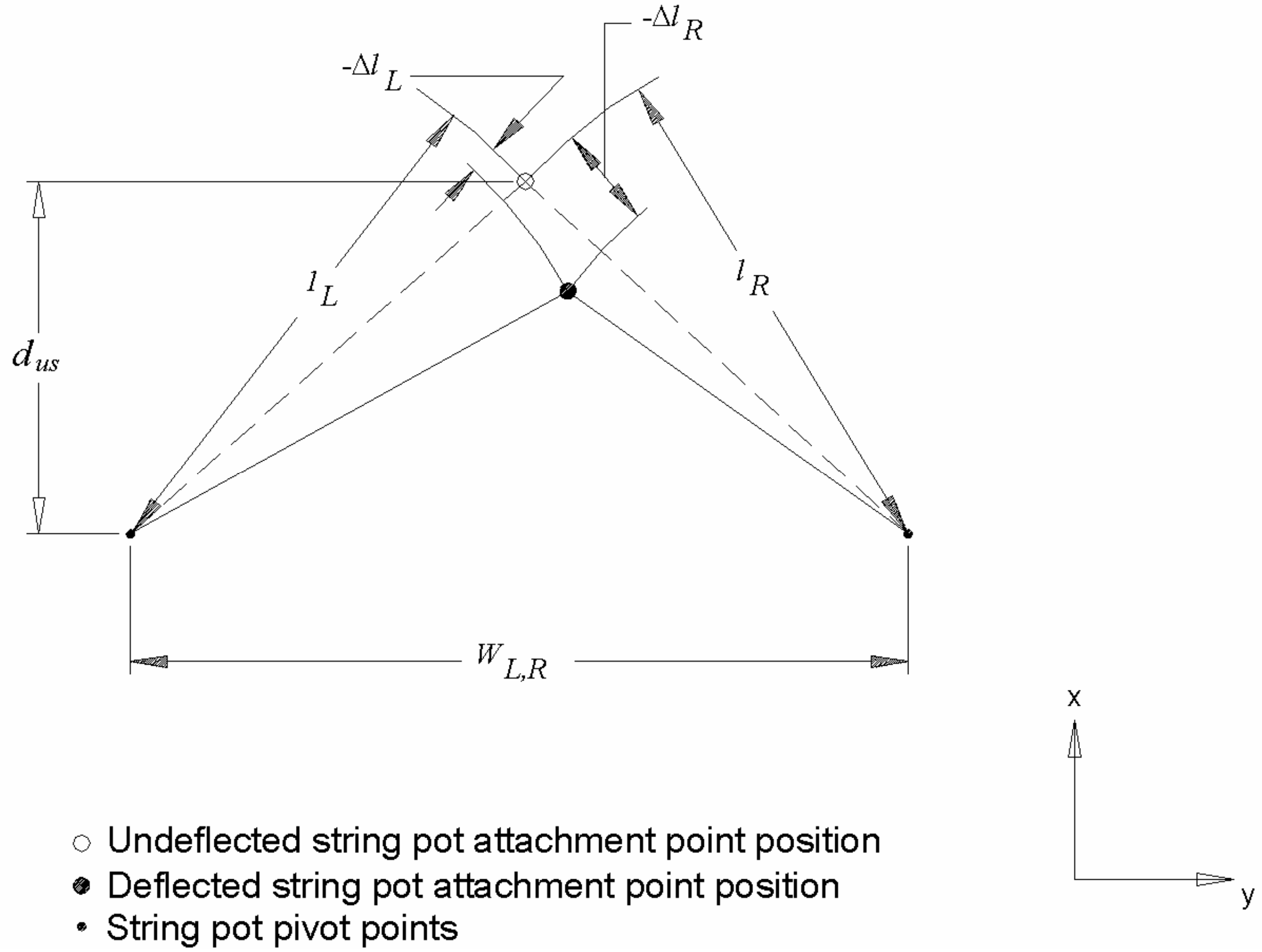


**Figure 1 — Chest potentiometer geometry shown for the upper sternum**

### 5.1.5 Upper and lower sternum velocity

Calculate the upper and lower sternum compression velocities by differentiating the upper and lower sternum deflections, respectively, using the trapezoidal rule, as shown below for the upper sternum. Filter the velocities using the SAE J211 Class 60 and convert the velocities to metres per second.

$$V_{us} = \frac{\left(\frac{d_{D_{x,us}}}{dt}\right)}{1\,000}$$

where

$V_{us}$ is the upper sternum velocity, in metres per second;

$D_{x,us}$ is the upper sternum deflection in the x direction, in millimetres;

$t$ is the time, in seconds;

1 000 is the conversion factor from millimetres to metres.

### 5.1.6 Upper and lower sternum velocity-compression

Calculate the upper and lower sternum velocity-compressions, as shown in the example equation for the upper sternum, given below:

$$VC_{us} = \frac{1{,}3 \times V_{us} D_{x,us}}{229}$$

where

$VC_{us}$ is the upper sternum velocity-compression, in metres per second;

$V_{us}$ is the upper sternum velocity, in metres per second;

$D_{x,us}$ is the upper sternum deflection in the $x$ direction, in millimetres;

1,3 is the factor to correct internally measured upper (or lower) sternum variables to external application;

229 is the dimensional factor used to normalize upper (or lower) sternum deflection for the $VC$ calculation, in millimetres.

Identify the maximum upper and lower sternum velocity-compressions, $VC_{us,max}$ and $VC_{ls,max}$ for $V_{us}$ and $V_{ls} \geq 3$ m/s, respectively, considering only cases where both $V$ and $D_x$ have negative values.

### 5.1.7 Helmet centroid point component velocities

Plot the helmet centroid point trajectory as described in 4.1.2. Evaluate $V_{x,h,fc}$, $V_{y,h,fc}$, and $V_{z,h,fc}$ relative to the inertial axis system and using the procedures described in Annex A of ISO 13232-4.

Calculate the helmet centroid point component velocities in the $x$, $y$, and $z$ directions from the high speed film data, as shown in the example for the x direction helmet centroid point velocity, given below:

$$V_{x,h,i} = \frac{x_{h,j+1} - x_{h,j-1}}{1000\left(t_{i+1} - t_{i-1}\right)}$$

where

$V_{x,h,i}$ is the helmet centroid point velocity in the $x$ direction at analysis frame $i$, in metres per second;

$x_{h,i+1}$ is the position of the helmet centroid point in the $x$ direction at analysis frame $i$+1, in millimetres;

$t_{i+1}$ is the time of analysis frame $i$+1, in seconds;

1 000 is the conversion factor from millimetres to metres.

### 5.1.8 Neck injury index (NII)

Calculate $NII$ using the equation given below:

$$NII(t) = \max\left(\left(\left(\frac{F_C(t)}{F_C^*} + \frac{F_T(t)}{F_T^*} + \left(\left(\frac{M_X(t)}{M_X^*}\right)^2 + \left(\frac{M_E(t)}{M_E^*} + \frac{M_F(t)}{M_F^*}\right)^2\right)^{1/2}\right)^2 + \left(\frac{M_Z(t)}{M_Z^*}\right)^2\right)^{1/2}, 3{,}1\left(\frac{F_C(t)}{F_C^*} + \frac{F_T(t)}{F_T^*}\right)\right)$$

where

$F_c(t)$ is the neck axial compression force (the minimum of $F_z$ or 0 (never a positive number));

$F_C^*$ is the normalization factor for compression ( $F_C^*$ = -6,53 kN);

$F_T(t)$ is the neck tension force (the maximum of $F_z$ or 0 (never a negative number));

$F_T^*$ is the normalization factor for tension ( $F_T^*$ = 3,34 kN);

$M_x(t)$ is the neck lateral flexion moment at the occipital condyle;

$M_X^*$ is the normalization factor for occipital condyle lateral flexion ( $M_X^*$ = 62,66 Nm);

$M_E(t)$ is the neck extension moment at the occipital condyle (the minimum of $M_y$ or 0 (never a positive number));

$M_E^*$ is the normalization factor for occipital condyle extension bending ( $M_E^*$ = -58,0 Nm);

$M_F(t)$ is the neck flexion moment at the occipital condyle (the maximum of $M_y$ or 0 (never a negative number));

$M_F^*$ is the normalization factor for occipital condyle flexion ( $M_F^*$ = 204,2 Nm);

$M_z(t)$ is the neck torsion moment;

$M_Z^*$ is the normalization factor for torsion ( $M_Z^*$ = 47,1 Nm).

Identify by means of time series analysis $NII_{max}$ the maximum value of $NII$.

Note - Assumptions and limitations for predicting neck injuries are given in subclause O.3.1.5 and Annex J.

## 5.2 Frangible component damage

Record the number of displaced and non-displaced fractures for each femur and tibia frangible bone. Record partial or complete dislocation or no injury for each knee. Record $p_{A,max}$. Use the evaluation methods described in 5.2.3 of ISO 13232-4.

## 5.3 Injury severity probabilities

Insert the injury variable values into the following relationships to determine the injury severity probability ($ISP$) for each AIS injury severity level, for each body region.

### 5.3.1 Head

Calculate the closed head GAMBIT $ISP_{Gmax,H}$ and the closed head HIC $ISP_{HIC,H}$ as a function of $G_{max}$ and $HIC$ respectively, for each $AIS \geq j$ injury severity level, using the injury assessment functions given in Tables 1a and 1b respectively. If any of the head injury assessment values are less than the minimum required value for the injury severity level, then the corresponding ISP value is 0.

The closed head $ISP$, $ISP_H$, for each AIS injury severity level, $j$, is defined as the larger of either $ISP_{Gmax,H,j}$ or $ISP_{HIC,H,j}$.

### 5.3.2 Chest

For each $AIS \geq j$ injury severity level, calculate the upper and lower thoracic compression $ISP_{C,us}$ and $ISP_{C,ls}$ as a function of $C_{us,max}$ and $C_{ls,max}$, respectively, and the upper and lower thoracic velocity-compression $ISP_{VC,us}$ and $ISP_{VC,ls}$, as a function of $VC_{us,max}$ and $VC_{ls,max}$, respectively, using the injury assessment functions given Tables 2 and 3, respectively. If any of the chest injury assessment values are less than the minimum required value for the injury severity level, then the corresponding ISP value is 0.

The thoracic compression $ISP_C$ for each AIS injury severity level, $j$, is defined as the larger of either $ISP_{C,us,j}$ or $ISP_{C,ls,j}$. The thoracic velocity-compression $ISP_{VC}$ for each severity level, $j$, is defined as the larger of either $ISP_{VC,us,j}$ or $ISP_{VC,ls,j}$. The overall thoracic $ISP$, $ISP_{Th}$, for each AIS injury severity level, $j$, is defined as the larger of either $ISP_{C,j}$ or $ISP_{VC,j}$.

### 5.3.3 Abdomen

Calculate the intra-abdominal penetration $ISP_A$ as a function of $p_{A,max}$ for each $AIS > j$ injury severity level using the injury assessment functions given in Table 4.

NOTE The researcher may choose to calculate $ISP_A$, the injury indices, and the injury costs by:

— replacing the measured value of $p_{A,max}$ with a zero;

— calculating the injury indices and injury costs as described in this part of ISO 13232;

— reporting both sets of values and the measured value of $p_{A,max}$ in the documentation;

— noting this deviation in the documentation.

**Table 1a — Closed head injury severity probability as a function of $G_{max}$**

| Severity level | Minimum $G_{max}$ required | Injury assessment function |
|---|---|---|
| AIS ≥ 1 | 0 | $ISP_{H,1} = 1 - \exp\left[-\left(G_{\max} / 0{,}755\right)^{3{,}5}\right]$ |
| AIS ≥ 2 | 0,125 | $ISP_{H,2} = 1 - \exp\left[-\left(\left(G_{\max} - 0{,}125\right) / 0{,}70\right)^{3{,}5}\right]$ |
| AIS ≥ 3 | 0,375 | $ISP_{H,3} = 1 - \exp\left[-\left(\left(G_{\max} - 0{,}375\right) / 0{,}64\right)^{3{,}5}\right]$ |
| AIS ≥ 4 | 0,438 | $ISP_{H,4} = 1 - \exp\left[-\left(\left(G_{\max} - 0{,}438\right) / 0{,}62\right)^{3{,}5}\right]$ |
| AIS ≥ 5 | 0,650 | $ISP_{H,5} = 1 - \exp\left[-\left(\left(G_{\max} - 0{,}065\right) / 0{,}54\right)^{2{,}2}\right]$ |
| AIS = 6 | 0,680 | $ISP_{H,6} = 1 - \exp\left[-\left(\left(G_{\max} - 0{,}680\right) / 0{,}60\right)^{1{,}8}\right]$ |

where

$ISP_{H,j}$ is the probability of a head injury of at least AIS severity level $j$;

AIS is defined in AIS-90;

$G_{max}$ is the maximum value of GAMBIT.

**Table 1b — Closed head injury severity probability as a function of $HIC$**

| Severity level | Minimum $HIC$ required | Injury assessment function |
|---|---|---|
| AIS ≥ 1 | 0 | $ISP_{HIC,H,1} = 1 - \exp\left[-\left(HIC / 560\right)^{2{,}98}\right]$ |
| AIS ≥ 2 | 0 | $ISP_{HIC,H,2} = ISP_{HIC,H,3} + \left(ISP_{HIC,H,1} - ISP_{HIC,H,3}\right) \times \left(55 / 123\right)$ |
| AIS ≥ 3 | 0 | $ISP_{HIC,H,3} = 1 - \exp\left[-\left(\left(HIC - 500\right) / 1990\right)^{4{,}5}\right]$ |
| AIS ≥ 4 | 450 | $ISP_{HIC,H,4} = ISP_{HIC,H,6} + \left(ISP_{HIC,H,3} - ISP_{HIC,H,6}\right) \times \left(24 / 41\right)$ |
| AIS ≥ 5 | 450 | $ISP_{HIC,H,5} = ISP_{HIC,H,6} + \left(ISP_{HIC,H,3} - ISP_{HIC,H,6}\right) \times \left(14 / 41\right)$ |
| AIS ≥ 6 | 450 | $ISP_{HIC,H,6} = 1 - \exp\left[-\left(\left(HIC - 450\right) / 3275\right)^{1{,}36}\right]$ |

**Table 2 — Thoracic compression injury severity probability as a function of $C_{us,max}$ and $C_{ls,max}$**

| Severity level | Minimum $C_{us,max}$ required | Injury assessment function[a] |
|---|---|---|
| AIS ≥ 1 | 1,77 | $ISP_{C,us,1} = 1 - \exp\left[-\left(\left(C_{us,\max} - 1{,}77\right)/24\right)^{6{,}00}\right]$ |
| AIS ≥ 2 | 7,47 | $ISP_{C,us,2} = 1 - \exp\left[-\left(\left(C_{us,\max} - 7{,}47\right)/24\right)^{6{,}00}\right]$ |
| AIS ≥ 3 | 13,22 | $ISP_{C,us,3} = 1 - \exp\left[-\left(\left(C_{us,\max} - 13{,}22\right)/24\right)^{6{,}00}\right]$ |
| AIS ≥ 4 | 18,97 | $ISP_{C,us,4} = 1 - \exp\left[-\left(\left(C_{us,\max} - 18{,}97\right)/24\right)^{6{,}00}\right]$ |
| AIS ≥ 5 | 24,72 | $ISP_{C,us,5} = 1 - \exp\left[-\left(\left(C_{us,\max} - 24{,}72\right)/24\right)^{6{,}00}\right]$ |
| AIS = 6 | 32,52 | $ISP_{C,us,6} = 1 - \exp\left[-\left(\left(C_{us,\max} - 32{,}52\right)/24\right)^{6{,}00}\right]$ |

where

$ISP_{C,us,j}$ is the probability of an upper thoracic compression injury of at least AIS severity level $j$;

AIS is defined in AIS-90;

$C_{us,max}$ is the upper sternum maximum compression, expressed as a percentage.

a The *ISP* calculation shown is for $C_{us,max}$. Calculate the *ISP* for $C_{ls,max}$, also.

**Table 3 — Thoracic injury velocity-compression severity probability as a function of $VC_{us,max}$ and $VC_{ls,max}$**

| Severity level | Minimum $V_{Cus,max}$ required | Injury assessment function[a] |
|---|---|---|
| AIS ≥ 1 | 0 | $ISP_{VC,us,1} = 1 - \exp\left[-\left(VC_{us,\max} / 0{,}30\right)^{0{,}99}\right]$ |
| AIS ≥ 2 | 0 | $ISP_{VC,us,2} = 1 - \exp\left[-\left(VC_{us,\max} / 0{,}68\right)^{1{,}46}\right]$ |
| AIS ≥ 3 | 0 | $ISP_{VC,us,3} = 1 - \exp\left[-\left(VC_{us,\max} / 1{,}40\right)^{2{,}85}\right]$ |
| AIS ≥ 4 | 0,4 | $ISP_{VC,us,4} = 1 - \exp\left[-\left(\left(VC_{us,\max} - 0{,}4\right)/1{,}291\right)^{3{,}10}\right]$ |
| AIS ≥ 5 | 1,00 | $ISP_{VC,us,5} = 1 - \exp\left[-\left(\left(VC_{us,\max} - 1{,}00\right)/0{,}995\right)^{3{,}10}\right]$ |
| AIS = 6 | 1,50 | $ISP_{VC,us,6} = 1 - \exp\left[-\left(\left(VC_{us,\max} - 1{,}50\right)/0{,}78\right)^{3{,}10}\right]$ |

where

$ISP_{VC,us,j}$ is the probability of an upper thoracic velocity-compression injury of at least AIS severity level $j$;

AIS is defined in AIS-90;

$VC_{us,max}$ is the upper sternum maximum velocity-compression, in metres per second.

a The *ISP* calculation shown is for $VC_{us,max}$. Calculate the *ISP* for $VC_{ls,max}$, also.

**Table 4 — Intra-abdominal penetration injury severity probability as a function of $P_{A,max}$**

| Severity level | Injury assessment function[a] |
|---|---|
| AIS ≥ 1 | $ISP_{A,1} = 1{,}57 \times 10^{-2} \times p_{A,\max}$ |
| AIS ≥ 2 | $ISP_{A,2} = 1{,}23 \times 10^{-2} \times p_{A,\max}$ |
| AIS ≥ 3 | $ISP_{A,3} = 1{,}55 \times 10^{-4} \times (p_{A,\max})^{2{,}00}$ |
| AIS = 4 | $ISP_{A,4} = 9{,}36 \times 10^{-13} \times (p_{A,\max})^{6{,}50}$ |

where

$ISP_{A,j}$ is the probability of an abdominal injury of at least AIS severity level $j$;

AIS is defined in AIS-90;

$p_{A,max}$ is the maximum penetration of the abdominal insert, in millimetres.

a The ISP calculation assumes that the $p_{A,\ max}$ is less than 60 mm. Values larger than this are extremely rare.

### 5.3.4 Neck

Calculate the neck $ISP_n$ as a function of $NII$ for each $AIS \geq j$ injury severity level using the injury assessment functions given in Table 5. If $NII_{max}$ is less than the minimum required value then $ISP_{n,j}$ = 0.

**Table 5 — Neck combined loading injury severity probability as a function of $NII$**

| Severity level | Minimum $NII_{max}$ required | Injury assessment function |
|---|---|---|
| AIS ≥ 1 | 1,06 | $ISP_{n,1} = 1 - e^{-\left(\left(\frac{NII_{\max} - 1{,}06}{4{,}38}\right)^{3{,}5}\right)}$ |
| AIS ≥ 2 | 1,86 | $ISP_{n,2} = 1 - e^{-\left(\left(\frac{NII_{\max} - 1{,}86}{4{,}38}\right)^{3{,}5}\right)}$ |
| AIS ≥ 3 | 2,29 | $ISP_{n,3} = 1 - e^{-\left(\left(\frac{NII_{\max} - 2{,}29}{4{,}38}\right)^{3{,}5}\right)}$ |
| AIS ≥ 4 | 4,73 | $ISP_{n,4} = 1 - e^{-\left(\left(\frac{NII_{\max} - 4{,}73}{4{,}38}\right)^{3{,}5}\right)}$ |
| AIS ≥ 5 | 4,73 | $ISP_{n,5} = 1 - e^{-\left(\left(\frac{NII_{\max} - 4{,}73}{4{,}38}\right)^{3{,}5}\right)}$ |

| Severity level | Minimum $NII_{max}$ required | Injury assessment function |
|---|---|---|
| AIS = 6 | 6,13 | $ISP_{n,6} = 1 - e^{-\left(\left(\frac{NII_{\max} - 6,13}{4,38}\right)^{3,5}\right)}$ |

where

$ISP_{n,j}$ is the probability of a neck injury of at least AIS severity level $j$;

AIS is defined in AIS-90;

$NII_{max}$ is the maximum value of neck injury index ($NII$).

## 5.4 Probability of discrete AIS injury severity level

### 5.4.1 Head, neck, thorax, abdomen

For each of the four body regions and each of the AIS injury severity levels, calculate the probability of sustaining an injury of the specific AIS injury severity level. Use the equation given below:

$$P_{ij} = ISP_{ij} - ISP_{ij+1}$$

where

$P_{i,j}$ is the probability of sustaining an injury of specific severity level $j$ to the body region $i$;

$ISP_{i,j}$ is the probability of sustaining an injury of at least severity level $j$ to the body region $i$.

### 5.4.2 Lower extremities

#### 5.4.2.1 Number of injuries

Based upon the frangible leg component damage recorded in 5.2, determine the number of injuries and AIS injury severity level of each, for the femur, tibia, and knee, using Table 6.

#### 5.4.2.2 Probability of an injury of a specific severity level

Because of the nature of the frangible leg components used, the probability of sustaining a lower extremity injury of a specific AIS injury severity level, $P_{lE,j}$ is equal to either 0 or 1 for each of the three AIS injury severity levels listed in Table 6. Determine the highest AIS injury severity level among all six leg components. Set $P_{lE,j}$ equal to 1 for that AIS injury severity level, $j$, and set $P_{lE,j}$ equal to 0 for the other two AIS injury severity levels.

**Table 6 — AIS injury severity level for frangible component damage**

| Femur mid-shaft fracture type | Knee dislocation | Tibia mid-shaft fracture type | AIS severity level |
|---|---|---|---|
| None | None | None | 0 |
| | Partial | Non-displaced | 2 |
| Displaced or non-displaced | Complete | Displaced | 3 |

For example, if there are only two leg components damaged during the test, a left knee partial dislocation and a right femur displaced fracture, $P_{lE,j}$ is determined to be 1 for AIS injury severity level 3 and 0 for AIS injury severity levels 0 and 2, as shown in Table 7.

**Table 7 — Example PIE,j determination**

| Damaged component | Damage type | AIS | $P_{lE,j}$ |
|---|---|---|---|
| Left tibia | None | 0 | 0 |
| Right tibia | None | 0 | 0 |
| Left knee | Partial dislocation | 2 | 0 |
| Right knee | None | 0 | 0 |
| Left femur | None | 0 | 0 |
| Right femur | Non-displaced fracture | 3 | 1 |

where

$P_{lE,j}$ is the probability of sustaining any lower extremity injury of the AIS injury severity level $j$.

#### 5.4.2.3 Permanent partial incapacity

Determine the number of damaged frangible leg components and the AIS injury severity level for each one. Using the criteria listed in Table 8, determine the maximum permanent partial incapacity (PPI) which would result from sustaining comparable injuries to the lower extremities.

**Table 8 — Permanent partial incapacity determination**

| If | | PPI = |
|---|---|---|
| $N_{F,3} + N_{K,3} + N_{K,2} + N_{T,3} + N_{T,2}$ | ≥ 3 | 0,38 |
| $N_{F,3} + N_{K,3} + N_{K,2} + N_{T,3} + N_{T,2}$ | = 2 | 0,27 |
| $N_{F,3}$ *or* $N_{T,3}$ *or* $N_{K,2}$ | = 1 | 0,15 |
| $N_{K,3}$ | = 1 | 0,22 |
| $N_{T,2}$ | = 1 | 0,07 |
| $N_{leg}$ | = 0 | 0,0 |

where

$N_{i,j}$ is the number of damaged frangible leg components $i$ of AIS injury severity level $j$;

$F$ is the femur component;

$T$ is the tibia component;

$K$ is the knee component.

For the example given in 5.4.2.2, the PPI is determined as follows:

$N_{K,2} + N_{F,3} = 2$, therefore PPI = 0,27

## 5.5 Injury costs

NOTE The term "cost" is used in this subclause in a specific and limited sense, and for test comparison purposes only (see def 3.5.7 of ISO 13232-1 for specific cost definitions). The "costs," as used here, represent average costs based on a simplified model of samples of bioeconomic data; collected over a particular time period and region; and for a limited range of specific injury types, severities, and body regions, which may be monitored in crash tests, and which can excluse the majority of the types, severities and locations of human body injuries, and some types of cost components. In no way do such injury costs consider, nor are they intended to consider, the market level costs of a proposed protective device. The "costs" described herein are only intended to provide a convenient, common basis for combining and comparing across body regions and crash tests and on a relative basis, different types, locations, and severities of injuries. For the foregoing reasons, such costs have limited applicability and are not intended nor appropriate for calculating, for example, the actual cost of a specific real accident, or the total societal or economic cost of a given device or design.

### 5.5.1 Medical costs

Tabulate the injuries by body region and AIS injury severity level. Determine the medical costs associated with each body region injury and each discrete AIS injury severity level, for each country, using the cost data listed in Annex A. Calculate the total medical cost associated with the injuries for each of the four body regions, including the head, neck, thorax, and abdomen, using the equation given below:

$$MDC_{i,tot} = \sum_{j=1}^{5} P_{i,j} \times MDC_{i,j}$$

where

$MDC_{i,tot}$ is the total medical cost associated with injuries to the body region $i$;

$P_{i,j}$ is the probability of sustaining an injury of specific severity level $j$ to the body region $i$;

$MDC_{i,j}$ is the medical cost associated with an injury to the body region $i$ of AIS injury severity level $j$.

Determine the medical cost associated with the lower extremity injuries, having the maximum AIS severity using the respective cost data listed in Annex A.

Determine the overall medical cost of injuries to the head, neck, thorax, abdomen, and lower extremities as given below:

$$MDC = \max\left(MDC_{i,tot}\right)$$

where

$MDC$ is the overall medical cost;

$MDC_{i,tot}$ is the total medical cost associated with injuries to the body region $i$.

### 5.5.2 Ancillary costs

Tabulate the injuries by body region and AIS injury severity level. Determine the ancillary costs associated with each body region injury and each discrete AIS injury severity level, for each country in the cost data listed in Annex A. Calculate the total ancillary cost associated with the injuries for each of the four body regions, including the head, neck, thorax, and abdomen, using the equation given below:

$$AC_{i,tot} \sum_{j=1}^{5} P_{i,j} \times AC_{i,j}$$

where

$AC_{i,tot}$ is the total ancillary cost associated with injuries sustained to the body region $i$;

$P_{i,j}$ is the probability of sustaining an injury of AIS injury severity level $j$ to the body region $i$;

$AC_{i,j}$ is the ancillary cost associated with an injury to the body region $i$ of AIS injury severity level $j$.

Determine the total ancillary cost associated with lower extremity injuries using the maximum PPI value, as determined in 5.4.2.3, and the respective cost data table given in Annex A.

Determine the overall ancillary cost of injuries to the head, neck, thorax, abdomen, and lower extremities as given below:

$$AC = \max\left(AC_{i,tot}\right)$$

where

$AC$ is the overall ancillary cost;

$AC_{i,tot}$ is the total ancillary cost associated with injuries sustained to the body region $i$.

### 5.5.3 Fatality cost

Determine the cost of fatality as defined in Annex A.

## 5.6 Probability of fatality

### 5.6.1 Due to AIS 6 injuries

Calculate the probability of fatality due to AIS 6 injuries to the head, neck, and/or the thorax using the equation given below:

$$P_{fatal,6} = 1 - \left[\left(1 - P_{H,6}\right) \times \left(1 - P_{n,6}\right) \times \left(1 - P_{Th,6}\right)\right]$$

where

$P_{fatal,6}$ is the probability of fatality due to an AIS 6 injury;

$P_{H,6}$ is the probability of sustaining an AIS 6 head injury;

$P_{n,6}$ is the probability of sustaining an AIS 6 neck injury;

$P_{Th,6}$ is the probability of sustaining an AIS 6 thoracic injury.

### 5.6.2 Due to non-AIS 6 injuries

Construct a table as shown in Table 9. In the table, for each AIS injury severity level, list the values for the previously calculated probabilities of injury for the head, neck, thorax, abdomen, and lower extremities, and the number of lower extremity injuries. Consider that both of the legs comprise a single body region named lower extremities.

**Table 9 — Injury probability and probable AIS**

| AIS | Body region | | | | | |
|---|---|---|---|---|---|---|
| | Head | Neck | Thorax | Abdomen | Lower extremities | |
| | | | | | Probability | Number of injuries |
| 0 | $P_{H,0}$ | $P_{n,0}$ | $P_{Th,0}$ | $P_{A,0}$ | $P_{lE,0}$ | - |
| 1 | $P_{H,1}$ | $P_{n,1}$ | $P_{Th,1}$ | $P_{A,1}$ | 0 | - |
| 2 | $P_{H,2}$ | $P_{n,2}$ | $P_{Th,2}$ | $P_{A,2}$ | $P_{lE,2}$ | $N_{lE,2}$ |
| 3 | $P_{H,3}$ | $P_{n,3}$ | $P_{Th,3}$ | $P_{A,3}$ | $P_{lE,3}$ | $N_{lE,3}$ |
| 4 | $P_{H,4}$ | $P_{n,4}$ | $P_{Th,4}$ | $P_{A,4}$ | 0 | - |
| 5 | $P_{H,5}$ | $P_{n,5}$ | $P_{Th,5}$ | 0 | 0 | - |
| 6 | $P_{H,6}$ | $P_{n,6}$ | $P_{Th,6}$ | 0 | 0 | - |
| Probable AIS | $PAIS_H$ | $PAIS_n$ | $PAIS_{Th}$ | $PAIS_A$ | $PAIS_{lE}$ | - |

The probability of fatality due to non-AIS 6 injuries includes the probability of fatality from all possible combinations of non-AIS 6 injuries. Calculate the probability of fatality for each possible combination of five non-AIS 6 injuries, one from each body region, and total them.

For each combination of five injury probabilities, determine the three largest corresponding AIS injury severity levels. Using these three AIS injury severity levels and Table B.1 in Annex B, determine the associated mortality rate for that combination of AIS injury severity levels. Calculate the probability of dying from that combination of non-AIS 6 severity levels.

EXAMPLE calculate the probability of fatality from a given combination of non-AIS 6 injuries, as shown below, for:

— head AIS 4;

— neck AIS 1;

— thorax AIS 1;

— abdomen AIS 2;

— lower extremities AIS 3.

Determine the mortality rate for the given combination of non-AIS 6 injuries using AIS 4, 3, and 2, because they are the three largest AIS injury severity levels. The mortality rate is, then:

$MR_{432} = 23{,}7099$

where

$MR_{432}$ is the mortality rate, from Table B.1, for the three largest AIS values of the five body regions,

4, 3, 2, expressed as a percentage.

Calculate the probability of fatality for the given combination of non-AIS 6 injuries using the following equation:

$$P_{fatal,41123}\ \frac{1}{100} \times 23{,}7099 \times P_{H,4} \times P_{n,1} \times P_{Th,1} \times P_{A,2} \times P_{lE,3}$$

where

$P_{fatal,41123}$ is the probability of fatality for the given combination of non-AIS 6 injuries;

$P_{H,4}$ is the probability of a head injury of AIS 4;

$P_{n,1}$ is the probability of a neck injury of AIS 1;

$P_{Th,1}$ is the probability of a thorax injury of AIS 1;

$P_{A,2}$ is the probability of an abdomen injury of AIS 2;

$P_{lE,3}$ is the probability of a lower extremities injury of AIS 3.

Calculate the probability of fatality from all combinations of non-AIS 6 injuries using the equation given below:

$$P_{fatal,5} = \frac{1}{100} \times \sum_{jH=0}^{5} \sum_{jn=0}^{5} \sum_{jTh=0}^{5} \sum_{jA=0}^{5} \sum_{jlE=0}^{5} MR_{jH,jn,jTh,jA,jlE} \times P_{H,jH} \times P_{n,jn} \times P_{Th,jTh} \times P_{A,jA} \times P_{lE,jE}$$

where

$P_{fatal,5}$ is the probability of fatality from all combinations of non-AIS 6 injuries;

$MR$ is the mortality rate, from Table B.1, with the three largest AIS values in descending order;

$P_{i,j}$ is the probability of sustaining an injury to the body region $i$ of the AIS injury severity level $j$, where $i$ is $H$, $n$, $Th$, $A$, or $lE$;

$jH$ is the AIS injury severity level for the head;

$jn$ is the AIS injury severity level for the neck;

$jTh$ is the AIS injury severity level for the thorax;

$jA$ is the AIS injury severity level for the abdomen;

$jlE$ is the AIS injury severity level for the lower extremities.

### 5.6.3 Overall

Calculate the overall probability of fatality using the equation below:

$$P_{fatal} = P_{fatal,6} + P_{fatal,5}$$

where

$P_{fatal}$ is the overall probability of fatality;

$P_{fatal,6}$ is the probability of fatality from an AIS 6 injury;

$P_{fatal,5}$ is the probability of fatality from non-AIS 6 injuries.

### 5.6.4 Risk of life threatening brain injury

Determine the risk of life threatening brain injury using the value for HIC calculated in 5.1.3 and the plot given in Figure 2. Locate the calculated HIC value on the horizontal axis and determine the corresponding risk of life threatening brain injury on the vertical axis.

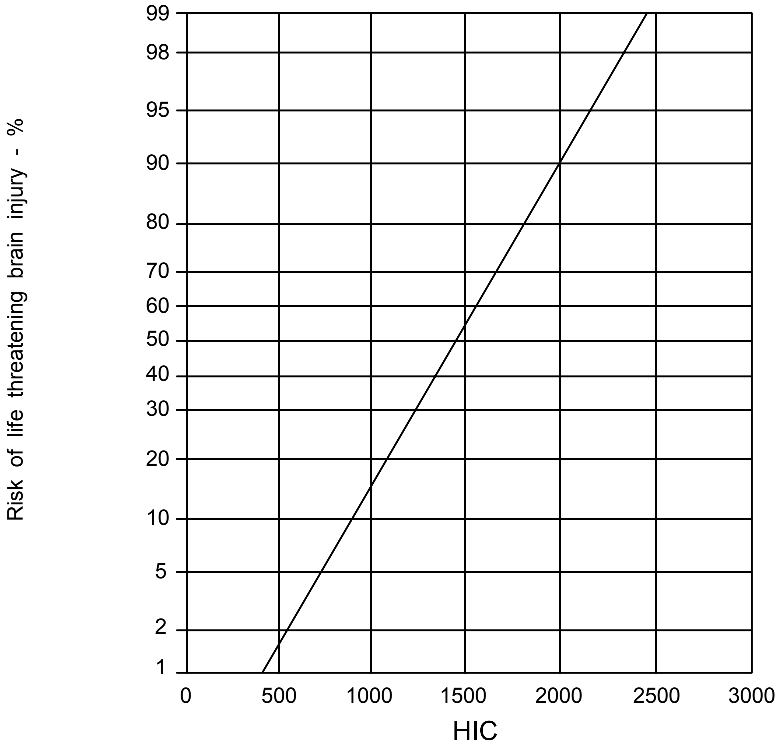


**Figure 2 — Risk of life threatening brain injury for HIC for $t_2 - t_1 \leq 0{,}015$ s**

## 5.7 Probable AIS

### 5.7.1 By body region

Calculate a single weighted average PAIS for each body region as shown in the equation below:

$$PAIS_i = \frac{\sum_{j=0}^{6} j \times P_{i,j}}{\sum_{j=0}^{6} P_{i,j}}$$

where

$PAIS_i$ is the weighted average probable AIS for the body region $i$, rounded to the nearest integer;

$j$ is the AIS injury severity level;

$P_{i,j}$ is the probability of sustaining an injury of the AIS injury severity level j to the body region $i$.

Insert these calculated PAIS values into Table 8 in the appropriate boxes.

Total the number of lower extremity injuries for each AIS level and include that number in Table 9. For example:

$$N_{lE,3} = N_{F,3} + N_{T,3} + N_{K,3}$$

where

$N_{lE,3}$ is the number of AIS 3 injuries to the lower extremities;

$F$ indicates femur injuries;

$T$ indicates tibia injuries;

$K$ indicates knee injuries.

### 5.7.2 Maximum PAIS

Calculate the maximum PAIS for all body regions as shown in the equation below:

$$PAIS_{\max} = \max\left(PAIS_i\right)$$

where

$PAIS_{max}$ is the maximum PAIS for all body regions;

$PAIS_i$ is the PAIS for the body region $i$.

### 5.7.3 Total PAIS

Calculate the total PAIS for all body regions as shown in the equation below:

$$PAIS_{tot} = PAIS_H + PAIS_n + PAIS_{Th} + PAIS_A + \sum_{j=2}^{3} j \times N_{lE,j}$$

where

$PAIS_{tot}$ is the total PAIS for all body regions;

$PAIS_H$ is the PAIS for the head;

$PAIS_n$ is the PAIS for the neck;

$PAIS_{Th}$ is the PAIS for the thorax;

$PAIS_A$ is the PAIS for the abdomen;

$j$ is the AIS injury severity level;

$N_{lE,j}$ is the number of lower extremity injuries for AIS injury severity level $j$.

## 5.8 Normalized injury costs

NOTE The term "cost" is used in this subclause in a specific and limited sense, and for test comparison purposes only (see def 3.5.7 of ISO 13232-1 for specific cost definitions). The "costs," as used here, represent average costs based on a simplified model of samples of bioeconomic data; collected over a particular time period and region; and for a limited range of specific injury types, severities, and body regions, which may be monitored in crash tests, and which can exclude the majority of the types, severities, and locations of human body injuries, and some types of cost components. In no way do such injury costs consider, nor are they intended to consider, the market level costs of a proposed protective device. The "costs" described herein are only intended to provide a convenient, common basis for combining and comparing across body regions and crash tests and on a relative basis, different types, locations, and severities of injuries. For the foregoing reasons, such costs have limited applicability and are not intended nor appropriate for calculating, for example, the actual cost of a specific real accident, or the total societal or economic cost of a given device or design.

Calculate the normalized cost of survival as shown in the equation below:

$$CS_{norm} = \frac{\left(\text{minimum of } \left(\left(MDC + AC\right) \text{or } CF\right)\right)\left(1 - P_{fatal}\right)}{CF}$$

where

$CS_{norm}$ is the normalized cost of survival;

$MDC$ is the medical cost;

$AC$ is the ancillary cost;

$P_{fatal}$ is the probability of fatality;

$CF$ is the cost of fatality;

The maximum value of $CS_{norm}$ is (1 - $P_{fatal}$).

The normalized cost of fatality ($CF_{norm}$) is equal to the probability of fatality ($P_{fatal}$).

Calculate the total normalized injury cost as shown in the equation below:

$$C_{norm} = CS_{norm} + CF_{norm}$$

where

$IC_{norm}$ is the total normalized injury cost;

$CS_{norm}$ is the normalized cost of survival;

$CF_{norm}$ is the normalized cost of fatality;

the maximum value of $IC_{norm}$ is 1,0.

### 5.8.1 Incremental normalized injury cost for each body region

Calculate the incremental normalized injury cost for each body region (head, neck, chest, abdomen, femurs, knees, tibias) according to 5.8 using for each body region only the injury assessment values associated with that body region, and setting the injury assessment values for all other body regions equal to zero.

NOTE In general the sum of the incremental normalized injury costs across all body regions will not equal the total normalized injury cost, due to injury cost interactions among the body regions and other non-linearities in their relationships.

## 5.9 Risk/benefit analysis

NOTE The term "cost" is used in this subclause in a specific and limited sense, and for test comparison purposes only (see def 3.5.7 of ISO 13232-1 for specific cost definitions). The "costs," as used here, represent average costs based on a simplified model of samples of bioeconomic data; collected over a particular time period and region; and for a limited range of specific injury types, severities, and body regions, which may be monitored in crash tests, and which can exclude the majority of the types, severities, and locations of human body injuries, and some types of cost components. In no way do such injury costs consider, nor are they intended to consider, the market level costs of a proposed protective device. The "costs" described herein are only intended to provide a convenient, common basis for combining and comparing across body regions and crash tests and on a relative basis, different types, locations, and severities of injuries. For the foregoing reasons, such costs have limited applicability and are not intended nor appropriate for calculating, for example, the actual cost of a specific real accident, or the total societal or economic cost of a given device or design.

### 5.9.1 Calculations of injury assessment variables and injury indices

For each of the 200 impact configurations defined in ISO 13232-2, calculate the values of the injury assessment variables and injury indices listed in Table 10.

**Table 10 — Injury assessment variables, change in head injury potential, and injury indices to be calculated for each impact configuration**

| **Injury assessment variable, change in head injury potential, injury index** | **Values to calculate** | | |
|---|---|---|---|
| | MC without protective device (1) | MC with protective device (2) | Change due to protective device (2) - (1) |
| Head maximum resultant linear acceleration | X | X | X |
| Head maximum resultant angular acceleration | X | X | X |
| Head maximum GAMBIT | X | X | X |
| Change in helmet trajectory | - | - | X |
| Percentage change in helmet velocity at helmet impact | - | - | X |
| HIC | X | X | X |
| Head PAIS | X | X | X |
| Neck PAIS | X | X | X |
| Chest PAIS | X | X | X |
| Abdomen PAIS | X | X | X |
| Sum of left and right femur PAIS | X | X | X |
| Sum of left and right knee PAIS | X | X | X |
| Sum of left and right tibia PAIS | X | X | X |
| Head incremental normalized injury cost | X | X | X |
| Neck incremental normalized injury cost | X | X | X |
| Chest incremental normalized injury cost | X | X | X |
| Abdomen incremental normalized injury cost | X | X | X |
| Femur incremental normalized injury cost | X | X | X |
| Knee incremental normalized injury cost | X | X | X |
| Tibia incremental normalized injury cost | X | X | X |
| Total normalized injury cost | X | X | X |

### 5.9.2 Change in head injury potential

For each of the 200 impact configurations defined in ISO 13232-2, determine the following head injury potential indices for each set of paired comparison tests.

#### 5.9.2.1 Change in helmet trajectory

Calculate the maximum vertical difference at the same $x_h$ value between the helmet trajectories for the baseline case and for the protective device case over the evaluation time interval defined in 4.1.2.

#### 5.9.2.2 Percentage change in helmet velocity at helmet impact

Calculate the percentage change of the resultant helmet velocity at first helmet/OV contact, from the baseline case to the protective device case over the evaluation time interval defined in 4.1.2.

### 5.9.3 Distributions of injury assessment variables, change in head injury potential, and injury indices

Using the tabulation described in Tables 10 and 11, plot the cumulative distribution function of the change due to the protective device for each injury assessment variable, change in head injury potential, and injury index, as follows:

- for a given injury assessment variable, change in head injury potential, or injury index, rank order the changes due to the protective device from the most negative to the most positive element, across the total number of impact configurations;
- for each impact configuration, list the frequency of occurrence ($FO$) using Table B.1 of ISO 13232-2;
- for each element, sum the $FO$ up to and including the $FO$ for that element, to determine the cumulative $FO$ for each element;
- for each element, divide the cumulative $FO$ by the total cumulative $FO$ to determine the cumulative distribution function;
- graph the cumulative distribution function with the values of the change, column 5 in Table 10, along the abscissa and the cumulative distribution function, column 6, along the ordinate.

### 5.9.4 Risk/benefit calculations

For each injury assessment variable, each body region's incremental normalized injury cost, and $IC_{norm}$ calculate the following, according to 5.9.4.1 to 5.9.4.4:

- the percentage of accidents which are beneficial, which indicate no effect, and which are harmful,
- the average benefit and average risk per accident,
- the risk/benefit percentage,
- the average net benefit per accident,
- the average benefit per beneficial case, and
- the average risk per harmful case.

Compare the resulting values for $IC_{norm}$ to the reference values given in Annex E.

#### 5.9.4.1 Percentages beneficial, no effect and harmful

For each of the cumulative distribution functions plotted in 5.9.3, calculate the:

- per cent of impacts having a negative change in the given cumulative distribution function. Designate this percentage as "beneficial";

— per cent of impacts having zero change in the given cumulative distribution function. Designate this percentage as "no effect";

— per cent of impacts having a positive change in the given cumulative distribution function. Designate this percentage as "harmful".

**Table 11 — Example table used to calculate the weighted cumulative distribution of change in maximum head acceleration due to a protective device**

Injury assessment variable, change in head injury potential, or injury index: Maximum head acceleration

| Rank order | Impact configuration | | | FO from Table B.1, ISO 13232-2 | Cumulative *FO* | Change due to protective device *g* | Cumulative distribution function |
|---|---|---|---|---|---|---|---|
| | Code | OV speed | MC speed | | | | |
| 1 | 413 | 0 | 13,4 | 5 | 5 | -212 | 0,01 |
| 2 | 115 | 6,7 | 6,7 | 4 | 9 | -208 | 0,02 |
| 3 | 314 | 6,7 | 13,4 | 6 | 15 | -189 | 0,03 |
| . | . | . | . | . | . | . | . |
| . | . | . | . | . | . | . | . |
| . | . | . | . | . | . | . | . |
| 198 | 313 | 0 | 9,8 | 2 | 489 | 153 | 0,98 |
| 199 | 711 | 0 | 9,8 | 2 | 491 | 192 | 0,98 |
| 200 | 414 | 0 | 13,4 | 10 | 501 | 247 | 1,0 |

#### 5.9.4.2 Average risk/benefit percentage

Across all impact configurations or events, calculate the average risk/benefit percentage for each injury assessment variable, each body region's incremental normalized injury cost, and $IC_{norm}$ as follows:

$$\text{average benefit } j = \text{ average decrease in injury index } j = \frac{1}{N}\sum_{\ell=1}^{N_{ben}}\left(-\Delta x_{l,j} \times FO_{\ell}\right)$$

$$\text{average risk } j = \text{ average increase in injury index } j = \frac{1}{N}\sum_{k-1}^{N_{risk}}\left(-\Delta x_{k,j} \times FO_{k}\right)$$

$$\text{risk/benefit percentage } j = \frac{\text{average risk}_j}{\text{average benefit}_j} \text{ x } 100\%$$

where

$N_{ben}$ is the number of configurations in which the protective device was beneficial (i.e., resulted in a decrease in the injury index value) for a given injury index;

$N_{risk}$ is the number of configurations in which the protective device is harmful (i.e., resulted in an increase in the injury index value) for a given injury index;

$\Delta x$ is the change in injury index value (protective device - baseline);

$P$ is the subscript for each impact configuration in which there was a decrease in the injury index value;

$k$ is the subscript for each impact configuration in which there was an increase in the injury index value;

$N$ is the total number of accidents;

EXAMPLE For MC/OV impacts, ISO 13232-2 indicates N=501.

$j$ is the subscript for each injury index or injury assessment value;

$FO$ is the frequency of occurrence of a given impact configuration or event in accidents, based on ISO 13232-2, Table B.1 for impact configurations.

#### 5.9.4.3 Average net benefit

Across all configurations or events, calculate the average net benefit for each injury assessment variable, each component normalized injury cost, and $IC_{norm}$ as follows:

$$\text{average net benefit}_j = \text{average benefit}_j - \text{average risk}_j$$

#### 5.9.4.4 Average benefit per beneficial case and average risk per harmful case

Across all configurations or events, calculate the average benefit per beneficial case and average risk per harmful case for each injury assessment variable, each component normalized injury cost, and $IC_{norm}$ as follows:

$$\text{average benefit per beneficial case}_j = \frac{N}{N_{ben}} \times \text{average benefit}_j$$

$$\text{average risk per harmful case}_j = \frac{N}{N_{risk}} \times \text{average risk}_j$$

## 6 Documentation

All injury assessment variables, injury potential variables, injury severity probabilities, and injury indices shall be documented for each of the national cost databases included in Annex A in accordance with ISO 13232-8. The results of any risk/benefit analysis shall be documented in accordance with Annex C of ISO 13232-8.

# Annex A
(normative)

# Injury costs

Use the tables in Annex A to determine the medical and ancillary costs for each body region and AIS injury severity level when calculating the overall costs in 5.5.1 and 5.5.2, respectively.

Tables A.1 and A.2 list respective medical and ancillary costs in 1988 U.S. dollars.

NOTE At the time of preparation of ISO 13232, the only cost data available were those of the USA, which are given below.

**Table A.1 — Medical costs**

| Body region | AIS injury severity level | Cost |
|---|---|---|
| Head | 1 | $ 784 |
| Head | 2 | 3 807 |
| Head | 3 | 14 169 |
| Head | 4 | 72 349 |
| Head | 5 | 263 306 |
| Neck | 3 | $ 20 509 |
| Neck | 4 | 440 037 |
| Neck | 5 | 530 695 |
| Thorax | 1 | $ 696 |
| Thorax | 2 | 3 410 |
| Thorax | 3 | 10 147 |
| Thorax | 4 | 19 577 |
| Thorax | 5 | 32 790 |
| Abdomen | 1 | $ 696 |
| Abdomen | 2 | 3 410 |
| Abdomen | 3 | 10 147 |
| Abdomen | 4 | 19 577 |
| Lower extremities | 2 | $ 7 881 |
| Lower extremities | 3 | 22 732 |

**Table A.2 — Ancillary costs**

| Body region | AIS injury severity level | PPI | Cost |
|---|---|---|---|
| Head | 1 | - | $ 2 664 |
| Head | 2 | - | 10 818 |
| Head | 3 | - | 47 819 |
| Head | 4 | - | 91 497 |
| Head | 5 | - | 320 571 |
| Neck | 3 | - | $ 76 267 |
| Neck | 4 | - | 391 007 |
| Neck | 5 | - | 463 314 |
| Thorax | 1 | - | $ 1 372 |
| Thorax | 2 | - | 10 886 |
| Thorax | 3 | - | 31 051 |
| Thorax | 4 | - | 46 853 |
| Thorax | 5 | - | 64 256 |
| Abdomen | 1 | - | $ 1 372 |
| Abdomen | 2 | - | 10 886 |
| Abdomen | 3 | - | 31 051 |
| Abdomen | 4 | - | 46 853 |
| Lower extremities | - | 07 | $ 27 370 |
| Lower extremities | - | 15 | 58 650 |
| Lower extremities | - | 22 | 86 020 |
| Lower extremities | - | 27 | 105 570 |
| Lower extremities | - | 38 | 148 580 |
| NOTE The cost of fatality is $596 580 in 1988 U.S. dollars. | | | |

# Annex B
(normative)

# Mortality rate

Use Table B.1 to determine the mortality rate for each combination of the three largest of five AIS injury severity levels, one for each body region. Use the mortality rates to calculate the probability of fatality due to non-AIS 6 injuries, as described in 5.6.2.

**Table B.1 — Mortality rates for all AIS combinations**

| Largest 3 AIS severity levels | Mortality rate<br>% |
|---|---|
| 0 0 0 | 0 |
| 1 0 0 | 0,1502 |
| 1 1 0 | 0,3481 |
| 1 1 1 | 0,8068 |
| 2 0 0 | 0,9379 |
| 2 1 0 | 1,2140 |
| 2 1 1 | 1,5713 |
| 2 2 0 | 2,0339 |
| 2 2 1 | 2,6327 |
| 2 2 2 | 3,4077 |
| 3 0 0 | 1,8198 |
| 3 1 0 | 2,0789 |
| 3 1 1 | 2,3750 |
| 3 2 0 | 2,7133 |
| 3 2 1 | 3,0997 |
| 3 2 2 | 3,5412 |
| 3 3 0 | 4,0456 |
| 3 3 1 | 4,6218 |
| 3 3 2 | 5,2800 |
| 3 3 3 | 6,0320 |
| 4 0 0 | 9,1459 |
| 4 1 0 | 10,3025 |
| 4 1 1 | 11,6052 |
| 4 2 0 | 13,0727 |
| 4 2 1 | 14,7258 |
| 4 2 2 | 16,5879 |
| 4 3 0 | 18,6855 |
| 4 3 1 | 21,0483 |
| 4 3 2 | 23,7099 |
| 4 3 3 | 26,7080 |
| 4 4 0 | 30,0853 |
| 4 4 1 | 33,8896 |
| 4 4 2 | 38,1750 |
| 4 4 3 | 43,0022 |
| 4 4 4 | 48,4399 |
| 5 0 0 | 24,5181 |
| 5 1 0 | 25,8821 |
| 5 1 1 | 27,3220 |
| 5 2 0 | 28,8420 |
| 5 2 1 | 30,4465 |
| 5 2 2 | 32,1403 |
| 5 3 0 | 33,9283 |
| 5 3 1 | 35,8158 |
| 5 3 2 | 37,8083 |
| 5 3 3 | 39,9117 |
| 5 4 0 | 42,1321 |
| 5 4 1 | 44,4759 |
| 5 4 2 | 46,9502 |
| 5 4 3 | 49,5622 |
| 5 4 4 | 52,3194 |
| 5 5 0 | 55,2300 |
| 5 5 1 | 58,0236 |
| 5 5 2 | 61,5461 |
| 5 5 3 | 64,9700 |
| 5 5 4 | 68,5844 |
| 5 5 5 | 72,3999 |
| 6 - - | 100,0000 |

# Annex C
(informative)

# ICM Variable and subscript definitions

The tables given in Annex C define the variables (Table C.1) and subscripts (Tables C.2 and C.3) used in ISO 13232-5.

**Table C.1 — Variable definitions**

| Variable | Definition |
|---|---|
| $PAIS_{i,j}$ | Probable AIS of severity level $j$ for a given body region $i$. |
| $ISP_{i,j}$ | Injury severity probability of an AIS injury severity level $j$ for a given body region $i$. |
| $P_{i,j}$ | Probability of sustaining a discrete injury of a specific AIS level $j$ to a specific body region $i$. |
| $V_{x,h}$ | Helmet centroid point velocity (in the x direction). |
| $a_{x,H}$ | Head linear acceleration (in the x direction). |
| $\alpha_{x,H}$ | Head angular acceleration (in the x direction). |
| $G$ | GAMBIT |
| $HIC$ | Head injury criterion. |
| $D_{us}$, $D_{ls}$ | Upper and lower sternum deflection. |
| $C_{us}$, $C_{ls}$ | Upper and lower sternum compression (normalized). |
| $\Delta l_{uL}$, $\Delta l_{uR}$ | Chest potentiometer displacements, upper left and right. |
| $\Delta l_{lL}$, $\Delta l_{lR}$ | Chest potentiometer displacements, lower left and right. |
| $p_A$ | Abdominal penetration. |
| $N_{i,j}$ | Number of injuries to the body region i of the AIS injury severity level $j$. |
| $PPI$<br>$NII$ | Permanent partial incapacity index.<br>Neck injury index. |
| | Ancillary costs: |
| $AC_{i,j}$ | — to the body region i of the AIS injury severity level $j$; |
| $AC_{i,tot}$ | — the total for body region $i$; |
| $AC$ | — overall. |
| | Medical costs: |
| $MDC_{i,j}$ | — to the body region $i$ of the AIS injury severity level $j$; |
| $MDC_{i,tot}$ | — the total for body region $i$; |
| $MDC$ | — overall. |

| Variable | Definition |
|---|---|
| $IC_{norm}$ | Injury cost, normalized. |
| $CS_{norm}$ | Cost of survival, normalized. |
| $CF_{norm}$ | Cost of fatality, normalized. |
| $P_{fatal,5}$ | Probability of fatality due to all possible combinations of injuries with AIS injury severity level < 6. |
| $P_{fatal,6}$ | Probability of fatality due to an injury of AIS injury severity level 6. |
| $P_{fatal}$ | Overall probability of fatality. |
| $V_{us}$, $V_{ls}$ | Upper and lower sternum velocity. |
| $VC_{us}$, $VC_{ls}$ | Upper and lower sternum velocity - compression. |
| $MR$ | Mortality rate. |

**Table C.2 — Body region subscript definition**

| Subscript | Body region |
|---|---|
| *A* | abdomen |
| *C* | thoracic compression |
| *F* | femur |
| *H* | head |
| *K* | knee |
| *lE* | lower extremities |
| *us* | upper sternum |
| *ls* | lower sternum |
| *n* | neck |
| *T* | tibia |
| *Th* | thorax |
| *VC* | thoracic velocity-compression |

**Table C.3 — Other subscripts**

| Subscript | Definition | Subscript | Definition |
|---|---|---|---|
| *comp* | compression | No subscript | overall |
| *ext* | extension | *peak* | peak value |
| *fatal* | fatality | *R* | right |
| *fc* | first contact | *r* | resultant |
| *flex* | flexion | *shear* | shear |
| *h* | helmet | *tens* | tension |
| *i* | index for body region | *tors* | torsion |
| *j* | AIS injury severity level | *tot* | total |

| Subscript | Definition | Subscript | Definition |
|---|---|---|---|
| $L$ | left | $uL$, $uR$, | upper left, upper right, |
| $max$ | maximum value | $lL$, $lR$ | lower left, lower right |
| $min$ | minimum value | $x$, $y$, $z$ | $x$, $y$, $z$ direction |
| $norm$ | normalized | $xy$, $yz$, $xz$, $xyz$ | resultant of two or three axes |

# Annex D
(informative)

# Example computer code of the injury cost model

An example computer code is given, which evaluates the injury cost model for the data given in Annex D of ISO 13232-2. The generated output is similar to that presented in Annex F of this part of ISO 13232. The code is written in FORTRAN-77. Figure D.1 shows a flow diagram of the computation.

```
c...+....1....+....2....+....3....+....4....+....5....+....6....+....7....+....8

      program ricm

c******************************************************************************
c
c    name
c
c      ricm - Execute the Injury Cost Model subroutine and print out
c             the results
c
c    description
c
c      This program prompts the user for Injury Cost Model input values
c      and then calls the analysis subroutine icm and prints out the
c      results.
c
c    version history
c
c      - original version by RMV, DRI, April 1993
c      - first revision by RMV, DRI, March 1993
c         - added prompted inputs for both upper and lower sternum Cmax
c           and VCmax
c         - changed model and subroutine name from Injury Cost Model II
c           (icm2) to Injury Cost Model (icm)
c         - changed subroutine name from wricm2 to wricm
c         - minor output unit and format changes
c         - minor comment changes
c      - second revision by RMV, DRI, August 1994
c         - PPI output added
c         - Risk of life threatening brain injury based on HIC added
c      - include HIC ISP for head AIS, revision by DPC, DRI, March 1998
c      - fourth revision by SM, May 2001 (taken from RHO and EPM)
c         - spaces added between prompt and input
c         - pager added to output
c         - write to file option added with test number prompt
c         - prompt user for output file name
c         - use included make file(Makefile) to compile
c      - fifth revision by SM, May 2001
c         - added neck injury criteria
c      - sixth revision by KDW, DRI, February 2002
c           -added new neck ISPn equation coefficients
c
c******************************************************************************
c
```

```
c     program parameters
c
      integer stdout
      parameter (stdout=6)
c
c     program variables
c
      integer nidatin, nrdatin, ndatout
      parameter (nidatin=5, nrdatin=6, ndatout=10)
      integer Idatin(nidatin), Ierr
      integer Icmax, Ivcmax
      real Rdatin(nrdatin), Table(9,6), Datout(ndatout)
      real Cmax, Cmaxls, Cmaxus, VCmax, VCmaxls, VCmaxus
      character*50 sidatin(nidatin), srdatin(nrdatin), sdatout(ndatout)
      character*13 sloc(2)
      character*20 aformat
      character  tnumstr*12,hline*60, overwrite*1, wnum*1
      character wdesc*10,tnum*12,tfile*50
      integer cnt,  fdout
c
c     program data
c

      data tnumstr/'File Name'/

      data sidatin/'Number of AIS 3 Femur Fractures',
     &            'Number of AIS 2 Tibia Fractures',
     &            'Number of AIS 3 Tibia Fractures',
     &            'Number of AIS 2 Knee Dislocation Injuries',
     &            'Number of AIS 3 Knee Dislocation Injuries'/
      data srdatin/'maximum Abdomen Penetration',
     &            'maximum GAMBIT',
     &            'Cmax',
     &            'VCmax',
     &            'HIC',
     &            'NII (2001 MATD Neck)'/
      data sdatout/'MAIS',
     &            'Total AIS',
     &            'Normalized Injury Cost',
     &            'Normalized Cost of Survival',
     &            'Normalized Cost of Dying',
     &            'Probability of Fatality',
     &            'Probability of Fatality due to non AIS 6 injuries',
     &            'Probability of Fatality due AIS 6 injuries',
     &            'Permanent Partial Incapacity',
     &            'Risk of life threatening brain injury (%)'/
      data sloc/'upper sternum','lower sternum'/
c
c******************************************************************************
c
c       write(stdout,*) 'Injury Cost Model - RICM (HIC ISP version)'
c
c     prompt the user for test name to be used in filename construction
c
      do cnt = 1,60
        hline(cnt:cnt) = char(45)
      end do
      write(stdout,101) hline
      write(stdout,101)
     *  'Injury Cost Model - RICM (HIC ISP version)'
```

```
c    *  '  Injury Cost Model Program        (version 3.0)'
      write(stdout,101) hline
  10  write(stdout,*)
      write(stdout,101)
     *  'Enter file name (8 characters maximum) to generate output file'
      write(stdout,101)
     *  'or Enter 0 for screen display only.'
      write(stdout,*)
      call aaccept('Enter '//tnumstr,tnum)
        if (lenstr(tnum).gt.8) then
        write(stdout,*)
     *  'Too many characters.'
        write(stdout,101)
        goto 10
       end if
c******************
c     prompt the window number if output file is to be made
c
      if (tnum.ne.'0') then
 15      write(*,101)
         write(stdout,101)
     *      'Enter analysis window <1,2> or <e> for entire run:  '
         call cread(wnum,1)
         if ( (wnum .eq. '1') .or. (wnum .eq. '2') ) then
            wdesc = wnum//'         '

         else if ( (wnum .eq. 'e') .or. (wnum .eq. 'E') ) then
            wnum(1:1) = 'E'
            wdesc = 'Entire Run'
         else
            write(stdout,*)
            write(stdout,101) 'That is not a valid window choice'
            goto 15
         end if

c
c     construct output file name and check to see if it already exists
c
        tfile= tnum
        write(aformat,'(a,i4,a)')'(a',lenstr(tnum),',a,a)'
        write(tfile,aformat) tnum,'.IC',wnum
        open(fdout, file = tfile, err = 900, status = 'new')
      end if
 120  continue
      write(stdout,*)
c
c
c     prompt the user for Injury Cost Model inputs other than Cmax and VCmax
c
      do k=1,nidatin
        Idatin(k) = iaccept('Enter '//sidatin(k))
      end do
      do k=1,2
        Rdatin(k) = raccept('Enter '//srdatin(k))
      end do
c
c     prompt the user for Cmax and VCmax values for the upper and lower
c     sternum
c
      Cmaxus = raccept('Enter Cmax for upper sternum')
```

```
      Cmaxls = raccept('Enter Cmax for lower sternum')
      VCmaxus = raccept('Enter VCmax for upper sternum')
      VCmaxls = raccept('Enter VCmax for lower sternum')

      Rdatin(5) = raccept('Enter '//srdatin(5))
      Rdatin(6) = raccept('Enter '//srdatin(6))
c
c      determine the larger Cmax value and location
c
      if(Cmaxus.gt.Cmaxls) then
        Cmax = Cmaxus
        Icmax = 1
      else
        Cmax = Cmaxls
        Icmax = 2
      end if
      Rdatin(3) = Cmax
c
c      determine the larger VCmax value and location
c
      if(VCmaxus.gt.VCmaxls) then
        VCmax = VCmaxus
        Ivcmax = 1
      else
        VCmax = VCmaxls
        Ivcmax = 2
      end if
      Rdatin(4) = VCmax
c
c      call the Injury Cost Model
c
      call icm(Idatin,Rdatin,Table,Datout,Ierr)

      if(Ierr.eq.0) then
c
c        write out model inputs and output to screen
c
        write(stdout,*)
        write(stdout,*)
        write(stdout,101) 'Injury Cost Model input:'
        write(stdout,*)
        write(stdout,*)

        do k=1,nidatin
          write(stdout,102) sidatin(k),idatin(k)
        end do
        do k=1,nrdatin
          if(k.ge.5) then
            write(stdout,105) srdatin(k),rdatin(k)
          else
            write(stdout,103) srdatin(k),rdatin(k)
          end if
        end do
        write(stdout,104) 'Location of Cmax ',sloc(Icmax)
        write(stdout,104) 'Location of VCmax',sloc(Ivcmax)
        write(stdout,*)
        write(stdout,*)
        write(stdout,*)
        write(stdout,*)
        write(stdout,*)
```

```
      write(stdout,*)

      pause

      write(stdout,*)
      write(stdout,101) 'Injury Cost Model output:'
      write(stdout,*)
      write(stdout,*)
      do k=1,ndatout
        if( (k.eq.1) .or. (k.eq.2) .or. (k.eq.10) ) then
          write(stdout,105) sdatout(k),datout(k)
        else
          write(stdout,103) sdatout(k),datout(k)
        end if
      end do
      write(stdout,*)
      write(stdout,*)
      write(stdout,*)
      write(stdout,*)
      write(stdout,*)
      write(stdout,*)
      write(stdout,*)
      write(stdout,*)

      pause

      write(stdout,*)
      write(stdout,101) 'Injury Probability by Body Region Table:'
      write(stdout,*)

c
c      write out Table 1
c
      write(stdout,*)
      call wricm(stdout,Table)

c*******************
c      write out model inputs and output to file if needed
c



           write(fdout,'(a, 2x, a)') 'Test Name     :',tnum

        write(fdout,'(a, 2x, a)') 'Analysis Window :',wdesc
        write(fdout,*)
        write(fdout,*)

        write(fdout,101) 'Injury Cost Model input:'
        write(fdout,*)
        write(fdout,*)

        do k=1,nidatin
          write(fdout,102) sidatin(k),idatin(k)
        end do
        do k=1,nrdatin
          if(k.ge.5) then
            write(fdout,105) srdatin(k),rdatin(k)
          else
            write(fdout,103) srdatin(k),rdatin(k)
```

```
          end if
        end do
        write(fdout,104) 'Location of Cmax ',sloc(Icmax)
        write(fdout,104) 'Location of VCmax',sloc(Ivcmax)
        write(fdout,*)
        write(fdout,*)
        write(fdout,101) 'Injury Cost Model output:'
        write(fdout,*)
        write(fdout,*)
        do k=1,ndatout
          if( (k.eq.1) .or. (k.eq.2) .or. (k.eq.10) ) then
            write(fdout,105) sdatout(k),datout(k)
          else
            write(fdout,103) sdatout(k),datout(k)
          end if
        end do
        write(fdout,*)
        write(fdout,*)
        write(fdout,101) 'Injury Probability by Body Region Table:'
        write(fdout,*)
c
c       write out Table 1
c
        write(fdout,*)
        call wricm(fdout,Table)

        close(fdout)

      else

        write(stdout,*) 'ICM subroutine error #',Ierr

          close(fdout)


      end if
c
c     done
c
      stop

c
c     output file error stuff
c
 900  write(stdout,*)
      write(stdout,101)
     *  '  File exists'
      write(stdout,101) '  Overwrite current file? (y/n)   '
      call cread(overwrite,1)
      if (overwrite .eq. 'y' .or. overwrite .eq. 'Y') then
        open(fdout, file = tfile, err = 901, status = 'old')
      else
        goto 10
      end if
      goto 120

 901  write(stdout,*) 'Error opening file - Exiting'
      stop
```

```
c
c     format statements
c
  101 format(1x,a)
  102 format(3x,a50,' = ',i4)
  103 format(3x,a50,' = ',f8.3)
  104 format(3x,a17,33x,' : ',a)
  105 format(3x,a50,' = ',f6.1)

      end

c...+....1....+....2....+....3....+....4....+....5....+....6....+....7....+....8
c...+....1....+....2....+....3....+....4....+....5....+....6....+....7....+....8

      integer function iaccept(prompt)
      character*(*) prompt
c
c     this function prompts the user for integer valued input
c
      integer stdout, stdin
      parameter (stdout=6, stdin=5)

      write(stdout,101) prompt(:lenstr(prompt))//':  '
      read(stdin,*) iaccept
      return

  101 format(1x,a,1x,$)

      end

c...+....1....+....2....+....3....+....4....+....5....+....6....+....7....+....8
c...+....1....+....2....+....3....+....4....+....5....+....6....+....7....+....8

      subroutine aaccept(prompt,aval)
      character*(*) prompt
      character*50 aval
c
c     this function prompts the user for character  input
c
      integer stdout, stdin
      parameter (stdout=6, stdin=5)

      write(stdout,101) prompt(:lenstr(prompt))//':  '
      read(stdin,'(a)') aval
      return

  101 format(1x,a,1x,$)

      end

c...+....1....+....2....+....3....+....4....+....5....+....6....+....7....+....8
c...+....1....+....2....+....3....+....4....+....5....+....6....+....7....+....8

      real function raccept(prompt)
      character*(*) prompt
c
c     this function prompts the user for real valued input
c
      integer stdout, stdin
      parameter (stdout=6, stdin=5)
```

```
      write(stdout,101) prompt(:lenstr(prompt))//':  '
      read(stdin,*) raccept
      return

  101 format(1x,a,1x,$)

      end

c...+....1....+....2....+....3....+....4....+....5....+....6....+....7....+....8
c...+....1....+....2....+....3....+....4....+....5....+....6....+....7....+....8

      integer function lenstr(string)
      character*(*) string
c
c     this function find the length of a string with trailing blanks
c     removed
c
      do lenstr=len(string),1,-1
        if(string(lenstr:lenstr).ne.' ') return
      end do
      return

      end

c...+....1....+....2....+....3....+....4....+....5....+....6....+....7....+....8
c...+....1....+....2....+....3....+....4....+....5....+....6....+....7....+....8

      subroutine icm(Idatin,Rdatin,Table,Datout,Ierr)
      integer Idatin(5), Ierr
      real Rdatin(6), Table(9,6), Datout(10)

c*******************************************************************************
c
c     name
c
c       icm - Evaluate the Injury Cost Model
c
c     description
c
c       This subroutine evaluates the Injury Cost Model for the inputs
c       in arrays Idatin and Rdatin.  Output is returned in arrays Table
c       and Datout.
c
c     calling sequence
c
c       argument  i/o  description
c       --------  ---  -----------
c       Idatin     i   integer data input array, elements as follows:
c                      element  symbol  description
c                      -------  ------  -----------
c                         1      FF3    number of AIS 3 femur fractures
c                         2      TF2    number of AIS 2 tibia fractures
c                         3      TF3    number of AIS 3 tibia fractures
c                         4      KDI2   number of AIS 2 knee dislocated
c                                       injuries
c                         5      KDI3   number of AIS 3 knee dislocated
c                                       injuries
c
c       Rdatin     i   real data input array, elements as follows:
```

```
c                 element  symbol  units  description
c                 -------  ------  -----  -----------
c                   1     AP      mm    maximum abdomen
c                                       penetration
c                   2     Gmax     -    maximum GAMBIT
c                   3     Cmax     %    maximum normalized chest
c                                       compression
c                   4     VCmax   m/s   maximum chest viscous
c                                       criteria when V>3 m/s
c                   5     HIC      -    Head Injury Criteria
c                   6     NII      -    Neck Injury Index
c
c     Table      o   table 1 values
c
c     Datout     o   real data output array, elements as follows:
c                 element  symbol  units  description
c                 -------  ------  -----  -----------
c                   1     MAIS          maximum AIS
c                   2     TAIS          total AIS
c                   3     NIC      -    Normalized Injury Cost
c                   4     NCOS     -    Normalized Cost of
c                                       Survival
c                   5     NCOD     -    Normalized Cost of Dying
c                   6     POF      -    Probability of Fatality
c                   7     POF5     -    POF due to non AIS 6
c                                       injuries
c                   8     POF6     -    POF due to AIS 6 injuries
c                   9     PPI      -    Permanent Partial
c                                       Incapacity
c                  10     Prisk    %    Risk of life threatening
c                                       brain injury
c
c     Ierr       o   error code
c                    0   - normal return
c                   1- 5 - index of out of range Idatin
c                  11-14 - index of out of range Rdatin
c
c    version history
c
c     - original version by RMV, DRI, March 1993
c     - first revision by RMV, DRI, April 1993
c        - AIS 3 knee dislocation injuries added
c        - Input range checking added
c     - second revision by RMV, DRI, March 1994
c        - changed model and subroutine name from Injury Cost Model II
c          (icm2) to Injury Cost Model (icm)
c        - changed hospital cost (HC) to medical cost (MDC)
c        - changed parameter names from AISmax to AIS6, AISsrv to AIS5
c     - third revision by RMV, DRI, August 1994
c        - added PPI to Datout output array
c        - added risk of life threatening brain injury calculation
c          based on HIC, HIC input was added to Rdatin and Prisk
c          output added to Datout arrays
c     - fourth revision by RMV, DRI, December 1994
c        - Corrected PPI for 1 leg injury
c     - include HIC ISP for to head AIS, revision by DPC, DRI, March 1998
c     - include Neck Injury Criteria, revision by KDW,RMV,SM, DRI, May 2001
c     - sixth revision by KDW, DRI, February 2002
c        - added new neck ISPn equation coefficients
c     - seventh revision by RMV, DRI, June 2004
```

```
c            - revised new neck ISPn equation coefficents
c
c*****************************************************************************
c
c    local parameters
c
c    AIS6 - fatal AIS
c    AIS5 - maximum survivable AIS
c
      integer AIS6, AIS5, jhic
      parameter (AIS6=6, AIS5=5, jhic=15)
c
c    local variables
c
      real Beta1(AIS6), Gamma1(AIS6), Eta1(AIS6)
      real Beta2(AIS6), Gamma2(AIS6), Eta2(AIS6)
      real Gamma3(AIS6)
       real Gamma5(AIS6)
        real Gamma6(AIS6),Eta6(AIS6)
      real Alpha4(AIS6), Beta4(AIS6)
      integer FF3, KDI2, KDI3, TF2, TF3
      integer i, itmp, j, kais(5), kais1, kais2, kais3, kais4, kais5
      integer krow, nLAIS2, nLAIS3, ntot
      real AP, Cmax, Gmax, VCmax
      real AAC(AIS5), AACT, AAIS(0:AIS6), AMDC(AIS5), AMDCT
      real AISP(AIS6)
      real CAC(AIS5), CACT, CAIS(0:AIS6), CMDC(AIS5), CMDCT
      real CISP(AIS6)
      real HAC(AIS5), HACT, HAIS(0:AIS6), HMDC(AIS5), HMDCT
      real HISP(AIS6)
       real HGISP(AIS6), HHICISP(AIS6)
      real LAC07, LAC15, LAC22, LAC27, LAC38
      real LACT, LAIS(0:AIS6), LMDC(AIS5), LMDCT
      real NAC(AIS5), NACT, NAIS(0:AIS6), NMDC(AIS5), NMDCT
      real NISP(AIS6)
      real MR(0:AIS5,0:AIS5,0:AIS5)
      real AC, CCISP, CVCISP, MDC, POF, POF5, POF6, PPI
      real APAIS, CPAIS, HPAIS, LPAIS, NPAIS
      integer IAPAIS, ICPAIS, IHPAIS, ILPAIS, INPAIS
      real COF, MAIS, NCOD, NCOS, NIC, TAIS
      real curve(2,jhic), HIC, Prisk, NII
c
c    ****************************************************************
c    ***                                                          ***
c    ***  data                                                    ***
c    ***                                                          ***
c    ****************************************************************
c
c    Injury Severity Probability function coefficients
c
      data Gamma1/0.0,0.125,0.375,0.438,0.650,0.680/
      data Eta1/0.755,0.70,0.64,0.62,0.54,0.60/
      data Beta1/3.5,3.5,3.5,3.5,2.2,1.8/
      data Gamma2/0.0,0.0,0.0,0.4,1.0,1.5/
      data Eta2/0.3,0.68,1.40,1.291,0.995,0.78/
      data Beta2/0.99,1.46,2.85,3.10,3.10,3.10/
      data Gamma3/1.77,7.47,13.22,18.97,24.72,32.52/
      data Alpha4/0.0157,0.0123,0.000155,9.36e-13,0.0,0.0/
      data Beta4/1.0,1.0,2.0,6.5,1.0,1.0/
      data Gamma5/0.0,0.0,0.0,450.0,450.0,450.0/
```

```
      data Gamma6/1.06,1.86,2.29,4.73,4.73,6.13/
      data Eta6/4.38,4.38,4.38,4.38,4.38,4.38/
c
c     Medical Cost data in U.S. Dollars
c
      data HMDC/   784.,  3807., 14169., 72349.,263306./
      data CMDC/   696.,  3410., 10147., 19577., 32790./
      data AMDC/   696.,  3410., 10147., 19577., 32790./
      data LMDC/     0.,  7881., 22732.,     0.,     0./
      data NMDC/     0.,     0., 20590.,440037.,530695./
c
c     Ancillary Cost data in U.S. Dollars
c
      data HAC/  2664., 10818., 47819., 91497.,320571./
      data CAC/  1372., 10886., 31051., 46853., 64256./
      data AAC/  1372., 10886., 31051., 46853., 64256./
      data LAC07/27370./, LAC15/58650./, LAC22/86020./, LAC27/105570./
      data LAC38/148580./
      data NAC/     0.,     0., 76267.,391007.,463314./
c
c     Mortality Rate data
c
      data (((MR(kais1,kais2,kais3),
     &                   kais3=0,kais2),kais2=0,kais1),kais1=0,AIS5)/
     &     0.0000,  0.1502,  0.3481,  0.8068,  0.9379,  1.2140,  1.5713,
     &     2.0339,  2.6327,  3.4077,  1.8198,  2.0789,  2.3750,  2.7133,
     &     3.0997,  3.5412,  4.0456,  4.6218,  5.2800,  6.0320,  9.1459,
     &    10.3025, 11.6052, 13.0727, 14.7258, 16.5879, 18.6855, 21.0483,
     &    23.7099, 26.7080, 30.0853, 33.8896, 38.1750, 43.0022, 48.4399,
     &    24.5181, 25.8821, 27.3220, 28.8420, 30.4465, 32.1403, 33.9283,
     &    35.8158, 37.8083, 39.9117, 42.1321, 44.4759, 46.9502, 49.5622,
     &    52.3194, 55.2300, 58.0236, 61.5461, 64.9700, 68.5844, 72.3999/
c
c     Cost of Fatality in U.S. Dollars
c
      data COF/596580./
c
c     Risk of life threatening brain injury vs HIC data
c
      data curve/  430.0,  1.0,
     &             550.0,  2.0,
     &             730.0,  5.0,
     &             890.0, 10.0,
     &            1080.0, 20.0,
     &            1220.0, 30.0,
     &            1340.0, 40.0,
     &            1450.0, 50.0,
     &            1560.0, 60.0,
     &            1680.0, 70.0,
     &            1820.0, 80.0,
     &            2010.0, 90.0,
     &            2170.0, 95.0,
     &            2350.0, 98.0,
     &            2470.0, 99.0/
c
c*******************************************************************************
c
c     *******************************************************************
c     ***                                                             ***
c     ***  Extract input data from input arrays                       ***
```

```
c     ***                                                  ***
c     ****************************************************************
c
      FF3   = Idatin(1)
      TF2   = Idatin(2)
      TF3   = Idatin(3)
      KDI2  = Idatin(4)
      KDI3  = Idatin(5)

      AP    = Rdatin(1)
      Gmax  = Rdatin(2)
      Cmax  = Rdatin(3)
      VCmax = Rdatin(4)
      HIC   = Rdatin(5)
      NII   = Rdatin(6)
c
c     check inputs for allowable ranges
c
      do 2 i=1,5
        if( (Idatin(i).lt.0) .or. (Idatin(i).gt.2) ) then
          Ierr = i
          return
        end if
    2 continue
      do 5 i=1,6
        if( (Rdatin(i).lt.0.0) ) then
          Ierr = 10+i
          return
        end if
    5 continue
c
c     ****************************************************************
c     ***                                                  ***
c     ***  Calculate injury severity probabilities (ISP) for head,   ***
c     ***  neck, chest, and abdomen                               ***
c     ***                                                  ***
c     ****************************************************************
c
c
c     begin loop through injury severity levels
c
      do 10 kais1=1,AIS6
c
c       calculate the head injury severity probability (ISP) based on
c       Gmax
c
        if(Gmax.ge.Gamma1(kais1)) then
          HGISP(kais1) =
     &      1.0-exp(-(((Gmax-Gamma1(kais1))/Eta1(kais1))**Beta1(kais1)))
        else
          HGISP(kais1) = 0.0
        end if
c
c       calculate the chest ISP based on VCmax
c
        if(VCmax.ge.Gamma2(kais1)) then
          CVCISP =
     &     1.0-exp(-(((VCmax-Gamma2(kais1))/Eta2(kais1))**Beta2(kais1)))
        else
          CVCISP = 0.0
```

```
      end if
c
c      calculate the chest ISP based on Cmax
c
      if(Cmax.ge.Gamma3(kais1)) then
        CCISP = 1.0-exp(-(((Cmax-Gamma3(kais1))/24.0)**6))
      else
        CCISP = 0.0
      end if
c
c      calculate the chest ISP based on the
c      of larger of the probabilities due to VCmax and Cmax
c
      CISP(kais1) = max(CVCISP,CCISP)
c
c      calculate the abdomen ISP based on penetration
c
      AISP(kais1) = Alpha4(kais1)*AP**Beta4(kais1)
c
c      calculate the neck ISP
c
      if(NII.ge.Gamma6(kais1)) then
        NISP(kais1) = 1.0 - exp(-1.0*(((NII-Gamma6(kais1))
     &                              /Eta6(kais1))**3.5))
      else
        NISP(kais1) = 0.0
      endif

   10 continue

c
c    calculate ISP for head using HIC
c
      if(HIC.ge.Gamma5(1)) then
         HHICISP(1) = 1.0-(exp(-((HIC/560.0)**2.98)))
      else
         HHICISP(1) = 0.0
      endif

      if(HIC.gt.Gamma5(3)) then
        HHICISP(3) = 1.0-(exp(-(((HIC+500.0)/1990.0)**4.5)))
      else
        HHICISP(3) = 0.0
      endif

      if(HIC.ge.Gamma5(6)) then
        HHICISP(6) = 1.0-(exp(-(((HIC-450.0)/3275.0)**1.36)))
      else
        HHICISP(6) = 0.0
      endif

      if(HIC.ge.Gamma5(2)) then
        HHICISP(2) = HHICISP(3)+((HHICISP(1)-HHICISP(3))*55.0/123.0)
      else
        HHICISP(2) = 0.0
      endif

      if(HIC.ge.Gamma5(4)) then
        HHICISP(4) = HHICISP(6)+((HHICISP(3)-HHICISP(6))*24.0/41.0)
      else
```

```
          HHICISP(4) = 0.0
        endif

        if(HIC.ge.Gamma5(5)) then
          HHICISP(5) = HHICISP(6)+((HHICISP(3)-HHICISP(6))*14.0/41.0)
        else
          HHICISP(5) = 0.0
        endif
c
c      calculate the maximum head ISP between HIC & Gmaxc
c
        do 12 kais1 = 1,AIS6
           HISP(kais1) = max(HGISP(kais1),HHICISP(kais1))
   12 continue
c
c      ****************************************************************
c      ***                                                         ***
c      ***  Calculate the probability of discrete AIS injuries by     ***
c      ***  body region                                            ***
c      ***                                                         ***
c      ****************************************************************
c
        HAIS(0) = 1.0-HISP(1)
        CAIS(0) = 1.0-CISP(1)
        AAIS(0) = 1.0-AISP(1)
        NAIS(0) = 1.0-NISP(1)
        do 15 kais1=1,AIS5
          HAIS(kais1) = HISP(kais1)-HISP(kais1+1)
          CAIS(kais1) = CISP(kais1)-CISP(kais1+1)
          AAIS(kais1) = AISP(kais1)-AISP(kais1+1)
          NAIS(kais1) = NISP(kais1)-NISP(kais1+1)
   15 continue
        HAIS(AIS6) = HISP(AIS6)
        CAIS(AIS6) = CISP(AIS6)
        AAIS(AIS6) = AISP(AIS6)
        NAIS(AIS6) = NISP(AIS6)
c
c      calculate the leg AIS based on worst AIS injury
c
        do 20 kais1=0,AIS6
          LAIS(kais1) = 0.0
   20 continue
        if( (FF3.ne.0) .or. (TF3.ne.0) .or. (KDI3.ne.0) ) then
          LAIS(3) = 1.0
        else if( (TF2.ne.0) .or. (KDI2.ne.0) ) then
          LAIS(2) = 1.0
        else
          LAIS(0) = 1.0
        end if
c
c      ****************************************************************
c      ***                                                         ***
c      ***  Calculate the maximum lower extremity Permanent Partial   ***
c      ***  Incapacity (PPI) and leg ancillary cost                 ***
c      ***                                                         ***
c      ****************************************************************
c
c      count the number of leg injuries
c
        ntot = FF3 + TF2 + TF3 + KDI2 + KDI3
```

```
      if(ntot.ge.3) then
c
c       three or more leg injuries
c
        PPI = 0.38
        LACT = LAC38

      else if(ntot.eq.2) then
c
c       two leg injuries
c
        PPI = 0.27
        LACT = LAC27

      else if(ntot.eq.1) then

        if(FF3.eq.1) then
c
c         1 AIS 3 femur fracture
c
          PPI = 0.15
          LACT = LAC15

        else if(KDI3.eq.1) then
c
c         1 AIS 3 knee dislocation injury
c
          PPI = 0.22
          LACT = LAC22

        else if(KDI2.eq.1) then
c
c         1 AIS 2 knee dislocation injury
c
          PPI = 0.15
          LACT = LAC15

        else if(TF3.eq.1) then
c
c         1 AIS 3 tibia fracture
c
          PPI = 0.15
          LACT = LAC15

        else if(TF2.eq.1) then
c
c         1 AIS 2 tibia fracture
c
          PPI = 0.07
          LACT = LAC07

        end if

      else
c
c       no leg injuries
c
        PPI = 0.0
        LACT = 0.0
```

```
      end if
c
c     *****************************************************************
c     ***                                                       ***
c     ***  Calculate medical and ancillary costs                 ***
c     ***                                                       ***
c     *****************************************************************
c
      HMDCT = 0.0
      NMDCT = 0.0
      CMDCT = 0.0
      AMDCT = 0.0
      LMDCT = 0.0
      HACT = 0.0
      NACT = 0.0
      CACT = 0.0
      AACT = 0.0
      do 30 kais1=1,AIS5
        HMDCT = HMDCT + HAIS(kais1)*HMDC(kais1)
        NMDCT = NMDCT + NAIS(kais1)*NMDC(kais1)
        CMDCT = CMDCT + CAIS(kais1)*CMDC(kais1)
        AMDCT = AMDCT + AAIS(kais1)*AMDC(kais1)
        LMDCT = LMDCT + LAIS(kais1)*LMDC(kais1)
        HACT = HACT + HAIS(kais1)*HAC(kais1)
        NACT = NACT + NAIS(kais1)*NAC(kais1)
        CACT = CACT + CAIS(kais1)*CAC(kais1)
        AACT = AACT + AAIS(kais1)*AAC(kais1)
   30 continue
      MDC = max(HMDCT,NMDCT,CMDCT,AMDCT,LMDCT)
      AC = max(HACT,NACT,CACT,AACT,LACT)
c
c     *****************************************************************
c     ***                                                       ***
c     ***  probability of fatality (POF)                      ***
c     ***                                                       ***
c     *****************************************************************
c
c     POF due to AIS 6 injuries
c
      POF6 = 1.0 - (1.0-HAIS(6))*(1.0-NAIS(6))*(1.0-CAIS(6))
c
c     POF due to survivable AIS (AIS<6) injuries
c
      POF5 = 0.0
      do 50 kais1=0,AIS5
        do 50 kais2=0,AIS5
          do 50 kais3=0,AIS5
            do 50 kais4=0,AIS5
              do 50 kais5=0,AIS5
c
c              sort kais from largest to smallest
c
              kais(1) = kais1
              kais(2) = kais2
              kais(3) = kais3
              kais(4) = kais4
              kais(5) = kais5
              do 45 i=1,4
                do 45 j=i+1,5
```

```
              if(kais(i).lt.kais(j)) then
                itmp = kais(i)
                kais(i) = kais(j)
                kais(j) = itmp
              end if
  45        continue
c
c           accumulate POF
c
c           the POF increment is probability of ais level combination
c           times the mortality rate based on 3 largest ais levels
c
          POF5 = POF5 + MR(kais(1),kais(2),kais(3))*HAIS(kais1)*
    &              NAIS(kais2)*CAIS(kais3)*AAIS(kais4)*LAIS(kais5)

  50 continue
     POF5 = 0.01*POF5
c
c     overall probability
c
     POF = POF6 + POF5
c
c     *****************************************************************
c     ***                                                 ***
c     ***  Calculate expected AIS                         ***
c     ***                                                 ***
c     *****************************************************************
c
     HPAIS = 0.0
     NPAIS = 0.0
     CPAIS = 0.0
     APAIS = 0.0
     LPAIS = 0.0
     do 55 kais1=1,AIS6
       HPAIS = HPAIS + kais1*HAIS(kais1)
       NPAIS = NPAIS + kais1*NAIS(kais1)
       CPAIS = CPAIS + kais1*CAIS(kais1)
       APAIS = APAIS + kais1*AAIS(kais1)
       LPAIS = LPAIS + kais1*LAIS(kais1)
  55 continue
c
c     round expected AIS to nearest integer
c
     IHPAIS = nint(HPAIS)
     INPAIS = nint(NPAIS)
     ICPAIS = nint(CPAIS)
     IAPAIS = nint(APAIS)
     ILPAIS = nint(LPAIS)
c
c     construct table
c
     do 60 kais1=0,AIS6
       krow = kais1+1
       Table(krow,1) = HAIS(kais1)
       Table(krow,2) = NAIS(kais1)
       Table(krow,3) = CAIS(kais1)
       Table(krow,4) = AAIS(kais1)
       Table(krow,5) = LAIS(kais1)
       Table(krow,6) = 0.0
  60 continue
```

```
      nLAIS2 = TF2 + KDI2
      nLAIS3 = FF3 + TF3 + KDI3
      Table(3,6) = nLAIS2
      Table(4,6) = nLAIS3

      krow = AIS6+2
      Table(krow,1) = HPAIS
      Table(krow,2) = NPAIS
      Table(krow,3) = CPAIS
      Table(krow,4) = APAIS
      Table(krow,5) = LPAIS
      Table(krow,6) = 0.0

      krow = AIS6+3
      Table(krow,1) = IHPAIS
      Table(krow,2) = INPAIS
      Table(krow,3) = ICPAIS
      Table(krow,4) = IAPAIS
      Table(krow,5) = ILPAIS
      Table(krow,6) = 0.0
c
c     calculate maximum AIS
c
      MAIS = max(IHPAIS, INPAIS, ICPAIS, IAPAIS, ILPAIS)
c
c     calculate total AIS
c
      TAIS = IHPAIS + INPAIS + ICPAIS + IAPAIS + 2*nLAIS2 + 3*nLAIS3
c
c     *****************************************************************
c     ***                                                           ***
c     ***  Calculate Normalized Injury Costs                        ***
c     ***                                                           ***
c     *****************************************************************
c
c     Cost of Survival
c
      if((MDC+AC).le.COF) then
        NCOS = ( MDC + AC ) * ( 1.0 - POF ) / COF
      else
        NCOS = (1.0 - POF)
      endif
c
c     Cost of Dying
c
      NCOD = POF
c
c     Total injury cost
c
      NIC = NCOS + NCOD
c
c     *****************************************************************
c     ***                                                           ***
c     ***  Calculate the Risk of Life Threatening Brain Injury      ***
c     ***                                                           ***
c     *****************************************************************
c
      if(HIC.lt.curve(1,1)) then
c
```

```
c      Risk is less than 1%, return 0%
c
        Prisk = 0.0

      else if(HIC.gt.curve(1,jhic)) then
c
c      Risk is greater than 99%, return 100%
c
        Prisk = 100.0

      else
c
c      interpolate risk from table
c
        do 70 i=1,jhic-1
          j = i+1
          if( (curve(1,i).le.HIC) .and. (HIC.le.curve(1,j)) ) then
            Prisk = curve(2,i) + (curve(2,j)-curve(2,i)) *
     &                      (HIC-curve(1,i)) / (curve(1,j)-curve(1,i))
          end if
   70   continue

      end if
c
c     *****************************************************************
c     ***                                                           ***
c     ***  store output in output data array                        ***
c     ***                                                           ***
c     *****************************************************************
c
      Datout(1) = MAIS
      Datout(2) = TAIS
      Datout(3) = NIC
      Datout(4) = NCOS
      Datout(5) = NCOD
      Datout(6) = POF
      Datout(7) = POF5
      Datout(8) = POF6
      Datout(9) = PPI
      Datout(10) = Prisk
c
c     done, normal return
c
      Ierr = 0
      return

      end

c...+....1....+....2....+....3....+....4....+....5....+....6....+....7....+....8
c...+....1....+....2....+....3....+....4....+....5....+....6....+....7....+....8

      subroutine wricm(Iout,Table)
      integer Iout
      real Table(9,6)

c******************************************************************************
c
c     name
c
c      wricm - Write the Injury Cost Model results
```

```
c
c    description
c
c      This subroutine writes the Injury Cost Model results for the
c      inputs in arrays Idatin and Rdatin and outputs in arrays Table
c      and Datout.
c
c    calling sequence
c
c      argument  i/o  description
c      --------  ---  -----------
c      Iout       i   output unit number
c      Idatin     i   integer data input array, elements as follows:
c                     element  symbol  description
c                     -------  ------  -----------
c                        1     FF3    number of AIS 3 femur fractures
c                        2     TF2    number of AIS 2 tibia fractures
c                        3     TF3    number of AIS 3 tibia fractures
c                        4     KDI2   number of AIS 2 knee dislocated
c                                      injuries
c                        5     KDI3   number of AIS 3 knee dislocated
c                                      injuries
c
c      Rdatin     i   real data input array, elements as follows:
c                     element  symbol  units  description
c                     -------  ------  -----  -----------
c                        1     AP      mm     maximum abdomen
c                                             penetration
c                        2     Gmax    -      maximum GAMBIT
c                        3     Cmax    %      maximum normalize chest
c                                             compression
c                        4     VCmax   m/s    maximum chest viscous
c                                             criteria when V>3 m/s
c                        5     HIC     -      Head Injury Criteria
c                        6     NII     -      Neck Injury Index
c
c      Table      o   table 1 values
c
c      Datout     o   real data output array, elements as follows:
c                     element  symbol  units  description
c                     -------  ------  -----  -----------
c                        1     MAIS           maximum AIS
c                        2     TAIS           total AIS
c                        3     NIC     -      Normalized Injury Cost
c                        4     NCOS    -      Normalized Cost of
c                                             Survival
c                        5     NCOD    -      Normalized Cost of Dying
c                        6     POF     -      Probability of Fatality
c                        7     POF5    -      POF due to non AIS 6
c                                             injuries
c                        8     POF6    -      POF due to AIS 6 injuries
c
c    version history
c
c      - original version by RMV, DRI, March 1993
c      - first revision by RMV, DRI, April 1993
c         - AIS 3 knee dislocation injuries added
c      - second revision by RMV, DRI, March 1994
c         - changed model and subroutine name from Injury Cost Model II
c           (wricm2) to Injury Cost Model (wricm)
```

```
c      - third revision by RMV, DRI, August 1994
c         - dimensions of Rdatin and Datout arrays changed
c
c******************************************************************************
c
c    local parameters
c
      integer kcol, krow
      character*69 blank, dline
c
c    data
c
      data blank/' '/
      data dline( 1:40)/'----------------------------------------'/
      data dline(41:69)/'-----------------------------'/
c
c******************************************************************************
c
c    write out Table
c
      write(Iout,101) dline,dline
      write(Iout,101) blank,
     & '                   BODY REGION                           '
      write(Iout,101) '  AIS ',dline
      write(Iout,102) blank,'    HEAD   ','    NECK    ','   CHEST   ',
     &               '  ABDOMEN  ','         LEG         '
      write(Iout,103) blank,('Probability',kcol=1,5),'# Injuries'
      write(Iout,103) (dline,kcol=1,7)
      do 10 krow=1,7
        write(Iout,104) krow-1,(Table(krow,kcol),kcol=1,5),
     &                   nint(Table(krow,6))
   10 continue
      write(Iout,103) (dline,kcol=1,7)
      krow=8
      write(Iout,105) ' PAIS ',(Table(krow,kcol),kcol=1,5)
      write(Iout,103) (dline,kcol=1,7)
      krow=9
      write(Iout,106) ' PAIS ',(nint(Table(krow,kcol)),kcol=1,5)
      write(Iout,103) (dline,kcol=1,7)

      return
c
c******************************************************************************
c
c    format statements
c
  101 format(1x,'|',a6,'|',a70,'|')
  102 format(1x,'|',a6,4('|',a11),'|',a22,'|')
  103 format(1x,'|',a6,5('|',a11),'|',a10,'|')
  104 format(1x,'|',3x,i1,2x,5('|',3x,f5.3,3x),'|',4x,i1,5x,'|')
  105 format(1x,'|',a6,5('|',3x,f5.3,3x),'|',10x,'|')
  106 format(1x,'|',a6,5('|',5x,i1,5x),'|',10x,'|')

      end

c...+....1....+....2....+....3....+....4....+....5....+....6....+....7....+....8
```

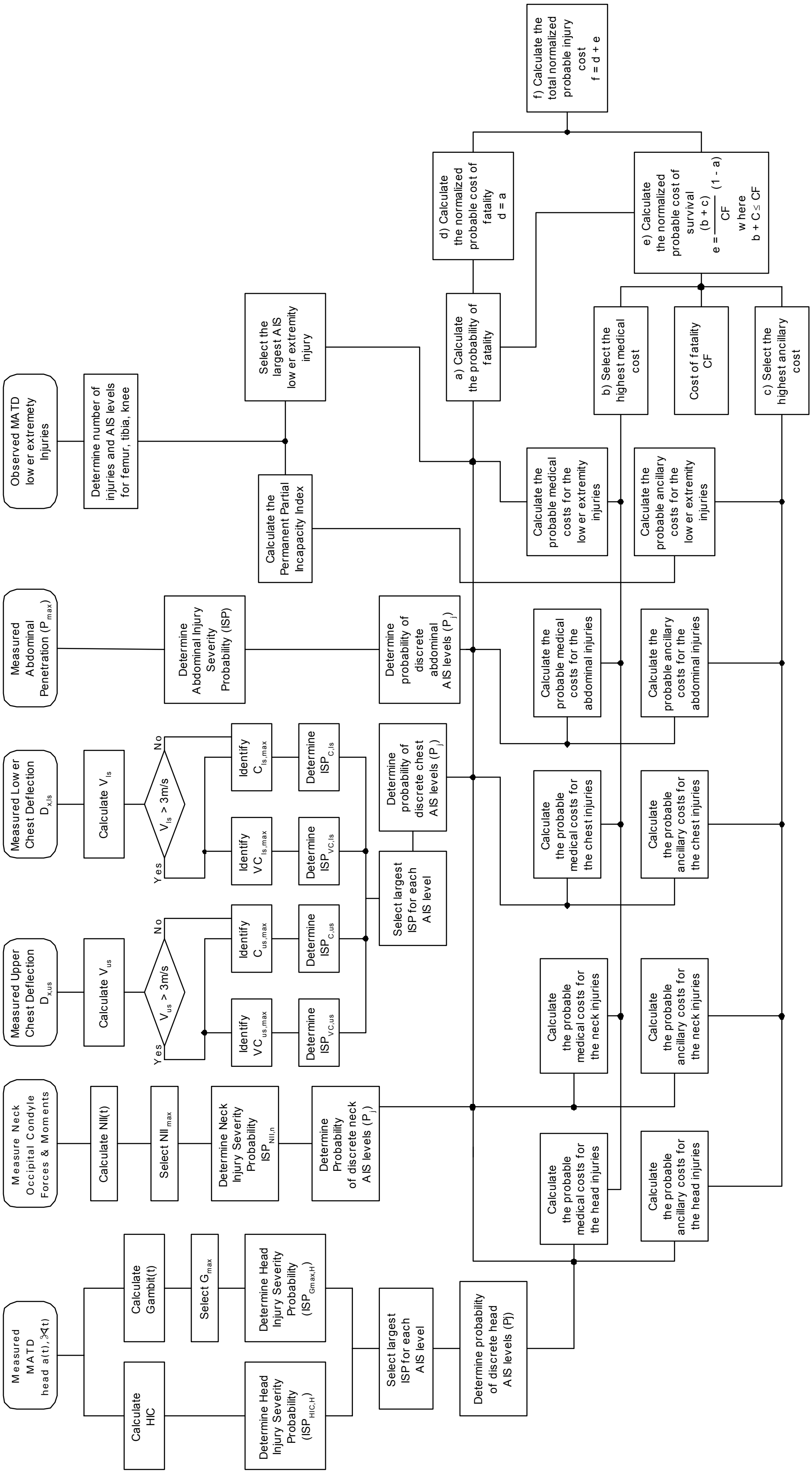


**Figure D.1 — Flow diagram of the injury cost model**

# Annex E
(informative)

## Comparison of results to reference risk and benefit values

NOTE This Annex provides potentially useful information for users of ISO 13232 regarding risk and benefit results. However, this information is provided only as a suggested reference guideline, and users may elect to develop other guidelines or have no particular guideline, depending on the nature of the research,

For $IC_{norm}$, compare the values calculated in 5.9.4.1 to 5.9.4.4 to the following reference values:

1) ideally, the percentage of accidents which are beneficial should be greater than the percentage which indicate no effect, which should be greater than the percentage which are harmful,

2) the risk/benefit percentage should be less than seven percent and should not be more than 12 percent[2) ] ,

3) the average net benefit should be greater than zero, and

4) the average benefit per beneficial case should be greater than the average risk per harmful case.

2) Based on the results for automobile seat belts (7 percent) based on Malliaris, et al., 1982, as described by Rogers, 1996, which is presumed to be an acceptable risk/benefit percentage; and the results for pre-1998 automobile passenger airbags (12 percent), based on Iijima, et al., 1998, which is presumed to be an unacceptable risk/benefit percentage.

# Annex F
(informative)

# Example probable injury cost data

Table F.1 lists and describes the column headings for Table F.2. Table F.2 lists example inputs to the injury cost model and resulting output. The inputs include different input combinations of injury assessment variables, leg injury occurrences, and probable AIS. The outputs include the maximum PAIS, total PAIS, normalized injury cost, and probability of fatality.

**Table F.1 — Legend for Table F.2**

| | |
|---|---|
| *GMAX* | maximum GAMBIT |
| *VC* | maximum VC, in metres per second |
| *CMAX* | maximum normalized chest compression, in percent |
| *PA* | abdominal penetration, in millimetres |
| *FEM* | AIS 2 femur fracture = 1, no fracture = 0 |
| *KNE* | AIS 2 knee dislocation = 1, no dislocation = 0 |
| *TIB* | tibia fracture = 1, no fracture = 0 |
| *NUM* | total number of leg injuries |
| *HP* | head probable AIS |
| *ThP* | thorax probable AIS |
| *AP* | abdomen probable AIS |
| *F* | femur AIS |
| *K* | knee AIS |
| *T* | tibia AIS |
| *MAIS* | maximum AIS |
| *TAIS* | total AIS |
| *POF* | probability of fatality, in percent |
| *ICn* | total normalized injury cost, in percent (Annex A U.S. data only) |

**Table F.2 — Example probable injury cost input/output results**

| *GMAX* | *VC* | *CMAX* | *PA* | *FEM* | *KNE* | *TIB* | *NUM* | *HP* | *ThP* | *AP* | *F* | *K* | *T* | *MAIS* | *TAIS* | *POF* | $IC_n$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | | | | | |
| 0.0 | 0.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0.0 | 0.0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 3 | 0 | 0 | 3 | 3 | 2 | 15 |
| 0.0 | 0.0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 2 | 0 | 2 | 2 | 1 | 12 |
| 0.0 | 0.0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 2 | 1 | 7 |
| 0.0 | 0.0 | 0 | 0 | 1 | 1 | 0 | 2 | 0 | 0 | 0 | 3 | 2 | 0 | 3 | 5 | 2 | 23 |
| 0.0 | 0.0 | 0 | 0 | 1 | 1 | 1 | 3 | 0 | 0 | 0 | 3 | 2 | 2 | 3 | 7 | 2 | 30 |
| | | | | | | | | | | | | | | | | | |
| 0.0 | 0.0 | 0 | 60 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 3 | 3 | 4 | 9 |
| 0.0 | 0.0 | 0 | 60 | 1 | 0 | 0 | 1 | 0 | 0 | 3 | 3 | 0 | 0 | 3 | 6 | 8 | 21 |
| 0.0 | 0.0 | 0 | 60 | 0 | 1 | 0 | 1 | 0 | 0 | 3 | 0 | 2 | 0 | 3 | 5 | 6 | 16 |
| 0.0 | 0.0 | 0 | 60 | 0 | 0 | 1 | 1 | 0 | 0 | 3 | 0 | 0 | 2 | 3 | 5 | 6 | 12 |
| 0.0 | 0.0 | 0 | 60 | 1 | 1 | 0 | 2 | 0 | 0 | 3 | 3 | 2 | 0 | 3 | 8 | 8 | 28 |
| 0.0 | 0.0 | 0 | 60 | 1 | 1 | 1 | 3 | 0 | 0 | 3 | 3 | 2 | 2 | 3 | 10 | 8 | 35 |
| | | | | | | | | | | | | | | | | | |
| 0.0 | 0.0 | 30 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 2 | 2 | 1 | 3 |
| 0.0 | 0.0 | 30 | 0 | 1 | 0 | 0 | 1 | 0 | 2 | 0 | 3 | 0 | 0 | 3 | 5 | 3 | 16 |
| 0.0 | 0.0 | 30 | 0 | 0 | 1 | 0 | 1 | 0 | 2 | 0 | 0 | 2 | 0 | 2 | 4 | 2 | 13 |
| 0.0 | 0.0 | 30 | 0 | 0 | 0 | 1 | 1 | 0 | 2 | 0 | 0 | 0 | 2 | 2 | 4 | 2 | 8 |
| 0.0 | 0.0 | 30 | 0 | 1 | 1 | 0 | 2 | 0 | 2 | 0 | 3 | 2 | 0 | 3 | 7 | 3 | 24 |
| 0.0 | 0.0 | 30 | 0 | 1 | 1 | 1 | 3 | 0 | 2 | 0 | 3 | 2 | 2 | 3 | 9 | 3 | 31 |
| | | | | | | | | | | | | | | | | | |
| 0.0 | 0.0 | 30 | 60 | 0 | 0 | 0 | 0 | 0 | 2 | 3 | 0 | 0 | 0 | 3 | 5 | 5 | 11 |
| 0.0 | 0.0 | 30 | 60 | 1 | 0 | 0 | 1 | 0 | 2 | 3 | 3 | 0 | 0 | 3 | 8 | 10 | 22 |
| 0.0 | 0.0 | 30 | 60 | 0 | 1 | 0 | 1 | 0 | 2 | 3 | 0 | 2 | 0 | 3 | 7 | 7 | 18 |
| 0.0 | 0.0 | 30 | 60 | 0 | 0 | 1 | 1 | 0 | 2 | 3 | 0 | 0 | 2 | 3 | 7 | 7 | 13 |
| 0.0 | 0.0 | 30 | 60 | 1 | 1 | 0 | 2 | 0 | 2 | 3 | 3 | 2 | 0 | 3 | 10 | 10 | 30 |
| 0.0 | 0.0 | 30 | 60 | 1 | 1 | 1 | 3 | 0 | 2 | 3 | 3 | 2 | 2 | 3 | 12 | 10 | 36 |
| | | | | | | | | | | | | | | | | | |
| 0.0 | 0.0 | 45 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 0 | 0 | 4 | 4 | 14 | 24 |
| 0.0 | 0.0 | 45 | 0 | 1 | 0 | 0 | 1 | 0 | 4 | 0 | 3 | 0 | 0 | 4 | 7 | 22 | 32 |
| 0.0 | 0.0 | 45 | 0 | 0 | 1 | 0 | 1 | 0 | 4 | 0 | 0 | 2 | 0 | 4 | 6 | 17 | 28 |
| 0.0 | 0.0 | 45 | 0 | 0 | 0 | 1 | 1 | 0 | 4 | 0 | 0 | 0 | 2 | 4 | 6 | 17 | 27 |
| 0.0 | 0.0 | 45 | 0 | 1 | 1 | 0 | 2 | 0 | 4 | 0 | 3 | 2 | 0 | 4 | 9 | 22 | 39 |
| 0.0 | 0.0 | 45 | 0 | 1 | 1 | 1 | 3 | 0 | 4 | 0 | 3 | 2 | 2 | 4 | 11 | 22 | 44 |
| | | | | | | | | | | | | | | | | | |
| 0.0 | 0.0 | 45 | 60 | 0 | 0 | 0 | 0 | 0 | 4 | 3 | 0 | 0 | 0 | 4 | 7 | 23 | 32 |
| 0.0 | 0.0 | 45 | 60 | 1 | 0 | 0 | 1 | 0 | 4 | 3 | 3 | 0 | 0 | 4 | 10 | 31 | 41 |
| 0.0 | 0.0 | 45 | 60 | 0 | 1 | 0 | 1 | 0 | 4 | 3 | 0 | 2 | 0 | 4 | 9 | 27 | 37 |
| 0.0 | 0.0 | 45 | 60 | 0 | 0 | 1 | 1 | 0 | 4 | 3 | 0 | 0 | 2 | 4 | 9 | 27 | 36 |
| 0.0 | 0.0 | 45 | 60 | 1 | 1 | 0 | 2 | 0 | 4 | 3 | 3 | 2 | 0 | 4 | 12 | 31 | 46 |
| 0.0 | 0.0 | 45 | 60 | 1 | 1 | 1 | 3 | 0 | 4 | 3 | 3 | 2 | 2 | 4 | 14 | 31 | 51 |
| | | | | | | | | | | | | | | | | | |
| 0.0 | 0.0 | 60 | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 0 | 0 | 0 | 0 | 6 | 6 | 92 | 92 |
| 0.0 | 0.0 | 60 | 0 | 1 | 0 | 0 | 1 | 0 | 6 | 0 | 3 | 0 | 0 | 6 | 9 | 93 | 94 |
| 0.0 | 0.0 | 60 | 0 | 0 | 1 | 0 | 1 | 0 | 6 | 0 | 0 | 2 | 0 | 6 | 8 | 93 | 93 |

| *GMAX* | *VC* | *CMAX* | *PA* | *FEM* | *KNE* | *TIB* | *NUM* | *HP* | *ThP* | *AP* | *F* | *K* | *T* | *MAIS* | *TAIS* | *POF* | $IC_n$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.0 | 0.0 | 60 | 0 | 0 | 0 | 1 | 1 | 0 | 6 | 0 | 0 | 0 | 2 | 6 | 8 | 93 | 93 |
| 0.0 | 0.0 | 60 | 0 | 1 | 1 | 0 | 2 | 0 | 6 | 0 | 3 | 2 | 0 | 6 | 11 | 93 | 95 |
| 0.0 | 0.0 | 60 | 0 | 1 | 1 | 1 | 3 | 0 | 6 | 0 | 3 | 2 | 2 | 6 | 13 | 93 | 95 |
| | | | | | | | | | | | | | | | | | |
| 0.0 | 0.0 | 60 | 60 | 0 | 0 | 0 | 0 | 0 | 6 | 3 | 0 | 0 | 0 | 6 | 9 | 93 | 93 |
| 0.0 | 0.0 | 60 | 60 | 1 | 0 | 0 | 1 | 0 | 6 | 3 | 3 | 0 | 0 | 6 | 12 | 94 | 95 |
| 0.0 | 0.0 | 60 | 60 | 0 | 1 | 0 | 1 | 0 | 6 | 3 | 0 | 2 | 0 | 6 | 11 | 93 | 94 |
| 0.0 | 0.0 | 60 | 60 | 0 | 0 | 1 | 1 | 0 | 6 | 3 | 0 | 0 | 2 | 6 | 11 | 93 | 94 |
| 0.0 | 0.0 | 60 | 60 | 1 | 1 | 0 | 2 | 0 | 6 | 3 | 3 | 2 | 0 | 6 | 14 | 94 | 95 |
| 0.0 | 0.0 | 60 | 60 | 1 | 1 | 1 | 3 | 0 | 6 | 3 | 3 | 2 | 2 | 6 | 16 | 94 | 96 |
| 0.0 | 1.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 3 | 3 | 7 | 14 |
| 0.0 | 1.5 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 3 | 0 | 3 | 0 | 0 | 3 | 6 | 12 | 24 |
| 0.0 | 1.5 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 3 | 0 | 0 | 2 | 0 | 3 | 5 | 9 | 20 |
| 0.0 | 1.5 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 3 | 0 | 0 | 0 | 2 | 3 | 5 | 9 | 16 |
| 0.0 | 1.5 | 0 | 0 | 1 | 1 | 0 | 2 | 0 | 3 | 0 | 3 | 2 | 0 | 3 | 8 | 12 | 31 |
| 0.0 | 1.5 | 0 | 0 | 1 | 1 | 1 | 3 | 0 | 3 | 0 | 3 | 2 | 2 | 3 | 10 | 12 | 37 |
| | | | | | | | | | | | | | | | | | |
| 0.0 | 1.5 | 0 | 60 | 0 | 0 | 0 | 0 | 0 | 3 | 3 | 0 | 0 | 0 | 3 | 6 | 14 | 21 |
| 0.0 | 1.5 | 0 | 60 | 1 | 0 | 0 | 1 | 0 | 3 | 3 | 3 | 0 | 0 | 3 | 9 | 21 | 32 |
| 0.0 | 1.5 | 0 | 60 | 0 | 1 | 0 | 1 | 0 | 3 | 3 | 0 | 2 | 0 | 3 | 8 | 18 | 28 |
| 0.0 | 1.5 | 0 | 60 | 0 | 0 | 1 | 1 | 0 | 3 | 3 | 0 | 0 | 2 | 3 | 8 | 18 | 24 |
| 0.0 | 1.5 | 0 | 60 | 1 | 1 | 0 | 2 | 0 | 3 | 3 | 3 | 2 | 0 | 3 | 11 | 21 | 38 |
| 0.0 | 1.5 | 0 | 60 | 1 | 1 | 1 | 3 | 0 | 3 | 3 | 3 | 2 | 2 | 3 | 13 | 21 | 44 |
| | | | | | | | | | | | | | | | | | |
| 0.0 | 2.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 0 | 0 | 0 | 0 | 6 | 6 | 91 | 91 |
| 0.0 | 2.5 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 6 | 0 | 3 | 0 | 0 | 6 | 9 | 92 | 93 |
| 0.0 | 2.5 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 6 | 0 | 0 | 2 | 0 | 6 | 8 | 91 | 92 |
| 0.0 | 2.5 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 6 | 0 | 0 | 0 | 2 | 6 | 8 | 91 | 92 |
| 0.0 | 2.5 | 0 | 0 | 1 | 1 | 0 | 2 | 0 | 6 | 0 | 3 | 2 | 0 | 6 | 11 | 92 | 94 |
| 0.0 | 2.5 | 0 | 0 | 1 | 1 | 1 | 3 | 0 | 6 | 0 | 3 | 2 | 2 | 6 | 13 | 92 | 94 |
| | | | | | | | | | | | | | | | | | |
| 0.0 | 2.5 | 0 | 60 | 0 | 0 | 0 | 0 | 0 | 6 | 3 | 0 | 0 | 0 | 6 | 9 | 92 | 92 |
| 0.0 | 2.5 | 0 | 60 | 1 | 0 | 0 | 1 | 0 | 6 | 3 | 3 | 0 | 0 | 6 | 12 | 93 | 94 |
| 0.0 | 2.5 | 0 | 60 | 0 | 1 | 0 | 1 | 0 | 6 | 3 | 0 | 2 | 0 | 6 | 11 | 92 | 93 |
| 0.0 | 2.5 | 0 | 60 | 0 | 0 | 1 | 1 | 0 | 6 | 3 | 0 | 0 | 2 | 6 | 11 | 92 | 93 |
| 0.0 | 2.5 | 0 | 60 | 1 | 1 | 0 | 2 | 0 | 6 | 3 | 3 | 2 | 0 | 6 | 14 | 93 | 94 |
| 0.0 | 2.5 | 0 | 60 | 1 | 1 | 1 | 3 | 0 | 6 | 3 | 3 | 2 | 2 | 6 | 16 | 93 | 95 |
| | | | | | | | | | | | | | | | | | |
| 0.0 | 3.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 0 | 0 | 0 | 0 | 6 | 6 | 100 | 100 |
| 0.0 | 3.0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 6 | 0 | 3 | 0 | 0 | 6 | 9 | 100 | 100 |
| 0.0 | 3.0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 6 | 0 | 0 | 2 | 0 | 6 | 8 | 100 | 100 |
| 0.0 | 3.0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 6 | 0 | 0 | 0 | 2 | 6 | 8 | 100 | 100 |
| 0.0 | 3.0 | 0 | 0 | 1 | 1 | 0 | 2 | 0 | 6 | 0 | 3 | 2 | 0 | 6 | 11 | 100 | 100 |
| 0.0 | 3.0 | 0 | 0 | 1 | 1 | 1 | 3 | 0 | 6 | 0 | 3 | 2 | 2 | 6 | 13 | 100 | 100 |
| | | | | | | | | | | | | | | | | | |
| 0.0 | 3.0 | 0 | 60 | 0 | 0 | 0 | 0 | 0 | 6 | 3 | 0 | 0 | 0 | 6 | 9 | 100 | 100 |
| 0.0 | 3.0 | 0 | 60 | 1 | 0 | 0 | 1 | 0 | 6 | 3 | 3 | 0 | 0 | 6 | 12 | 100 | 100 |

| *GMAX* | *VC* | *CMAX* | *PA* | *FEM* | *KNE* | *TIB* | *NUM* | *HP* | *ThP* | *AP* | *F* | *K* | *T* | *MAIS* | *TAIS* | *POF* | $IC_n$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.0 | 3.0 | 0 | 60 | 0 | 1 | 0 | 1 | 0 | 6 | 3 | 0 | 2 | 0 | 6 | 11 | 100 | 100 |
| 0.0 | 3.0 | 0 | 60 | 0 | 0 | 1 | 1 | 0 | 6 | 3 | 0 | 0 | 2 | 6 | 11 | 100 | 100 |
| 0.0 | 3.0 | 0 | 60 | 1 | 1 | 0 | 2 | 0 | 6 | 3 | 3 | 2 | 0 | 6 | 14 | 100 | 100 |
| 0.0 | 3.0 | 0 | 60 | 1 | 1 | 1 | 3 | 0 | 6 | 3 | 3 | 2 | 2 | 6 | 16 | 100 | 100 |
| | | | | | | | | | | | | | | | | | |
| 0.6 | 0.0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 |
| 0.6 | 0.0 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 3 | 0 | 0 | 3 | 4 | 2 | 16 |
| 0.6 | 0.0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 2 | 0 | 2 | 3 | 1 | 12 |
| 0.6 | 0.0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 2 | 2 | 3 | 1 | 7 |
| 0.6 | 0.0 | 0 | 0 | 1 | 1 | 0 | 2 | 1 | 0 | 0 | 3 | 2 | 0 | 3 | 6 | 2 | 23 |
| 0.6 | 0.0 | 0 | 0 | 1 | 1 | 1 | 3 | 1 | 0 | 0 | 3 | 2 | 2 | 3 | 8 | 2 | 30 |
| | | | | | | | | | | | | | | | | | |
| 0.6 | 0.0 | 0 | 60 | 0 | 0 | 0 | 0 | 1 | 0 | 3 | 0 | 0 | 0 | 3 | 4 | 4 | 10 |
| 0.6 | 0.0 | 0 | 60 | 1 | 0 | 0 | 1 | 1 | 0 | 3 | 3 | 0 | 0 | 3 | 7 | 9 | 22 |
| 0.6 | 0.0 | 0 | 60 | 0 | 1 | 0 | 1 | 1 | 0 | 3 | 0 | 2 | 0 | 3 | 6 | 6 | 17 |
| 0.6 | 0.0 | 0 | 60 | 0 | 0 | 1 | 1 | 1 | 0 | 3 | 0 | 0 | 2 | 3 | 6 | 6 | 12 |
| 0.6 | 0.0 | 0 | 60 | 1 | 1 | 0 | 2 | 1 | 0 | 3 | 3 | 2 | 0 | 3 | 9 | 9 | 29 |
| 0.6 | 0.0 | 0 | 60 | 1 | 1 | 1 | 3 | 1 | 0 | 3 | 3 | 2 | 2 | 3 | 11 | 9 | 35 |
| 0.6 | 0.0 | 30 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 0 | 0 | 0 | 0 | 2 | 3 | 1 | 3 |
| 0.6 | 0.0 | 30 | 0 | 1 | 0 | 0 | 1 | 1 | 2 | 0 | 3 | 0 | 0 | 3 | 6 | 3 | 16 |
| 0.6 | 0.0 | 30 | 0 | 0 | 1 | 0 | 1 | 1 | 2 | 0 | 0 | 2 | 0 | 2 | 5 | 2 | 13 |
| 0.6 | 0.0 | 30 | 0 | 0 | 0 | 1 | 1 | 1 | 2 | 0 | 0 | 0 | 2 | 2 | 5 | 2 | 8 |
| 0.6 | 0.0 | 30 | 0 | 1 | 1 | 0 | 2 | 1 | 2 | 0 | 3 | 2 | 0 | 3 | 8 | 3 | 24 |
| 0.6 | 0.0 | 30 | 0 | 1 | 1 | 1 | 3 | 1 | 2 | 0 | 3 | 2 | 2 | 3 | 10 | 3 | 31 |
| | | | | | | | | | | | | | | | | | |
| 0.6 | 0.0 | 30 | 60 | 0 | 0 | 0 | 0 | 1 | 2 | 3 | 0 | 0 | 0 | 3 | 6 | 6 | 12 |
| 0.6 | 0.0 | 30 | 60 | 1 | 0 | 0 | 1 | 1 | 2 | 3 | 3 | 0 | 0 | 3 | 9 | 11 | 23 |
| 0.6 | 0.0 | 30 | 60 | 0 | 1 | 0 | 1 | 1 | 2 | 3 | 0 | 2 | 0 | 3 | 8 | 8 | 18 |
| 0.6 | 0.0 | 30 | 60 | 0 | 0 | 1 | 1 | 1 | 2 | 3 | 0 | 0 | 2 | 3 | 8 | 8 | 14 |
| 0.6 | 0.0 | 30 | 60 | 1 | 1 | 0 | 2 | 1 | 2 | 3 | 3 | 2 | 0 | 3 | 11 | 11 | 30 |
| 0.6 | 0.0 | 30 | 60 | 1 | 1 | 1 | 3 | 1 | 2 | 3 | 3 | 2 | 2 | 3 | 13 | 11 | 36 |
| | | | | | | | | | | | | | | | | | |
| 0.6 | 0.0 | 45 | 0 | 0 | 0 | 0 | 0 | 1 | 4 | 0 | 0 | 0 | 0 | 4 | 5 | 15 | 25 |
| 0.6 | 0.0 | 45 | 0 | 1 | 0 | 0 | 1 | 1 | 4 | 0 | 3 | 0 | 0 | 4 | 8 | 23 | 34 |
| 0.6 | 0.0 | 45 | 0 | 0 | 1 | 0 | 1 | 1 | 4 | 0 | 0 | 2 | 0 | 4 | 7 | 18 | 29 |
| 0.6 | 0.0 | 45 | 0 | 0 | 0 | 1 | 1 | 1 | 4 | 0 | 0 | 0 | 2 | 4 | 7 | 18 | 28 |
| 0.6 | 0.0 | 45 | 0 | 1 | 1 | 0 | 2 | 1 | 4 | 0 | 3 | 2 | 0 | 4 | 10 | 23 | 40 |
| 0.6 | 0.0 | 45 | 0 | 1 | 1 | 1 | 3 | 1 | 4 | 0 | 3 | 2 | 2 | 4 | 12 | 23 | 45 |
| | | | | | | | | | | | | | | | | | |
| 0.6 | 0.0 | 45 | 60 | 0 | 0 | 0 | 0 | 1 | 4 | 3 | 0 | 0 | 0 | 4 | 8 | 24 | 33 |
| 0.6 | 0.0 | 45 | 60 | 1 | 0 | 0 | 1 | 1 | 4 | 3 | 3 | 0 | 0 | 4 | 11 | 32 | 41 |
| 0.6 | 0.0 | 45 | 60 | 0 | 1 | 0 | 1 | 1 | 4 | 3 | 0 | 2 | 0 | 4 | 10 | 28 | 37 |
| 0.6 | 0.0 | 45 | 60 | 0 | 0 | 1 | 1 | 1 | 4 | 3 | 0 | 0 | 2 | 4 | 10 | 28 | 36 |
| 0.6 | 0.0 | 45 | 60 | 1 | 1 | 0 | 2 | 1 | 4 | 3 | 3 | 2 | 0 | 4 | 13 | 32 | 46 |
| 0.6 | 0.0 | 45 | 60 | 1 | 1 | 1 | 3 | 1 | 4 | 3 | 3 | 2 | 2 | 4 | 15 | 32 | 51 |
| | | | | | | | | | | | | | | | | | |
| 0.6 | 0.0 | 60 | 0 | 0 | 0 | 0 | 0 | 1 | 6 | 0 | 0 | 0 | 0 | 6 | 7 | 92 | 92 |

| *GMAX* | *VC* | *CMAX* | *PA* | *FEM* | *KNE* | *TIB* | *NUM* | *HP* | *ThP* | *AP* | *F* | *K* | *T* | *MAIS* | *TAIS* | *POF* | $IC_n$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.6 | 0.0 | 60 | 0 | 1 | 0 | 0 | 1 | 1 | 6 | 0 | 3 | 0 | 0 | 6 | 10 | 93 | 94 |
| 0.6 | 0.0 | 60 | 0 | 0 | 1 | 0 | 1 | 1 | 6 | 0 | 0 | 2 | 0 | 6 | 9 | 93 | 93 |
| 0.6 | 0.0 | 60 | 0 | 0 | 0 | 1 | 1 | 1 | 6 | 0 | 0 | 0 | 2 | 6 | 9 | 93 | 93 |
| 0.6 | 0.0 | 60 | 0 | 1 | 1 | 0 | 2 | 1 | 6 | 0 | 3 | 2 | 0 | 6 | 12 | 93 | 95 |
| 0.6 | 0.0 | 60 | 0 | 1 | 1 | 1 | 3 | 1 | 6 | 0 | 3 | 2 | 2 | 6 | 14 | 93 | 95 |
| | | | | | | | | | | | | | | | | | |
| 0.6 | 0.0 | 60 | 60 | 0 | 0 | 0 | 0 | 1 | 6 | 3 | 0 | 0 | 0 | 6 | 10 | 93 | 94 |
| 0.6 | 0.0 | 60 | 60 | 1 | 0 | 0 | 1 | 1 | 6 | 3 | 3 | 0 | 0 | 6 | 13 | 94 | 95 |
| 0.6 | 0.0 | 60 | 60 | 0 | 1 | 0 | 1 | 1 | 6 | 3 | 0 | 2 | 0 | 6 | 12 | 94 | 94 |
| 0.6 | 0.0 | 60 | 60 | 0 | 0 | 1 | 1 | 1 | 6 | 3 | 0 | 0 | 2 | 6 | 12 | 94 | 94 |
| 0.6 | 0.0 | 60 | 60 | 1 | 1 | 0 | 2 | 1 | 6 | 3 | 3 | 2 | 0 | 6 | 15 | 94 | 95 |
| 0.6 | 0.0 | 60 | 60 | 1 | 1 | 1 | 3 | 1 | 6 | 3 | 3 | 2 | 2 | 6 | 17 | 94 | 96 |
| | | | | | | | | | | | | | | | | | |
| 0.6 | 1.5 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 3 | 0 | 0 | 0 | 0 | 3 | 4 | 7 | 15 |
| 0.6 | 1.5 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 3 | 0 | 3 | 0 | 0 | 3 | 7 | 13 | 25 |
| 0.6 | 1.5 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 3 | 0 | 0 | 2 | 0 | 3 | 6 | 10 | 21 |
| 0.6 | 1.5 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 3 | 0 | 0 | 0 | 2 | 3 | 6 | 10 | 17 |
| 0.6 | 1.5 | 0 | 0 | 1 | 1 | 0 | 2 | 1 | 3 | 0 | 3 | 2 | 0 | 3 | 9 | 13 | 32 |
| 0.6 | 1.5 | 0 | 0 | 1 | 1 | 1 | 3 | 1 | 3 | 0 | 3 | 2 | 2 | 3 | 11 | 13 | 38 |
| | | | | | | | | | | | | | | | | | |
| 0.6 | 1.5 | 0 | 60 | 0 | 0 | 0 | 0 | 1 | 3 | 3 | 0 | 0 | 0 | 3 | 7 | 15 | 22 |
| 0.6 | 1.5 | 0 | 60 | 1 | 0 | 0 | 1 | 1 | 3 | 3 | 3 | 0 | 0 | 3 | 10 | 21 | 32 |
| 0.6 | 1.5 | 0 | 60 | 0 | 1 | 0 | 1 | 1 | 3 | 3 | 0 | 2 | 0 | 3 | 9 | 18 | 28 |
| 0.6 | 1.5 | 0 | 60 | 0 | 0 | 1 | 1 | 1 | 3 | 3 | 0 | 0 | 2 | 3 | 9 | 18 | 25 |
| 0.6 | 1.5 | 0 | 60 | 1 | 1 | 0 | 2 | 1 | 3 | 3 | 3 | 2 | 0 | 3 | 12 | 21 | 38 |
| 0.6 | 1.5 | 0 | 60 | 1 | 1 | 1 | 3 | 1 | 3 | 3 | 3 | 2 | 2 | 3 | 14 | 21 | 44 |
| | | | | | | | | | | | | | | | | | |
| 0.6 | 2.5 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 6 | 0 | 0 | 0 | 0 | 6 | 7 | 91 | 91 |
| 0.6 | 2.5 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 6 | 0 | 3 | 0 | 0 | 6 | 10 | 92 | 93 |
| 0.6 | 2.5 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 6 | 0 | 0 | 2 | 0 | 6 | 9 | 91 | 92 |
| 0.6 | 2.5 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 6 | 0 | 0 | 0 | 2 | 6 | 9 | 91 | 92 |
| 0.6 | 2.5 | 0 | 0 | 1 | 1 | 0 | 2 | 1 | 6 | 0 | 3 | 2 | 0 | 6 | 12 | 92 | 94 |
| 0.6 | 2.5 | 0 | 0 | 1 | 1 | 1 | 3 | 1 | 6 | 0 | 3 | 2 | 2 | 6 | 14 | 92 | 94 |
| | | | | | | | | | | | | | | | | | |
| 0.6 | 2.5 | 0 | 60 | 0 | 0 | 0 | 0 | 1 | 6 | 3 | 0 | 0 | 0 | 6 | 10 | 92 | 92 |
| 0.6 | 2.5 | 0 | 60 | 1 | 0 | 0 | 1 | 1 | 6 | 3 | 3 | 0 | 0 | 6 | 13 | 93 | 94 |
| 0.6 | 2.5 | 0 | 60 | 0 | 1 | 0 | 1 | 1 | 6 | 3 | 0 | 2 | 0 | 6 | 12 | 92 | 93 |
| 0.6 | 2.5 | 0 | 60 | 0 | 0 | 1 | 1 | 1 | 6 | 3 | 0 | 0 | 2 | 6 | 12 | 92 | 93 |
| 0.6 | 2.5 | 0 | 60 | 1 | 1 | 0 | 2 | 1 | 6 | 3 | 3 | 2 | 0 | 6 | 15 | 93 | 94 |
| 0.6 | 2.5 | 0 | 60 | 1 | 1 | 1 | 3 | 1 | 6 | 3 | 3 | 2 | 2 | 6 | 17 | 93 | 95 |
| | | | | | | | | | | | | | | | | | |
| 0.6 | 3.0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 6 | 0 | 0 | 0 | 0 | 6 | 7 | 100 | 100 |
| 0.6 | 3.0 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 6 | 0 | 3 | 0 | 0 | 6 | 10 | 100 | 100 |
| 0.6 | 3.0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 6 | 0 | 0 | 2 | 0 | 6 | 9 | 100 | 100 |
| 0.6 | 3.0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 6 | 0 | 0 | 0 | 2 | 6 | 9 | 100 | 100 |
| 0.6 | 3.0 | 0 | 0 | 1 | 1 | 0 | 2 | 1 | 6 | 0 | 3 | 2 | 0 | 6 | 12 | 100 | 100 |
| 0.6 | 3.0 | 0 | 0 | 1 | 1 | 1 | 3 | 1 | 6 | 0 | 3 | 2 | 2 | 6 | 14 | 100 | 100 |

| *GMAX* | *VC* | *CMAX* | *PA* | *FEM* | *KNE* | *TIB* | *NUM* | *HP* | *ThP* | *AP* | *F* | *K* | *T* | *MAIS* | *TAIS* | *POF* | $IC_n$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | | | | | |
| 0.6 | 3.0 | 0 | 60 | 0 | 0 | 0 | 0 | 1 | 6 | 3 | 0 | 0 | 0 | 6 | 10 | 100 | 100 |
| 0.6 | 3.0 | 0 | 60 | 1 | 0 | 0 | 1 | 1 | 6 | 3 | 3 | 0 | 0 | 6 | 13 | 100 | 100 |
| 0.6 | 3.0 | 0 | 60 | 0 | 1 | 0 | 1 | 1 | 6 | 3 | 0 | 2 | 0 | 6 | 12 | 100 | 100 |
| 0.6 | 3.0 | 0 | 60 | 0 | 0 | 1 | 1 | 1 | 6 | 3 | 0 | 0 | 2 | 6 | 12 | 100 | 100 |
| 0.6 | 3.0 | 0 | 60 | 1 | 1 | 0 | 2 | 1 | 6 | 3 | 3 | 2 | 0 | 6 | 15 | 100 | 100 |
| 0.6 | 3.0 | 0 | 60 | 1 | 1 | 1 | 3 | 1 | 6 | 3 | 3 | 2 | 2 | 6 | 17 | 100 | 100 |
| | | | | | | | | | | | | | | | | | |
| 0.9 | 0.0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 3 | 3 | 17 | 23 |
| 0.9 | 0.0 | 0 | 0 | 1 | 0 | 0 | 1 | 3 | 0 | 0 | 3 | 0 | 0 | 3 | 6 | 20 | 31 |
| 0.9 | 0.0 | 0 | 0 | 0 | 1 | 0 | 1 | 3 | 0 | 0 | 0 | 2 | 0 | 3 | 5 | 19 | 29 |
| 0.9 | 0.0 | 0 | 0 | 0 | 0 | 1 | 1 | 3 | 0 | 0 | 0 | 0 | 2 | 3 | 5 | 19 | 25 |
| 0.9 | 0.0 | 0 | 0 | 1 | 1 | 0 | 2 | 3 | 0 | 0 | 3 | 2 | 0 | 3 | 8 | 20 | 37 |
| 0.9 | 0.0 | 0 | 0 | 1 | 1 | 1 | 3 | 3 | 0 | 0 | 3 | 2 | 2 | 3 | 10 | 20 | 43 |
| | | | | | | | | | | | | | | | | | |
| 0.9 | 0.0 | 0 | 60 | 0 | 0 | 0 | 0 | 3 | 0 | 3 | 0 | 0 | 0 | 3 | 6 | 22 | 28 |
| 0.9 | 0.0 | 0 | 60 | 1 | 0 | 0 | 1 | 3 | 0 | 3 | 3 | 0 | 0 | 3 | 9 | 27 | 37 |
| 0.9 | 0.0 | 0 | 60 | 0 | 1 | 0 | 1 | 3 | 0 | 3 | 0 | 2 | 0 | 3 | 8 | 24 | 34 |
| 0.9 | 0.0 | 0 | 60 | 0 | 0 | 1 | 1 | 3 | 0 | 3 | 0 | 0 | 2 | 3 | 8 | 24 | 30 |
| 0.9 | 0.0 | 0 | 60 | 1 | 1 | 0 | 2 | 3 | 0 | 3 | 3 | 2 | 0 | 3 | 11 | 27 | 43 |
| 0.9 | 0.0 | 0 | 60 | 1 | 1 | 1 | 3 | 3 | 0 | 3 | 3 | 2 | 2 | 3 | 13 | 27 | 48 |
| | | | | | | | | | | | | | | | | | |
| 0.9 | 0.0 | 30 | 0 | 0 | 0 | 0 | 0 | 3 | 2 | 0 | 0 | 0 | 0 | 3 | 5 | 18 | 24 |
| 0.9 | 0.0 | 30 | 0 | 1 | 0 | 0 | 1 | 3 | 2 | 0 | 3 | 0 | 0 | 3 | 8 | 21 | 32 |
| 0.9 | 0.0 | 30 | 0 | 0 | 1 | 0 | 1 | 3 | 2 | 0 | 0 | 2 | 0 | 3 | 7 | 20 | 30 |
| 0.9 | 0.0 | 30 | 0 | 0 | 0 | 1 | 1 | 3 | 2 | 0 | 0 | 0 | 2 | 3 | 7 | 20 | 26 |
| 0.9 | 0.0 | 30 | 0 | 1 | 1 | 0 | 2 | 3 | 2 | 0 | 3 | 2 | 0 | 3 | 10 | 21 | 38 |
| 0.9 | 0.0 | 30 | 0 | 1 | 1 | 1 | 3 | 3 | 2 | 0 | 3 | 2 | 2 | 3 | 12 | 21 | 44 |
| | | | | | | | | | | | | | | | | | |
| 0.9 | 0.0 | 30 | 60 | 0 | 0 | 0 | 0 | 3 | 2 | 3 | 0 | 0 | 0 | 3 | 8 | 24 | 29 |
| 0.9 | 0.0 | 30 | 60 | 1 | 0 | 0 | 1 | 3 | 2 | 3 | 3 | 0 | 0 | 3 | 11 | 28 | 38 |
| 0.9 | 0.0 | 30 | 60 | 0 | 1 | 0 | 1 | 3 | 2 | 3 | 0 | 2 | 0 | 3 | 10 | 25 | 35 |
| 0.9 | 0.0 | 30 | 60 | 0 | 0 | 1 | 1 | 3 | 2 | 3 | 0 | 0 | 2 | 3 | 10 | 25 | 31 |
| 0.9 | 0.0 | 30 | 60 | 1 | 1 | 0 | 2 | 3 | 2 | 3 | 3 | 2 | 0 | 3 | 13 | 28 | 43 |
| 0.9 | 0.0 | 30 | 60 | 1 | 1 | 1 | 3 | 3 | 2 | 3 | 3 | 2 | 2 | 3 | 15 | 28 | 48 |
| | | | | | | | | | | | | | | | | | |
| 0.9 | 0.0 | 45 | 0 | 0 | 0 | 0 | 0 | 3 | 4 | 0 | 0 | 0 | 0 | 4 | 7 | 32 | 40 |
| 0.9 | 0.0 | 45 | 0 | 1 | 0 | 0 | 1 | 3 | 4 | 0 | 3 | 0 | 0 | 4 | 10 | 39 | 47 |
| 0.9 | 0.0 | 45 | 0 | 0 | 1 | 0 | 1 | 3 | 4 | 0 | 0 | 2 | 0 | 4 | 9 | 35 | 44 |
| 0.9 | 0.0 | 45 | 0 | 0 | 0 | 1 | 1 | 3 | 4 | 0 | 0 | 0 | 2 | 4 | 9 | 35 | 43 |
| 0.9 | 0.0 | 45 | 0 | 1 | 1 | 0 | 2 | 3 | 4 | 0 | 3 | 2 | 0 | 4 | 12 | 39 | 52 |
| 0.9 | 0.0 | 45 | 0 | 1 | 1 | 1 | 3 | 3 | 4 | 0 | 3 | 2 | 2 | 4 | 14 | 39 | 57 |
| | | | | | | | | | | | | | | | | | |
| 0.9 | 0.0 | 45 | 60 | 0 | 0 | 0 | 0 | 3 | 4 | 3 | 0 | 0 | 0 | 4 | 10 | 40 | 47 |
| 0.9 | 0.0 | 45 | 60 | 1 | 0 | 0 | 1 | 3 | 4 | 3 | 3 | 0 | 0 | 4 | 13 | 44 | 52 |
| 0.9 | 0.0 | 45 | 60 | 0 | 1 | 0 | 1 | 3 | 4 | 3 | 0 | 2 | 0 | 4 | 12 | 41 | 49 |
| 0.9 | 0.0 | 45 | 60 | 0 | 0 | 1 | 1 | 3 | 4 | 3 | 0 | 0 | 2 | 4 | 12 | 41 | 48 |

| *GMAX* | *VC* | *CMAX* | *PA* | *FEM* | *KNE* | *TIB* | *NUM* | *HP* | *ThP* | *AP* | *F* | *K* | *T* | *MAIS* | *TAIS* | *POF* | $IC_n$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.9 | 0.0 | 45 | 60 | 1 | 1 | 0 | 2 | 3 | 4 | 3 | 3 | 2 | 0 | 4 | 15 | 44 | 56 |
| 0.9 | 0.0 | 45 | 60 | 1 | 1 | 1 | 3 | 3 | 4 | 3 | 3 | 2 | 2 | 4 | 17 | 44 | 60 |
| | | | | | | | | | | | | | | | | | |
| 0.9 | 0.0 | 60 | 0 | 0 | 0 | 0 | 0 | 3 | 6 | 0 | 0 | 0 | 0 | 6 | 9 | 94 | 94 |
| 0.9 | 0.0 | 60 | 0 | 1 | 0 | 0 | 1 | 3 | 6 | 0 | 3 | 0 | 0 | 6 | 12 | 95 | 95 |
| 0.9 | 0.0 | 60 | 0 | 0 | 1 | 0 | 1 | 3 | 6 | 0 | 0 | 2 | 0 | 6 | 11 | 94 | 95 |
| 0.9 | 0.0 | 60 | 0 | 0 | 0 | 1 | 1 | 3 | 6 | 0 | 0 | 0 | 2 | 6 | 11 | 94 | 95 |
| 0.9 | 0.0 | 60 | 0 | 1 | 1 | 0 | 2 | 3 | 6 | 0 | 3 | 2 | 0 | 6 | 14 | 95 | 96 |
| 0.9 | 0.0 | 60 | 0 | 1 | 1 | 1 | 3 | 3 | 6 | 0 | 3 | 2 | 2 | 6 | 16 | 95 | 96 |
| | | | | | | | | | | | | | | | | | |
| 0.9 | 0.0 | 60 | 60 | 0 | 0 | 0 | 0 | 3 | 6 | 3 | 0 | 0 | 0 | 6 | 12 | 95 | 95 |
| 0.9 | 0.0 | 60 | 60 | 1 | 0 | 0 | 1 | 3 | 6 | 3 | 3 | 0 | 0 | 6 | 15 | 95 | 96 |
| 0.9 | 0.0 | 60 | 60 | 0 | 1 | 0 | 1 | 3 | 6 | 3 | 0 | 2 | 0 | 6 | 14 | 95 | 95 |
| 0.9 | 0.0 | 60 | 60 | 0 | 0 | 1 | 1 | 3 | 6 | 3 | 0 | 0 | 2 | 6 | 14 | 95 | 95 |
| 0.9 | 0.0 | 60 | 60 | 1 | 1 | 0 | 2 | 3 | 6 | 3 | 3 | 2 | 0 | 6 | 17 | 95 | 96 |
| 0.9 | 0.0 | 60 | 60 | 1 | 1 | 1 | 3 | 3 | 6 | 3 | 3 | 2 | 2 | 6 | 19 | 95 | 96 |
| | | | | | | | | | | | | | | | | | |
| 0.9 | 1.5 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 3 | 0 | 0 | 0 | 0 | 3 | 6 | 25 | 31 |
| 0.9 | 1.5 | 0 | 0 | 1 | 0 | 0 | 1 | 3 | 3 | 0 | 3 | 0 | 0 | 3 | 9 | 30 | 40 |
| 0.9 | 1.5 | 0 | 0 | 0 | 1 | 0 | 1 | 3 | 3 | 0 | 0 | 2 | 0 | 3 | 8 | 27 | 37 |
| 0.9 | 1.5 | 0 | 0 | 0 | 0 | 1 | 1 | 3 | 3 | 0 | 0 | 0 | 2 | 3 | 8 | 27 | 34 |
| 0.9 | 1.5 | 0 | 0 | 1 | 1 | 0 | 2 | 3 | 3 | 0 | 3 | 2 | 0 | 3 | 11 | 30 | 45 |
| 0.9 | 1.5 | 0 | 0 | 1 | 1 | 1 | 3 | 3 | 3 | 0 | 3 | 2 | 2 | 3 | 13 | 30 | 50 |
| | | | | | | | | | | | | | | | | | |
| 0.9 | 1.5 | 0 | 60 | 0 | 0 | 0 | 0 | 3 | 3 | 3 | 0 | 0 | 0 | 3 | 9 | 32 | 38 |
| 0.9 | 1.5 | 0 | 60 | 1 | 0 | 0 | 1 | 3 | 3 | 3 | 3 | 0 | 0 | 3 | 12 | 36 | 45 |
| 0.9 | 1.5 | 0 | 60 | 0 | 1 | 0 | 1 | 3 | 3 | 3 | 0 | 2 | 0 | 3 | 11 | 33 | 42 |
| 0.9 | 1.5 | 0 | 60 | 0 | 0 | 1 | 1 | 3 | 3 | 3 | 0 | 0 | 2 | 3 | 11 | 33 | 39 |
| 0.9 | 1.5 | 0 | 60 | 1 | 1 | 0 | 2 | 3 | 3 | 3 | 3 | 2 | 0 | 3 | 14 | 36 | 50 |
| 0.9 | 1.5 | 0 | 60 | 1 | 1 | 1 | 3 | 3 | 3 | 3 | 3 | 2 | 2 | 3 | 16 | 36 | 54 |
| | | | | | | | | | | | | | | | | | |
| 0.9 | 2.5 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 6 | 0 | 0 | 0 | 0 | 6 | 9 | 93 | 93 |
| 0.9 | 2.5 | 0 | 0 | 1 | 0 | 0 | 1 | 3 | 6 | 0 | 3 | 0 | 0 | 6 | 12 | 94 | 94 |
| 0.9 | 2.5 | 0 | 0 | 0 | 1 | 0 | 1 | 3 | 6 | 0 | 0 | 2 | 0 | 6 | 11 | 93 | 94 |
| 0.9 | 2.5 | 0 | 0 | 0 | 0 | 1 | 1 | 3 | 6 | 0 | 0 | 0 | 2 | 6 | 11 | 93 | 94 |
| 0.9 | 2.5 | 0 | 0 | 1 | 1 | 0 | 2 | 3 | 6 | 0 | 3 | 2 | 0 | 6 | 14 | 94 | 95 |
| 0.9 | 2.5 | 0 | 0 | 1 | 1 | 1 | 3 | 3 | 6 | 0 | 3 | 2 | 2 | 6 | 16 | 94 | 95 |
| | | | | | | | | | | | | | | | | | |
| 0.9 | 2.5 | 0 | 60 | 0 | 0 | 0 | 0 | 3 | 6 | 3 | 0 | 0 | 0 | 6 | 12 | 94 | 94 |
| 0.9 | 2.5 | 0 | 60 | 1 | 0 | 0 | 1 | 3 | 6 | 3 | 3 | 0 | 0 | 6 | 15 | 94 | 95 |
| 0.9 | 2.5 | 0 | 60 | 0 | 1 | 0 | 1 | 3 | 6 | 3 | 0 | 2 | 0 | 6 | 14 | 94 | 95 |
| 0.9 | 2.5 | 0 | 60 | 0 | 0 | 1 | 1 | 3 | 6 | 3 | 0 | 0 | 2 | 6 | 14 | 94 | 94 |
| 0.9 | 2.5 | 0 | 60 | 1 | 1 | 0 | 2 | 3 | 6 | 3 | 3 | 2 | 0 | 6 | 17 | 94 | 95 |
| 0.9 | 2.5 | 0 | 60 | 1 | 1 | 1 | 3 | 3 | 6 | 3 | 3 | 2 | 2 | 6 | 19 | 94 | 96 |
| | | | | | | | | | | | | | | | | | |
| 0.9 | 3.0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 6 | 0 | 0 | 0 | 0 | 6 | 9 | 100 | 100 |
| 0.9 | 3.0 | 0 | 0 | 1 | 0 | 0 | 1 | 3 | 6 | 0 | 3 | 0 | 0 | 6 | 12 | 100 | 100 |

| *GMAX* | *VC* | *CMAX* | *PA* | *FEM* | *KNE* | *TIB* | *NUM* | *HP* | *ThP* | *AP* | *F* | *K* | *T* | *MAIS* | *TAIS* | *POF* | $IC_n$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.9 | 3.0 | 0 | 0 | 0 | 1 | 0 | 1 | 3 | 6 | 0 | 0 | 2 | 0 | 6 | 11 | 100 | 100 |
| 0.9 | 3.0 | 0 | 0 | 0 | 0 | 1 | 1 | 3 | 6 | 0 | 0 | 0 | 2 | 6 | 11 | 100 | 100 |
| 0.9 | 3.0 | 0 | 0 | 1 | 1 | 0 | 2 | 3 | 6 | 0 | 3 | 2 | 0 | 6 | 14 | 100 | 100 |
| 0.9 | 3.0 | 0 | 0 | 1 | 1 | 1 | 3 | 3 | 6 | 0 | 3 | 2 | 2 | 6 | 16 | 100 | 100 |
| | | | | | | | | | | | | | | | | | |
| 0.9 | 3.0 | 0 | 60 | 0 | 0 | 0 | 0 | 3 | 6 | 3 | 0 | 0 | 0 | 6 | 12 | 100 | 100 |
| 0.9 | 3.0 | 0 | 60 | 1 | 0 | 0 | 1 | 3 | 6 | 3 | 3 | 0 | 0 | 6 | 15 | 100 | 100 |
| 0.9 | 3.0 | 0 | 60 | 0 | 1 | 0 | 1 | 3 | 6 | 3 | 0 | 2 | 0 | 6 | 14 | 100 | 100 |
| 0.9 | 3.0 | 0 | 60 | 0 | 0 | 1 | 1 | 3 | 6 | 3 | 0 | 0 | 2 | 6 | 14 | 100 | 100 |
| 0.9 | 3.0 | 0 | 60 | 1 | 1 | 0 | 2 | 3 | 6 | 3 | 3 | 2 | 0 | 6 | 17 | 100 | 100 |
| 0.9 | 3.0 | 0 | 60 | 1 | 1 | 1 | 3 | 3 | 6 | 3 | 3 | 2 | 2 | 6 | 19 | 100 | 100 |
| | | | | | | | | | | | | | | | | | |
| 1.2 | 0.0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 5 | 5 | 59 | 66 |
| 1.2 | 0.0 | 0 | 0 | 1 | 0 | 0 | 1 | 5 | 0 | 0 | 3 | 0 | 0 | 5 | 8 | 62 | 69 |
| 1.2 | 0.0 | 0 | 0 | 0 | 1 | 0 | 1 | 5 | 0 | 0 | 0 | 2 | 0 | 5 | 7 | 60 | 67 |
| 1.2 | 0.0 | 0 | 0 | 0 | 0 | 1 | 1 | 5 | 0 | 0 | 0 | 0 | 2 | 5 | 7 | 60 | 67 |
| 1.2 | 0.0 | 0 | 0 | 1 | 1 | 0 | 2 | 5 | 0 | 0 | 3 | 2 | 0 | 5 | 10 | 62 | 72 |
| 1.2 | 0.0 | 0 | 0 | 1 | 1 | 1 | 3 | 5 | 0 | 0 | 3 | 2 | 2 | 5 | 12 | 62 | 74 |
| | | | | | | | | | | | | | | | | | |
| 1.2 | 0.0 | 0 | 60 | 0 | 0 | 0 | 0 | 5 | 0 | 3 | 0 | 0 | 0 | 5 | 8 | 63 | 69 |
| 1.2 | 0.0 | 0 | 60 | 1 | 0 | 0 | 1 | 5 | 0 | 3 | 3 | 0 | 0 | 5 | 11 | 67 | 72 |
| 1.2 | 0.0 | 0 | 60 | 0 | 1 | 0 | 1 | 5 | 0 | 3 | 0 | 2 | 0 | 5 | 10 | 65 | 71 |
| 1.2 | 0.0 | 0 | 60 | 0 | 0 | 1 | 1 | 5 | 0 | 3 | 0 | 0 | 2 | 5 | 10 | 65 | 71 |
| 1.2 | 0.0 | 0 | 60 | 1 | 1 | 0 | 2 | 5 | 0 | 3 | 3 | 2 | 0 | 5 | 13 | 67 | 75 |
| 1.2 | 0.0 | 0 | 60 | 1 | 1 | 1 | 3 | 5 | 0 | 3 | 3 | 2 | 2 | 5 | 15 | 67 | 77 |
| | | | | | | | | | | | | | | | | | |
| 1.2 | 0.0 | 30 | 0 | 0 | 0 | 0 | 0 | 5 | 2 | 0 | 0 | 0 | 0 | 5 | 7 | 60 | 67 |
| 1.2 | 0.0 | 30 | 0 | 1 | 0 | 0 | 1 | 5 | 2 | 0 | 3 | 0 | 0 | 5 | 10 | 63 | 70 |
| 1.2 | 0.0 | 30 | 0 | 0 | 1 | 0 | 1 | 5 | 2 | 0 | 0 | 2 | 0 | 5 | 9 | 61 | 68 |
| 1.2 | 0.0 | 30 | 0 | 0 | 0 | 1 | 1 | 5 | 2 | 0 | 0 | 0 | 2 | 5 | 9 | 61 | 68 |
| 1.2 | 0.0 | 30 | 0 | 1 | 1 | 0 | 2 | 5 | 2 | 0 | 3 | 2 | 0 | 5 | 12 | 63 | 73 |
| 1.2 | 0.0 | 30 | 0 | 1 | 1 | 1 | 3 | 5 | 2 | 0 | 3 | 2 | 2 | 5 | 14 | 63 | 75 |
| | | | | | | | | | | | | | | | | | |
| 1.2 | 0.0 | 30 | 60 | 0 | 0 | 0 | 0 | 5 | 2 | 3 | 0 | 0 | 0 | 5 | 10 | 64 | 70 |
| 1.2 | 0.0 | 30 | 60 | 1 | 0 | 0 | 1 | 5 | 2 | 3 | 3 | 0 | 0 | 5 | 13 | 67 | 73 |
| 1.2 | 0.0 | 30 | 60 | 0 | 1 | 0 | 1 | 5 | 2 | 3 | 0 | 2 | 0 | 5 | 12 | 65 | 71 |
| 1.2 | 0.0 | 30 | 60 | 0 | 0 | 1 | 1 | 5 | 2 | 3 | 0 | 0 | 2 | 5 | 12 | 65 | 71 |
| 1.2 | 0.0 | 30 | 60 | 1 | 1 | 0 | 2 | 5 | 2 | 3 | 3 | 2 | 0 | 5 | 15 | 67 | 75 |
| 1.2 | 0.0 | 30 | 60 | 1 | 1 | 1 | 3 | 5 | 2 | 3 | 3 | 2 | 2 | 5 | 17 | 67 | 78 |
| | | | | | | | | | | | | | | | | | |
| 1.2 | 0.0 | 45 | 0 | 0 | 0 | 0 | 0 | 5 | 4 | 0 | 0 | 0 | 0 | 5 | 9 | 68 | 74 |
| 1.2 | 0.0 | 45 | 0 | 1 | 0 | 0 | 1 | 5 | 4 | 0 | 3 | 0 | 0 | 5 | 12 | 73 | 77 |
| 1.2 | 0.0 | 45 | 0 | 0 | 1 | 0 | 1 | 5 | 4 | 0 | 0 | 2 | 0 | 5 | 11 | 71 | 76 |
| 1.2 | 0.0 | 45 | 0 | 0 | 0 | 1 | 1 | 5 | 4 | 0 | 0 | 0 | 2 | 5 | 11 | 71 | 76 |
| 1.2 | 0.0 | 45 | 0 | 1 | 1 | 0 | 2 | 5 | 4 | 0 | 3 | 2 | 0 | 5 | 14 | 73 | 80 |
| 1.2 | 0.0 | 45 | 0 | 1 | 1 | 1 | 3 | 5 | 4 | 0 | 3 | 2 | 2 | 5 | 16 | 73 | 81 |
| | | | | | | | | | | | | | | | | | |

| *GMAX* | *VC* | *CMAX* | *PA* | *FEM* | *KNE* | *TIB* | *NUM* | *HP* | *ThP* | *AP* | *F* | *K* | *T* | *MAIS* | *TAIS* | *POF* | $IC_n$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.2 | 0.0 | 45 | 60 | 0 | 0 | 0 | 0 | 5 | 4 | 3 | 0 | 0 | 0 | 5 | 12 | 73 | 77 |
| 1.2 | 0.0 | 45 | 60 | 1 | 0 | 0 | 1 | 5 | 4 | 3 | 3 | 0 | 0 | 5 | 15 | 74 | 79 |
| 1.2 | 0.0 | 45 | 60 | 0 | 1 | 0 | 1 | 5 | 4 | 3 | 0 | 2 | 0 | 5 | 14 | 73 | 78 |
| 1.2 | 0.0 | 45 | 60 | 0 | 0 | 1 | 1 | 5 | 4 | 3 | 0 | 0 | 2 | 5 | 14 | 73 | 78 |
| 1.2 | 0.0 | 45 | 60 | 1 | 1 | 0 | 2 | 5 | 4 | 3 | 3 | 2 | 0 | 5 | 17 | 74 | 81 |
| 1.2 | 0.0 | 45 | 60 | 1 | 1 | 1 | 3 | 5 | 4 | 3 | 3 | 2 | 2 | 5 | 19 | 74 | 82 |
| | | | | | | | | | | | | | | | | | |
| 1.2 | 0.0 | 60 | 0 | 0 | 0 | 0 | 0 | 5 | 6 | 0 | 0 | 0 | 0 | 6 | 11 | 97 | 98 |
| 1.2 | 0.0 | 60 | 0 | 1 | 0 | 0 | 1 | 5 | 6 | 0 | 3 | 0 | 0 | 6 | 14 | 98 | 98 |
| 1.2 | 0.0 | 60 | 0 | 0 | 1 | 0 | 1 | 5 | 6 | 0 | 0 | 2 | 0 | 6 | 13 | 97 | 98 |
| 1.2 | 0.0 | 60 | 0 | 0 | 0 | 1 | 1 | 5 | 6 | 0 | 0 | 0 | 2 | 6 | 13 | 97 | 98 |
| 1.2 | 0.0 | 60 | 0 | 1 | 1 | 0 | 2 | 5 | 6 | 0 | 3 | 2 | 0 | 6 | 16 | 98 | 98 |
| 1.2 | 0.0 | 60 | 0 | 1 | 1 | 1 | 3 | 5 | 6 | 0 | 3 | 2 | 2 | 6 | 18 | 98 | 98 |
| | | | | | | | | | | | | | | | | | |
| 1.2 | 0.0 | 60 | 60 | 0 | 0 | 0 | 0 | 5 | 6 | 3 | 0 | 0 | 0 | 6 | 14 | 98 | 98 |
| 1.2 | 0.0 | 60 | 60 | 1 | 0 | 0 | 1 | 5 | 6 | 3 | 3 | 0 | 0 | 6 | 17 | 98 | 98 |
| 1.2 | 0.0 | 60 | 60 | 0 | 1 | 0 | 1 | 5 | 6 | 3 | 0 | 2 | 0 | 6 | 16 | 98 | 98 |
| 1.2 | 0.0 | 60 | 60 | 0 | 0 | 1 | 1 | 5 | 6 | 3 | 0 | 0 | 2 | 6 | 16 | 98 | 98 |
| 1.2 | 0.0 | 60 | 60 | 1 | 1 | 0 | 2 | 5 | 6 | 3 | 3 | 2 | 0 | 6 | 19 | 98 | 98 |
| 1.2 | 0.0 | 60 | 60 | 1 | 1 | 1 | 3 | 5 | 6 | 3 | 3 | 2 | 2 | 6 | 21 | 98 | 98 |
| | | | | | | | | | | | | | | | | | |
| 1.2 | 1.5 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 3 | 0 | 0 | 0 | 0 | 5 | 8 | 64 | 71 |
| 1.2 | 1.5 | 0 | 0 | 1 | 0 | 0 | 1 | 5 | 3 | 0 | 3 | 0 | 0 | 5 | 11 | 68 | 74 |
| 1.2 | 1.5 | 0 | 0 | 0 | 1 | 0 | 1 | 5 | 3 | 0 | 0 | 2 | 0 | 5 | 10 | 66 | 72 |
| 1.2 | 1.5 | 0 | 0 | 0 | 0 | 1 | 1 | 5 | 3 | 0 | 0 | 0 | 2 | 5 | 10 | 66 | 72 |
| 1.2 | 1.5 | 0 | 0 | 1 | 1 | 0 | 2 | 5 | 3 | 0 | 3 | 2 | 0 | 5 | 13 | 68 | 76 |
| 1.2 | 1.5 | 0 | 0 | 1 | 1 | 1 | 3 | 5 | 3 | 0 | 3 | 2 | 2 | 5 | 15 | 68 | 79 |
| | | | | | | | | | | | | | | | | | |
| 1.2 | 1.5 | 0 | 60 | 0 | 0 | 0 | 0 | 5 | 3 | 3 | 0 | 0 | 0 | 5 | 11 | 69 | 74 |
| 1.2 | 1.5 | 0 | 60 | 1 | 0 | 0 | 1 | 5 | 3 | 3 | 3 | 0 | 0 | 5 | 14 | 70 | 76 |
| 1.2 | 1.5 | 0 | 60 | 0 | 1 | 0 | 1 | 5 | 3 | 3 | 0 | 2 | 0 | 5 | 13 | 69 | 75 |
| 1.2 | 1.5 | 0 | 60 | 0 | 0 | 1 | 1 | 5 | 3 | 3 | 0 | 0 | 2 | 5 | 13 | 69 | 75 |
| 1.2 | 1.5 | 0 | 60 | 1 | 1 | 0 | 2 | 5 | 3 | 3 | 3 | 2 | 0 | 5 | 16 | 70 | 78 |
| 1.2 | 1.5 | 0 | 60 | 1 | 1 | 1 | 3 | 5 | 3 | 3 | 3 | 2 | 2 | 5 | 18 | 70 | 80 |
| | | | | | | | | | | | | | | | | | |
| 1.2 | 2.5 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 6 | 0 | 0 | 0 | 0 | 6 | 11 | 97 | 97 |
| 1.2 | 2.5 | 0 | 0 | 1 | 0 | 0 | 1 | 5 | 6 | 0 | 3 | 0 | 0 | 6 | 14 | 97 | 98 |
| 1.2 | 2.5 | 0 | 0 | 0 | 1 | 0 | 1 | 5 | 6 | 0 | 0 | 2 | 0 | 6 | 13 | 97 | 97 |
| 1.2 | 2.5 | 0 | 0 | 0 | 0 | 1 | 1 | 5 | 6 | 0 | 0 | 0 | 2 | 6 | 13 | 97 | 97 |
| 1.2 | 2.5 | 0 | 0 | 1 | 1 | 0 | 2 | 5 | 6 | 0 | 3 | 2 | 0 | 6 | 16 | 97 | 98 |
| 1.2 | 2.5 | 0 | 0 | 1 | 1 | 1 | 3 | 5 | 6 | 0 | 3 | 2 | 2 | 6 | 18 | 97 | 98 |
| | | | | | | | | | | | | | | | | | |
| 1.2 | 2.5 | 0 | 60 | 0 | 0 | 0 | 0 | 5 | 6 | 3 | 0 | 0 | 0 | 6 | 14 | 97 | 98 |
| 1.2 | 2.5 | 0 | 60 | 1 | 0 | 0 | 1 | 5 | 6 | 3 | 3 | 0 | 0 | 6 | 17 | 97 | 98 |
| 1.2 | 2.5 | 0 | 60 | 0 | 1 | 0 | 1 | 5 | 6 | 3 | 0 | 2 | 0 | 6 | 16 | 97 | 98 |
| 1.2 | 2.5 | 0 | 60 | 0 | 0 | 1 | 1 | 5 | 6 | 3 | 0 | 0 | 2 | 6 | 16 | 97 | 98 |
| 1.2 | 2.5 | 0 | 60 | 1 | 1 | 0 | 2 | 5 | 6 | 3 | 3 | 2 | 0 | 6 | 19 | 97 | 98 |

| *GMAX* | *VC* | *CMAX* | *PA* | *FEM* | *KNE* | *TIB* | *NUM* | *HP* | *ThP* | *AP* | *F* | *K* | *T* | *MAIS* | *TAIS* | *POF* | $IC_n$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.2 | 2.5 | 0 | 60 | 1 | 1 | 1 | 3 | 5 | 6 | 3 | 3 | 2 | 2 | 6 | 21 | 97 | 98 |
| | | | | | | | | | | | | | | | | | |
| 1.2 | 3.0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 6 | 0 | 0 | 0 | 0 | 6 | 11 | 100 | 100 |
| 1.2 | 3.0 | 0 | 0 | 1 | 0 | 0 | 1 | 5 | 6 | 0 | 3 | 0 | 0 | 6 | 14 | 100 | 100 |
| 1.2 | 3.0 | 0 | 0 | 0 | 1 | 0 | 1 | 5 | 6 | 0 | 0 | 2 | 0 | 6 | 13 | 100 | 100 |
| 1.2 | 3.0 | 0 | 0 | 0 | 0 | 1 | 1 | 5 | 6 | 0 | 0 | 0 | 2 | 6 | 13 | 100 | 100 |
| 1.2 | 3.0 | 0 | 0 | 1 | 1 | 0 | 2 | 5 | 6 | 0 | 3 | 2 | 0 | 6 | 16 | 100 | 100 |
| 1.2 | 3.0 | 0 | 0 | 1 | 1 | 1 | 3 | 5 | 6 | 0 | 3 | 2 | 2 | 6 | 18 | 100 | 100 |
| | | | | | | | | | | | | | | | | | |
| 1.2 | 3.0 | 0 | 60 | 0 | 0 | 0 | 0 | 5 | 6 | 3 | 0 | 0 | 0 | 6 | 14 | 100 | 100 |
| 1.2 | 3.0 | 0 | 60 | 1 | 0 | 0 | 1 | 5 | 6 | 3 | 3 | 0 | 0 | 6 | 17 | 100 | 100 |
| 1.2 | 3.0 | 0 | 60 | 0 | 1 | 0 | 1 | 5 | 6 | 3 | 0 | 2 | 0 | 6 | 16 | 100 | 100 |
| 1.2 | 3.0 | 0 | 60 | 0 | 0 | 1 | 1 | 5 | 6 | 3 | 0 | 0 | 2 | 6 | 16 | 100 | 100 |
| 1.2 | 3.0 | 0 | 60 | 1 | 1 | 0 | 2 | 5 | 6 | 3 | 3 | 2 | 0 | 6 | 19 | 100 | 100 |
| 1.2 | 3.0 | 0 | 60 | 1 | 1 | 1 | 3 | 5 | 6 | 3 | 3 | 2 | 2 | 6 | 21 | 100 | 100 |
| | | | | | | | | | | | | | | | | | |
| 2.0 | 0.0 | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 0 | 0 | 0 | 0 | 0 | 6 | 6 | 99 | 99 |
| 2.0 | 0.0 | 0 | 0 | 1 | 0 | 0 | 1 | 6 | 0 | 0 | 3 | 0 | 0 | 6 | 9 | 99 | 99 |
| 2.0 | 0.0 | 0 | 0 | 0 | 1 | 0 | 1 | 6 | 0 | 0 | 0 | 2 | 0 | 6 | 8 | 99 | 99 |
| 2.0 | 0.0 | 0 | 0 | 0 | 0 | 1 | 1 | 6 | 0 | 0 | 0 | 0 | 2 | 6 | 8 | 99 | 99 |
| 2.0 | 0.0 | 0 | 0 | 1 | 1 | 0 | 2 | 6 | 0 | 0 | 3 | 2 | 0 | 6 | 11 | 99 | 99 |
| 2.0 | 0.0 | 0 | 0 | 1 | 1 | 1 | 3 | 6 | 0 | 0 | 3 | 2 | 2 | 6 | 13 | 99 | 99 |
| | | | | | | | | | | | | | | | | | |
| 2.0 | 0.0 | 0 | 60 | 0 | 0 | 0 | 0 | 6 | 0 | 3 | 0 | 0 | 0 | 6 | 9 | 99 | 99 |
| 2.0 | 0.0 | 0 | 60 | 1 | 0 | 0 | 1 | 6 | 0 | 3 | 3 | 0 | 0 | 6 | 12 | 99 | 99 |
| 2.0 | 0.0 | 0 | 60 | 0 | 1 | 0 | 1 | 6 | 0 | 3 | 0 | 2 | 0 | 6 | 11 | 99 | 99 |
| 2.0 | 0.0 | 0 | 60 | 0 | 0 | 1 | 1 | 6 | 0 | 3 | 0 | 0 | 2 | 6 | 11 | 99 | 99 |
| 2.0 | 0.0 | 0 | 60 | 1 | 1 | 0 | 2 | 6 | 0 | 3 | 3 | 2 | 0 | 6 | 14 | 99 | 99 |
| 2.0 | 0.0 | 0 | 60 | 1 | 1 | 1 | 3 | 6 | 0 | 3 | 3 | 2 | 2 | 6 | 16 | 99 | 99 |
| | | | | | | | | | | | | | | | | | |
| 2.0 | 0.0 | 30 | 0 | 0 | 0 | 0 | 0 | 6 | 2 | 0 | 0 | 0 | 0 | 6 | 8 | 99 | 99 |
| 2.0 | 0.0 | 30 | 0 | 1 | 0 | 0 | 1 | 6 | 2 | 0 | 3 | 0 | 0 | 6 | 11 | 99 | 99 |
| 2.0 | 0.0 | 30 | 0 | 0 | 1 | 0 | 1 | 6 | 2 | 0 | 0 | 2 | 0 | 6 | 10 | 99 | 99 |
| 2.0 | 0.0 | 30 | 0 | 0 | 0 | 1 | 1 | 6 | 2 | 0 | 0 | 0 | 2 | 6 | 10 | 99 | 99 |
| 2.0 | 0.0 | 30 | 0 | 1 | 1 | 0 | 2 | 6 | 2 | 0 | 3 | 2 | 0 | 6 | 13 | 99 | 99 |
| 2.0 | 0.0 | 30 | 0 | 1 | 1 | 1 | 3 | 6 | 2 | 0 | 3 | 2 | 2 | 6 | 15 | 99 | 99 |
| | | | | | | | | | | | | | | | | | |
| 2.0 | 0.0 | 30 | 60 | 0 | 0 | 0 | 0 | 6 | 2 | 3 | 0 | 0 | 0 | 6 | 11 | 99 | 99 |
| 2.0 | 0.0 | 30 | 60 | 1 | 0 | 0 | 1 | 6 | 2 | 3 | 3 | 0 | 0 | 6 | 14 | 99 | 99 |
| 2.0 | 0.0 | 30 | 60 | 0 | 1 | 0 | 1 | 6 | 2 | 3 | 0 | 2 | 0 | 6 | 13 | 99 | 99 |
| 2.0 | 0.0 | 30 | 60 | 0 | 0 | 1 | 1 | 6 | 2 | 3 | 0 | 0 | 2 | 6 | 13 | 99 | 99 |
| 2.0 | 0.0 | 30 | 60 | 1 | 1 | 0 | 2 | 6 | 2 | 3 | 3 | 2 | 0 | 6 | 16 | 99 | 99 |
| 2.0 | 0.0 | 30 | 60 | 1 | 1 | 1 | 3 | 6 | 2 | 3 | 3 | 2 | 2 | 6 | 18 | 99 | 99 |
| | | | | | | | | | | | | | | | | | |
| 2.0 | 0.0 | 45 | 0 | 0 | 0 | 0 | 0 | 6 | 4 | 0 | 0 | 0 | 0 | 6 | 10 | 99 | 99 |
| 2.0 | 0.0 | 45 | 0 | 1 | 0 | 0 | 1 | 6 | 4 | 0 | 3 | 0 | 0 | 6 | 13 | 99 | 99 |
| 2.0 | 0.0 | 45 | 0 | 0 | 1 | 0 | 1 | 6 | 4 | 0 | 0 | 2 | 0 | 6 | 12 | 99 | 99 |

| *GMAX* | *VC* | *CMAX* | *PA* | *FEM* | *KNE* | *TIB* | *NUM* | *HP* | *ThP* | *AP* | *F* | *K* | *T* | *MAIS* | *TAIS* | *POF* | $IC_n$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2.0 | 0.0 | 45 | 0 | 0 | 0 | 1 | 1 | 6 | 4 | 0 | 0 | 0 | 2 | 6 | 12 | 99 | 99 |
| 2.0 | 0.0 | 45 | 0 | 1 | 1 | 0 | 2 | 6 | 4 | 0 | 3 | 2 | 0 | 6 | 15 | 99 | 99 |
| 2.0 | 0.0 | 45 | 0 | 1 | 1 | 1 | 3 | 6 | 4 | 0 | 3 | 2 | 2 | 6 | 17 | 99 | 99 |
| | | | | | | | | | | | | | | | | | |
| 2.0 | 0.0 | 45 | 60 | 0 | 0 | 0 | 0 | 6 | 4 | 3 | 0 | 0 | 0 | 6 | 13 | 99 | 99 |
| 2.0 | 0.0 | 45 | 60 | 1 | 0 | 0 | 1 | 6 | 4 | 3 | 3 | 0 | 0 | 6 | 16 | 99 | 99 |
| 2.0 | 0.0 | 45 | 60 | 0 | 1 | 0 | 1 | 6 | 4 | 3 | 0 | 2 | 0 | 6 | 15 | 99 | 99 |
| 2.0 | 0.0 | 45 | 60 | 0 | 0 | 1 | 1 | 6 | 4 | 3 | 0 | 0 | 2 | 6 | 15 | 99 | 99 |
| 2.0 | 0.0 | 45 | 60 | 1 | 1 | 0 | 2 | 6 | 4 | 3 | 3 | 2 | 0 | 6 | 18 | 99 | 99 |
| 2.0 | 0.0 | 45 | 60 | 1 | 1 | 1 | 3 | 6 | 4 | 3 | 3 | 2 | 2 | 6 | 20 | 99 | 99 |
| | | | | | | | | | | | | | | | | | |
| 2.0 | 0.0 | 60 | 0 | 0 | 0 | 0 | 0 | 6 | 6 | 0 | 0 | 0 | 0 | 6 | 12 | 100 | 100 |
| 2.0 | 0.0 | 60 | 0 | 1 | 0 | 0 | 1 | 6 | 6 | 0 | 3 | 0 | 0 | 6 | 15 | 100 | 100 |
| 2.0 | 0.0 | 60 | 0 | 0 | 1 | 0 | 1 | 6 | 6 | 0 | 0 | 2 | 0 | 6 | 14 | 100 | 100 |
| 2.0 | 0.0 | 60 | 0 | 0 | 0 | 1 | 1 | 6 | 6 | 0 | 0 | 0 | 2 | 6 | 14 | 100 | 100 |
| 2.0 | 0.0 | 60 | 0 | 1 | 1 | 0 | 2 | 6 | 6 | 0 | 3 | 2 | 0 | 6 | 17 | 100 | 100 |
| 2.0 | 0.0 | 60 | 0 | 1 | 1 | 1 | 3 | 6 | 6 | 0 | 3 | 2 | 2 | 6 | 19 | 100 | 100 |
| | | | | | | | | | | | | | | | | | |
| 2.0 | 0.0 | 60 | 60 | 0 | 0 | 0 | 0 | 6 | 6 | 3 | 0 | 0 | 0 | 6 | 15 | 100 | 100 |
| 2.0 | 0.0 | 60 | 60 | 1 | 0 | 0 | 1 | 6 | 6 | 3 | 3 | 0 | 0 | 6 | 18 | 100 | 100 |
| 2.0 | 0.0 | 60 | 60 | 0 | 1 | 0 | 1 | 6 | 6 | 3 | 0 | 2 | 0 | 6 | 17 | 100 | 100 |
| 2.0 | 0.0 | 60 | 60 | 0 | 0 | 1 | 1 | 6 | 6 | 3 | 0 | 0 | 2 | 6 | 17 | 100 | 100 |
| 2.0 | 0.0 | 60 | 60 | 1 | 1 | 0 | 2 | 6 | 6 | 3 | 3 | 2 | 0 | 6 | 20 | 100 | 100 |
| 2.0 | 0.0 | 60 | 60 | 1 | 1 | 1 | 3 | 6 | 6 | 3 | 3 | 2 | 2 | 6 | 22 | 100 | 100 |
| | | | | | | | | | | | | | | | | | |
| 2.0 | 1.5 | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 3 | 0 | 0 | 0 | 0 | 6 | 9 | 99 | 99 |
| 2.0 | 1.5 | 0 | 0 | 1 | 0 | 0 | 1 | 6 | 3 | 0 | 3 | 0 | 0 | 6 | 12 | 99 | 99 |
| 2.0 | 1.5 | 0 | 0 | 0 | 1 | 0 | 1 | 6 | 3 | 0 | 0 | 2 | 0 | 6 | 11 | 99 | 99 |
| 2.0 | 1.5 | 0 | 0 | 0 | 0 | 1 | 1 | 6 | 3 | 0 | 0 | 0 | 2 | 6 | 11 | 99 | 99 |
| 2.0 | 1.5 | 0 | 0 | 1 | 1 | 0 | 2 | 6 | 3 | 0 | 3 | 2 | 0 | 6 | 14 | 99 | 99 |
| 2.0 | 1.5 | 0 | 0 | 1 | 1 | 1 | 3 | 6 | 3 | 0 | 3 | 2 | 2 | 6 | 16 | 99 | 99 |
| | | | | | | | | | | | | | | | | | |
| 2.0 | 1.5 | 0 | 60 | 0 | 0 | 0 | 0 | 6 | 3 | 3 | 0 | 0 | 0 | 6 | 12 | 99 | 99 |
| 2.0 | 1.5 | 0 | 60 | 1 | 0 | 0 | 1 | 6 | 3 | 3 | 3 | 0 | 0 | 6 | 15 | 99 | 99 |
| 2.0 | 1.5 | 0 | 60 | 0 | 1 | 0 | 1 | 6 | 3 | 3 | 0 | 2 | 0 | 6 | 14 | 99 | 99 |
| 2.0 | 1.5 | 0 | 60 | 0 | 0 | 1 | 1 | 6 | 3 | 3 | 0 | 0 | 2 | 6 | 14 | 99 | 99 |
| 2.0 | 1.5 | 0 | 60 | 1 | 1 | 0 | 2 | 6 | 3 | 3 | 3 | 2 | 0 | 6 | 17 | 99 | 99 |
| 2.0 | 1.5 | 0 | 60 | 1 | 1 | 1 | 3 | 6 | 3 | 3 | 3 | 2 | 2 | 6 | 19 | 99 | 99 |
| | | | | | | | | | | | | | | | | | |
| 2.0 | 2.5 | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 6 | 0 | 0 | 0 | 0 | 6 | 12 | 100 | 100 |
| 2.0 | 2.5 | 0 | 0 | 1 | 0 | 0 | 1 | 6 | 6 | 0 | 3 | 0 | 0 | 6 | 15 | 100 | 100 |
| 2.0 | 2.5 | 0 | 0 | 0 | 1 | 0 | 1 | 6 | 6 | 0 | 0 | 2 | 0 | 6 | 14 | 100 | 100 |
| 2.0 | 2.5 | 0 | 0 | 0 | 0 | 1 | 1 | 6 | 6 | 0 | 0 | 0 | 2 | 6 | 14 | 100 | 100 |
| 2.0 | 2.5 | 0 | 0 | 1 | 1 | 0 | 2 | 6 | 6 | 0 | 3 | 2 | 0 | 6 | 17 | 100 | 100 |
| 2.0 | 2.5 | 0 | 0 | 1 | 1 | 1 | 3 | 6 | 6 | 0 | 3 | 2 | 2 | 6 | 19 | 100 | 100 |
| | | | | | | | | | | | | | | | | | |
| 2.0 | 2.5 | 0 | 60 | 0 | 0 | 0 | 0 | 6 | 6 | 3 | 0 | 0 | 0 | 6 | 15 | 100 | 100 |

| *GMAX* | *VC* | *CMAX* | *PA* | *FEM* | *KNE* | *TIB* | *NUM* | *HP* | *ThP* | *AP* | *F* | *K* | *T* | *MAIS* | *TAIS* | *POF* | $IC_n$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2.0 | 2.5 | 0 | 60 | 1 | 0 | 0 | 1 | 6 | 6 | 3 | 3 | 0 | 0 | 6 | 18 | 100 | 100 |
| 2.0 | 2.5 | 0 | 60 | 0 | 1 | 0 | 1 | 6 | 6 | 3 | 0 | 2 | 0 | 6 | 17 | 100 | 100 |
| 2.0 | 2.5 | 0 | 60 | 0 | 0 | 1 | 1 | 6 | 6 | 3 | 0 | 0 | 2 | 6 | 17 | 100 | 100 |
| 2.0 | 2.5 | 0 | 60 | 1 | 1 | 0 | 2 | 6 | 6 | 3 | 3 | 2 | 0 | 6 | 20 | 100 | 100 |
| 2.0 | 2.5 | 0 | 60 | 1 | 1 | 1 | 3 | 6 | 6 | 3 | 3 | 2 | 2 | 6 | 22 | 100 | 100 |
| | | | | | | | | | | | | | | | | | |
| 2.0 | 3.0 | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 6 | 0 | 0 | 0 | 0 | 6 | 12 | 100 | 100 |
| 2.0 | 3.0 | 0 | 0 | 1 | 0 | 0 | 1 | 6 | 6 | 0 | 3 | 0 | 0 | 6 | 15 | 100 | 100 |
| 2.0 | 3.0 | 0 | 0 | 0 | 1 | 0 | 1 | 6 | 6 | 0 | 0 | 2 | 0 | 6 | 14 | 100 | 100 |
| 2.0 | 3.0 | 0 | 0 | 0 | 0 | 1 | 1 | 6 | 6 | 0 | 0 | 0 | 2 | 6 | 14 | 100 | 100 |
| 2.0 | 3.0 | 0 | 0 | 1 | 1 | 0 | 2 | 6 | 6 | 0 | 3 | 2 | 0 | 6 | 17 | 100 | 100 |
| 2.0 | 3.0 | 0 | 0 | 1 | 1 | 1 | 3 | 6 | 6 | 0 | 3 | 2 | 2 | 6 | 19 | 100 | 100 |
| | | | | | | | | | | | | | | | | | |
| 2.0 | 3.0 | 0 | 60 | 0 | 0 | 0 | 0 | 6 | 6 | 3 | 0 | 0 | 0 | 6 | 15 | 100 | 100 |
| 2.0 | 3.0 | 0 | 60 | 1 | 0 | 0 | 1 | 6 | 6 | 3 | 3 | 0 | 0 | 6 | 18 | 100 | 100 |
| 2.0 | 3.0 | 0 | 60 | 0 | 1 | 0 | 1 | 6 | 6 | 3 | 0 | 2 | 0 | 6 | 17 | 100 | 100 |
| 2.0 | 3.0 | 0 | 60 | 0 | 0 | 1 | 1 | 6 | 6 | 3 | 0 | 0 | 2 | 6 | 17 | 100 | 100 |
| 2.0 | 3.0 | 0 | 60 | 1 | 1 | 0 | 2 | 6 | 6 | 3 | 3 | 2 | 0 | 6 | 20 | 100 | 100 |
| 2.0 | 3.0 | 0 | 60 | 1 | 1 | 1 | 3 | 6 | 6 | 3 | 3 | 2 | 2 | 6 | 22 | 100 | 100 |

# Annex G
(informative)

# Probability distribution curves

The probability distribution of head injuries as a function of maximum GAMBIT is given in Figure G.1. The probability distribution of thoracic injury severity as a function of mid-sternum compression is given in Figure G.2. The probability distribution of thoracic injuries as a function of mid-sternum velocity-compression is given in Figure G.3. The probability distribution of abdominal injuries as a function of abdomen penetration is given in Figure G.4. The probability distribution of neck injuries as a function of maximum *NII* is given in Figure G.5.

References cited in Annex G are listed in Annex B of ISO 13232-1.

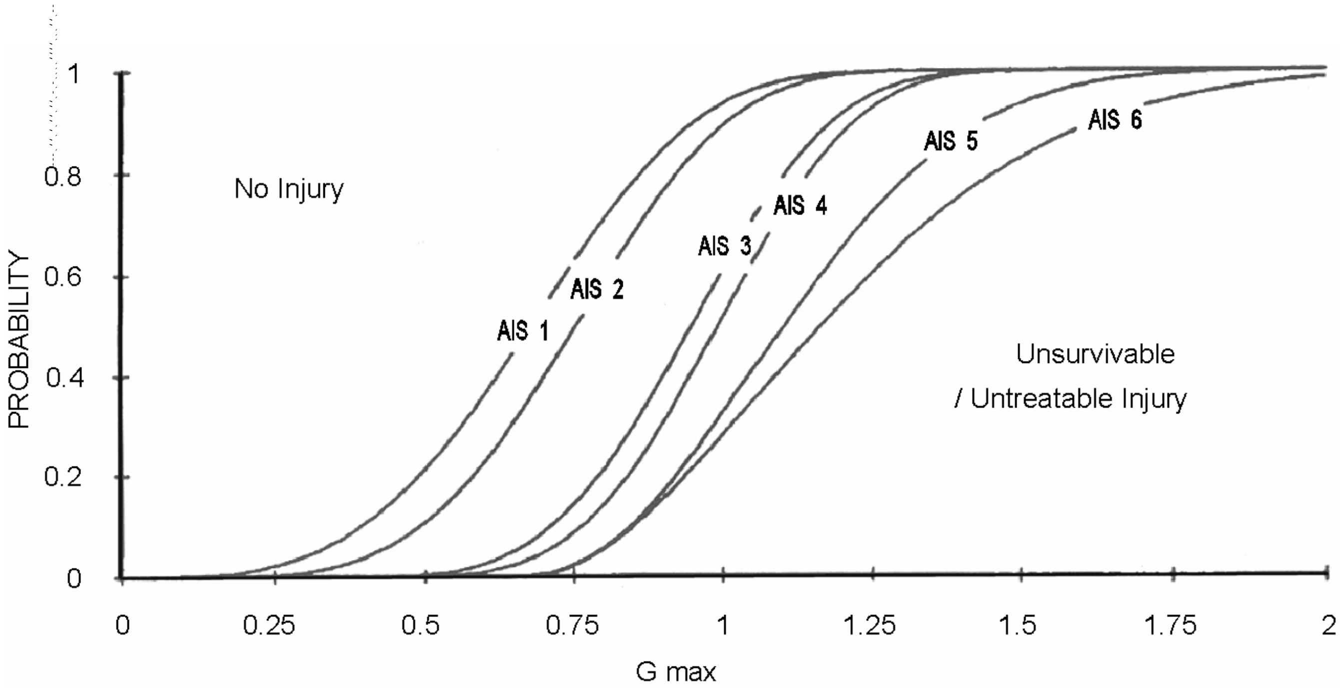


**Figure G.1 — Probability distribution of head injuries as a function of $G_{max}$ (Kramer & Appel, 1990)**

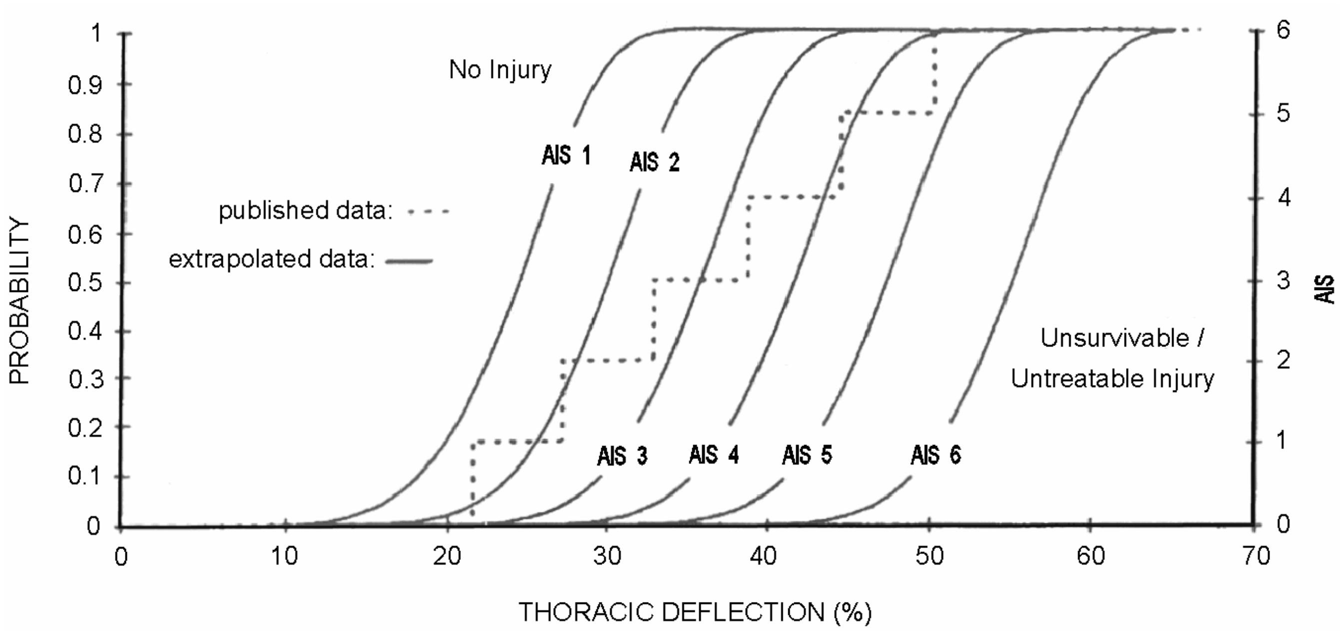


**Figure G.2 — Probability distribution of thoracic injury as a function of maximum resultant upper (or lower) sternum compression (Kroell, et al., 1974)**

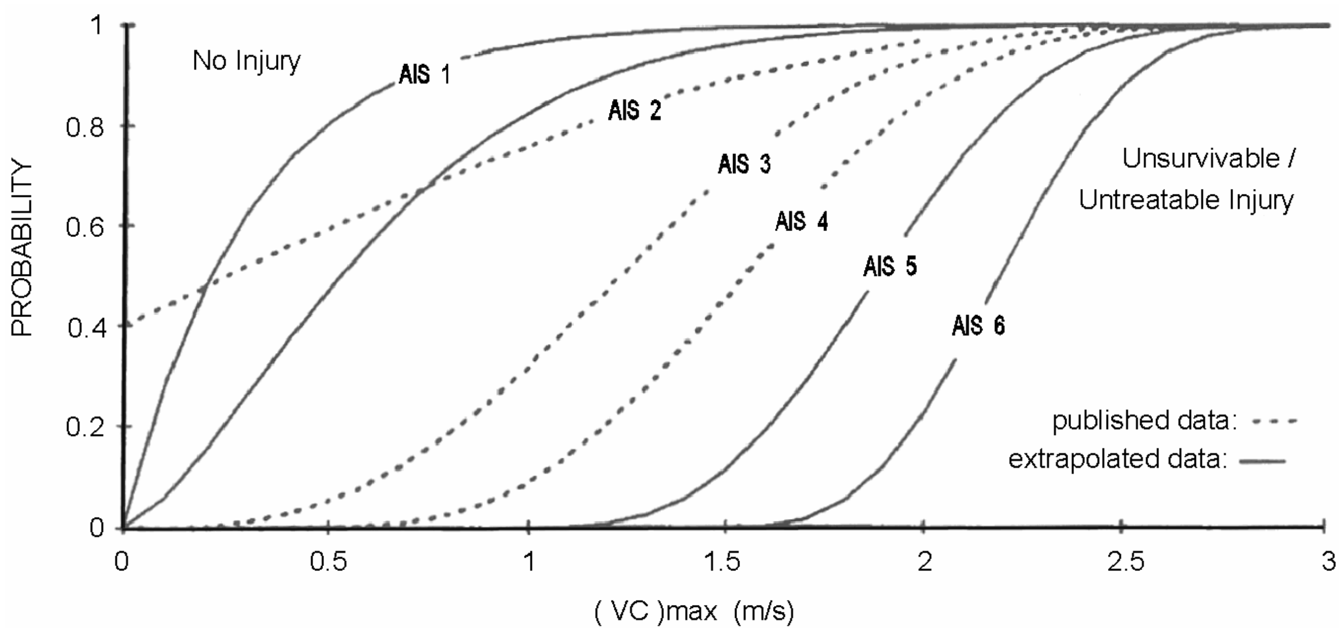


**Figure G.3 — Probability distribution of thoracic injuries as a function of maximum resultant upper (or lower) sternum velocity-compression (Lowne & Janssen, 1990)**

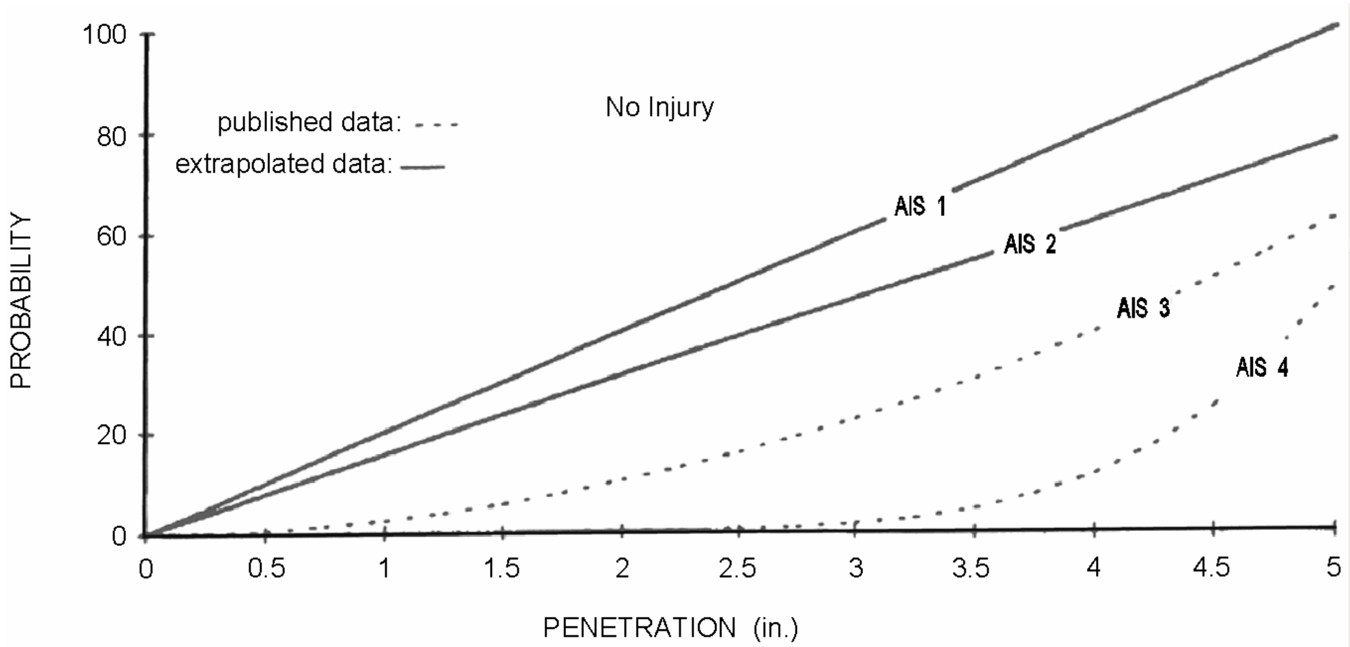


**Figure G.4 — Probability distribution of human abdominal injuries as a function of maximum human abdominal penetration (Rouhana, et al., 1990)**

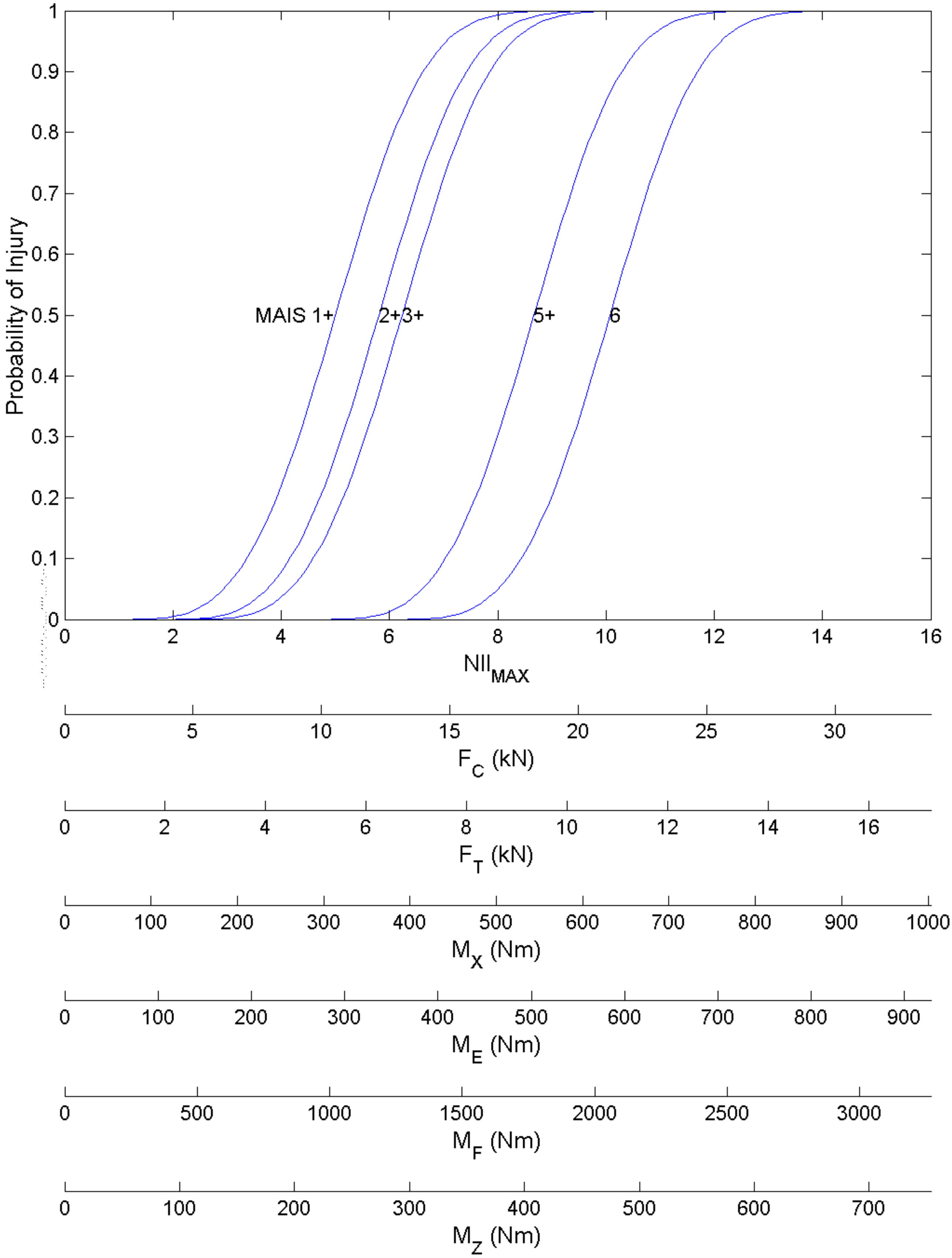


**Figure G.5 — Probability distribution of neck injury as a function of $NII_{max}$**

NOTE The horizontal axis scales other than $NII_{max}$ assume that all other forces other than the denoted force are zero.

# Annex H
(informative)

# Example cumulative distribution function plots

## H.1 Principle

Example cumulative distribution function graphs for change in injury assessment variables or injury indices due to the protective device.

## H.2 Procedure

Plot the cumulative distribution functions calculated in 5.9.3 for each of the injury assessment variables listed in Table 10 as shown in Figure H.1. Plot the cumulative distribution functions calculated in 5.9.3 for each of the injury indices listed in Table 10 as shown in Figure H.2.

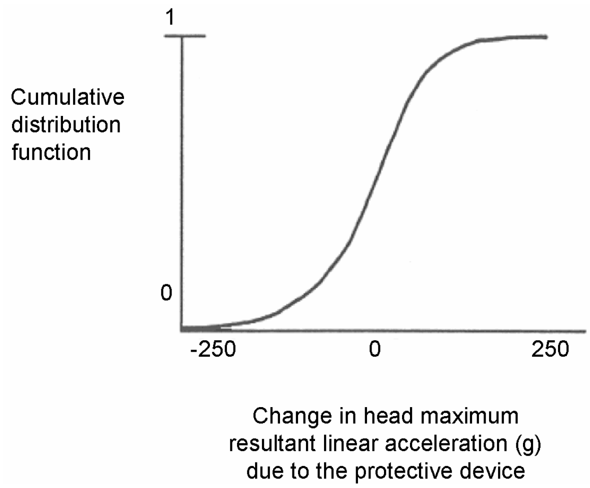


**Figure H.1 — Example of a continuous cumulative distribution function graph for change in an injury assessment variable**

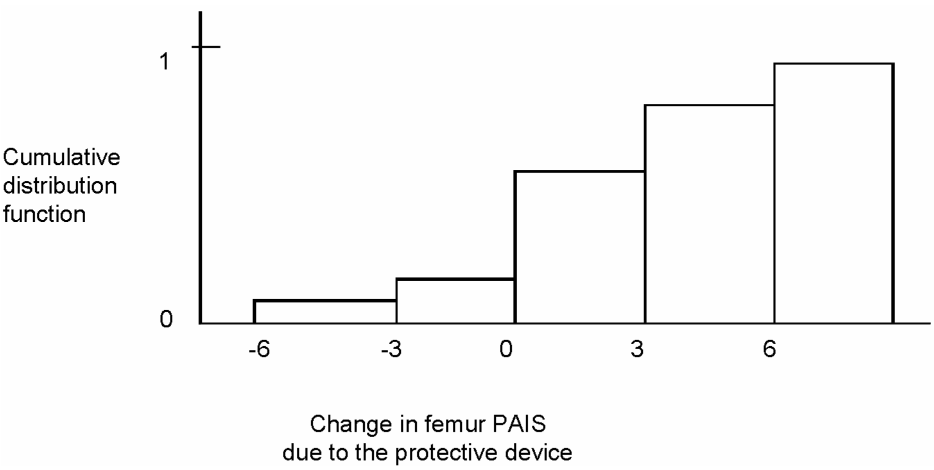


**Figure H.2 — Example of a discrete cumulative distribution function graph for change in an injury index**

# Annex I
(informative)

# Example computer code for calculations of head contacts

```
C     **********************************************************************
      PROGRAM CONTACT
C     ----------------------------------------------------------------------
C     Programme CONTACT
C     But: DÈterminer le temps de contact de la tÍte pour ensuite
C         calculer le HIC sur cette pÈriode. ¿ noter qu'il peut y
C         voir plusieurs temps de contact et qu'ainsi plusieurs HIC
C         peut Ítre calculÈs.
C
C     Version (1.0) 01-mai-92    Version basÈe sur un papier
C                                Test Device Head Contact Duration Analysis
C                                et sur la convention de signes SAE J211
C     Version (1.1) 09-sep-92    Version traitant 4 boites
C     ----------------------------------------------------------------------

      REAL*4 Y(4096),YY(4096),ZSAUT
      INTEGER*2 ICH,IUN,GROUPE(4),CHAN(4,6),UNIT(4,6)! 4 Groupes ‡ vÈrifier
      CHARACTER*1 COMD
      INTEGER*2 TYPE_MANNEQUIN
      CHARACTER*8 MANQIN(12)
      DATA MANQIN /'PART 572','HYB III ','HYB IIIe','EUROSID ',
     :'USSID   ','Inconnu ','BIOSID  ','EUROSID1','HYB IIIm',
     :'3ANS-YRS','6ANS-YRS','9 kg    '/
      COMMON /CANCOM/ ICH(40),IUN(40),TYPE_MANNEQUIN(40)
      INTEGER*2 HICCHN,PULTIM,PULPTS,HICT1,HICT2
      COMMON /HICDAT/ HICCHN,PULTIM,PULPTS,HICT1,HICT2,
     :          SUPHIC,AMPLT1,AMPLT2,AMPMAX,AMPBAR
      REAL*8 TABHIC(4,3),TABT1(4,3),TABT2(4,3),MAXTAB1,MAXTAB2,MAXHIC

      CHARACTER*12 TITLE(4)
      DATA TITLE /'DRIVHEAD.CNT','PASSHEAD.CNT','PAS1HEAD.CNT',
     :        'PAS2HEAD.CNT'/
      CHARACTER*80 MESS
C     ----------------------------------------------------------------------
C     Variables globales
C     ----------------------------------------------------------------------
      REAL*8  LBL,PLBL,ALBL
      REAL*4  VTBL,WTBL
      REAL*4  TBL(50,3),UNITS(50)

      INTEGER*2 ADRES,ITBL,DTBL,IDUM(78)
      INTEGER*2 FCLASS(50),ICON(10),IBOITE
      INTEGER   NCHAN,ITE(500),ITD(500)

      LOGICAL*1 INGENR(16),TECHCN(16),CLIENT(32)
      LOGICAL*1 TITRE(32),CONTRT(16),TEXT
      LOGICAL*1 CDATE,ADATE,AUTO,PROG,TCNO

      COMMON /LABELS/ PLBL(2,30)
      COMMON /MATHEM/ VTBL(10),DTBL(10),ITBL(10),WTBL(10),
     :          NCHS,LCHN,NVECS,NDIFS,NINTS,NCHAN,IDUZ
```

```
      COMMON /PARAMS/ SAMPRT,PRETRG,CDATE(9),ADATE(9),PROG(6),
     :          TCNO(6),AUTO(16)
      COMMON /PLTPAR/ LBL(2,50),ALBL(2,50)
      CHARACTER*6   CVTCNO           ! pour encoder le no. de T.C.

      REAL FACTEUR_MASSE
      COMMON /FACCOM/ FACTEUR_MASSE
C     ***********************************************************************
C     Debut du programme
C     ***********************************************************************

      CALL ERRSET(63,.TRUE.,.FALSE.,.TRUE.,.FALSE.,)
      CALL CHECK(NCAN,IGO)           ! VÈrifier o˘ sont les canaux
      IF (IGO.EQ.0) GOTO 1000        ! CHECK.CFG n'existe pas

C     -------------------------------------------------------------------
C     Ouvrir un fichier contenant les rÈsultant de CONTACT
C     -------------------------------------------------------------------
      CALL ASSIGN(12,'CONTACT.DAT')

C     -------------------------------------------------------------------
C     VÈrifier si les groupes a traiter sont valides
C     -------------------------------------------------------------------
      DO 10 I=1,4                    ! Boucler sur le nbre de groupes
        ISUM=0                       ! Initialiser somme pour ch. gr.
        DO 11 J=1,3                      ! Boucler sur les canaux de tete
          IF (ICH(J+(I*9-9)).NE.0) THEN  ! Canaux de tete
            ISUM=ISUM+1                  ! IncrÈ. ISUM si canal trouvÈ
            CHAN(I,J)=ICH(J+(I*9-9))! Retenir le no du canal
           UNIT(I,J)=IUN(J+(I*9-9))  ! Retenir le no d'unitÈ logique
          ENDIF                      ! Fin de test sur tete
11      CONTINUE                         ! Fin de la boucle
        DO 12 J=4,6                      ! Boucler sur les canaux du cou
          IF(ICH(J+(I*9-9)).NE.0) THEN   ! Canaux du cou (vieux titres)
           ISUM=ISUM+1                   ! IncrÈ. ISUM si canal trouvÈ
            GROUPE(I)=1                  ! 1 pour vieux titres
            CHAN(I,J)=ICH(J+(I*9-9))! Retenir le no du canal
           UNIT(I,J)=IUN(J+(I*9-9))  ! Retenir le no d'unitÈ logique
          ELSE IF(ICH(J+(I*9-9)+3).NE.0) THEN ! Canaux cou: nouveaux titres
           ISUM=ISUM+1                   ! IncrÈ. ISUM si canal trouvÈ
            GROUPE(I)=2                  ! 2 pour nouveaux titres
            CHAN(I,J)=ICH(J+(I*9-9)+3)   ! Retenir le no du canal
           UNIT(I,J)=IUN(J+(I*9-9)+3)    ! Retenir le no d'unitÈ logique
          ENDIF                      ! Fin du test sur canaux 4 @ 9
12      CONTINUE                         ! Fin de boucle canaux du cou
        IF(ISUM.NE.6) GROUPE(I)=0             ! Si groupe courant pas 6 can.=0
10    CONTINUE                       ! Fin de la boucle par groupe

C     -------------------------------------------------------------------
C     Calcul de la force externe rÈsultante de la tÍte pour chaque groupe
C     -------------------------------------------------------------------
      IFOIS=0                        ! Aucun graphique de trace
      IBOUK=0                            ! Pas de carrÈ
      IPAGE=0                            ! No du pied de page
      DO 1 IL=1,4                    ! Boucler sur 4 titres possibles
        IF(GROUPE(IL).EQ.0) THEN         ! Groupe incomplet
          TABHIC(IL,1)=-1.0              ! Donc Non/Applicable
          GOTO 1                     ! Boucler ‡ nouveau
        ENDIF                    ! Fin de test de groupe
        IBOUK=IBOUK+1                    ! Nbre de carrÈ ds CONTACT.X
```

```
      IGRP=GROUPE(IL)             ! Le type de groupe
      CALL FORCE_EXT(IL,IGRP,Y,TITRE,CHAN,UNIT)! Cal. force
C                 _______________________Maximum
C                /    ___________________Minimum
C               /   /    _______________Echelle (+)
C              /   /   /    ___________Echelle (-)
C             /   /   /   /     ______Temps du max
C            /   /   /   /    /   ___Temps du min
C           /   /   /   /    /  /
      CALL DSCALE(Y,YMAX,YMIN,IMAX,IMIN,KMX,KMN,IDIV,IUNIT)
      IMIN=0                     ! Forcer les Èchelles 0 @ max

C     ----------------------------------------------------------------
C     Calcul des temps d'engagement et de desengagement t(e) et t(d)
C     ----------------------------------------------------------------

      DO KJ=1,500                 ! Boucler sur le nombre temps
        ITE(KJ)=0                 ! Initialiser tous les TE
        ITD(KJ)=0                 ! Initialiser tous les TD
      ENDDO                      ! Fin de boucle TE TD

      CALL TEMPS_ENGAGE(Y,ITE,ITD)          ! Calculer tous les Te et Td

C     ----------------------------------------------------------------
C     …valuer tous les HIC pour tous les TE et TD trouvÈs
C     ----------------------------------------------------------------
      IUNIT=IUN(36+IL)            ! No de l'unitÈ logique de RES
      KKK=ICH(36+IL)              ! No ducanal de la RESULTANTE

      ZMAX=0.0
      DO 110 KI=1,500             ! Boucler sur possibilitÈ de 500
        IF(ITE(KI).EQ.0.OR.ITD(KI).EQ.0) GOTO 110! Fini, plus de TE et TD
        INT=ITD(KI)-ITE(KI)       ! Intervalle maximun pour HIC
        CALL LOCATE(9,22,'CONTACT Ètudie l''intervalle suivant')
        TYPE 312,ITE(KI),ITD(KI)
        IF(INT.LE.10) GOTO 110
        CALL HICSUB(KKK,TABT1,TABT2,TABHIC,IL,IBOUK,IUNIT,INT,
    :ITE(KI))
        IF(SUPHIC.GT.ZMAX) THEN           ! Tester si on a un HIC max
          MAXTAB1=TABT1(IL,1)
          MAXTAB2=TABT2(IL,1)
           MAXHIC=TABHIC(IL,1)
           ZMAX=SUPHIC            ! Retenir le HIC max
          ITT1=HICT1              ! Le temps T1
           ITT2=HICT2             ! et le temps T2
          ITTE=ITE(KI)            ! Enregistrer le Te corresp.
          ITTD=ITD(KI)            ! Et le Td correspondant.
        ENDIF                    ! Fin de test sur HIC max
        CALL CLS(8,1)             ! Efacer a partir de (4,1)
110   CONTINUE                    ! Fin de boucle sur Te,Td poss.
      TABT1(IL,1)=MAXTAB1              ! Tabuler le T1 max
      TABT2(IL,1)=MAXTAB2              ! Tabuler le T2 max
      TABHIC(IL,1)=MAXHIC              ! Tabuler le HIC max
C     ----------------------------------------------------------------
C     Tracer le rÈsultats
C     ----------------------------------------------------------------

      IPAGE=IPAGE+1               ! IncrÈm. le no de pied de page
      CALL IMP_CONTACT(Y,IMIN,IMAX,IDIV,IPAGE,
    :PRETRG,SAMPRT,TITRE,AUTO,TCNO,CDATE,ITTE,ITTD,IL)
```

```
      IFOIS=1                          ! Au moins un graphe de trace

C     ----------------------------------------------------------------
C     CrÈer un fichier ASCII avec le FORCE de contact courante
C     ----------------------------------------------------------------
      CALL ASSIGN(8,TITLE(IL),12)            ! Ouvrir 1 fichier= nom du canal
      DO JK=1,4000                     ! Boucler sur nbre de points
        WRITE(8,404)Y(JK)                ! Ecrire le data dans le fichier
      ENDDO                            ! Fin de la boucle
      CALL CLOSE(8)                    ! Fermer le fichier Data
1    CONTINUE                          ! Fin de la boucle
C    -----------------------------------------------------------------
C    …crire les rÈsultats dans CONTACT.DAT
C    -----------------------------------------------------------------
     DO JJ=1,4
       WRITE(12,466) TABHIC(JJ,1),TABT1(JJ,1),TABT2(JJ,1)
     ENDDO

C    -----------------------------------------------------------------
C    CrÈation d'un nouveau rÈpertoire
C    -----------------------------------------------------------------
     IF(IFOIS.EQ.0) THEN
      CALL CLS(2,1)
      CALL LOCATE(12,18,'Il manque des canaux pour calculer CONTACT')
      WRITE(66,*)'Il manque des canaux pour calculer CONTACT'
      GOTO 1000
     ENDIF
     ENCODE (6,350,CVTCNO) TCNO  ! encoder le no. de T.C.
     CALL NEW_DIRECTORY(CVTCNO,'CNT')
C    ------------------------------------------------------------------
C    Fin du programme CONTACT
C    ------------------------------------------------------------------
     CALL PLOT(0.0,0.0,10)                ! …jecter la derniËre page
     CALL EXCLLN                       ! Retour en LN03
     CALL PLOT(0.0,0.0,999)               ! Fin du dessin
     CALL FUNMCR('PRINT /NONOTIFY CONTACT.X')
1000      CALL FUNMCR('REPLY /NONOTIFY/TERM=(OPA0) "FIN DE CONTACT 1.1"')

312 FORMAT(30X,'Te:',i4,5x,'Td:',i4)
350 FORMAT(6A1)
404 FORMAT(1X,F20.6)               ! Format Dainius
466 FORMAT(1X,F7.2,1X,F6.4,1X,F6.4)
     STOP 'CONTACT terminÈ'
     END

C    ************************************************************************
C         No du groupe   Type de groupe   UnitÈ logique du groupe
C                \  /              /
     SUBROUTINE FORCE_EXT(K,IGR,F,TITRE,CHAN,UNIT)
C                    /   \     \
C               Data Res     \  No des canaux du groupe
C                     Titre de l'essai
C
C    Version: 1.0         6-Mai-92Alain Caron,ing
C
C    But: Calculer la force externe resultante de la tete selon:
C
C          ______________________________________________________
C      F=  / [(Ma(x)-Fx)**2  + (Ma(y)-Fy)**2 + (Ma(z)-Fz)**2]
C         \/
```

```
C    M : la masse de la tete = 4500 grammes (Fourni par R.M)
C    a(x), a(y) et a(z): les accÈlÈration de la tÍte dans les 3 axes
C    Fx,Fy et Fz      : les forces du cou (pour les signes voir SAE J211)
C    F                : la force rÈsultante
C    *********************************************************************

     REAL*4 Y(4096),Z(4096),F(4096),MASSE,G
     INTEGER*2 ICH,IUN,IGR,CHAN(4,6),UNIT(4,6)
     INTEGER*2 TYPE_MANNEQUIN
     CHARACTER*8 MANQIN(12)
     DATA MANQIN /'PART 572','HYB III ','HYB IIIe','EUROSID ',
    :'USSID   ','Inconnu ','BIOSID  ','EUROSID1','HYB IIIm',
    :'3ANS-YRS','6ANS-YRS','9 kg    '/
     COMMON /CANCOM/ ICH(40),IUN(40),TYPE_MANNEQUIN(40)
     REAL FACTEUR_MASSE
     COMMON /FACCOM/ FACTEUR_MASSE
C    ---------------------------------------------------------------------
C    Variables globales
C    ---------------------------------------------------------------------
     REAL*8  LBL,PLBL,ALBL
     REAL*4  VTBL,WTBL
     REAL*4  TBL(50,3),UNITS(50)

     INTEGER*2 ADRES,ITBL,DTBL,IDUM(78)
     INTEGER*2 FCLASS(50),ICON(10),IBOITE
     INTEGER  NCHAN

     LOGICAL*1 INGENR(16),TECHCN(16),CLIENT(32)
     LOGICAL*1 TITRE(32),CONTRT(16),TEXT
     LOGICAL*1 CDATE,ADATE,AUTO,PROG,TCNO

     COMMON /LABELS/ PLBL(2,30)
     COMMON /MATHEM/ VTBL(10),DTBL(10),ITBL(10),WTBL(10),
    :            NCHS,LCHN,NVECS,NDIFS,NINTS,NCHAN,IDUZ
     COMMON /PARAMS/ SAMPRT,PRETRG,CDATE(9),ADATE(9),PROG(6),
    :            TCNO(6),AUTO(16)
     COMMON /PLTPAR/ LBL(2,50),ALBL(2,50)

C    =========================================================================
C    DÈbut de la sous-routine
C    =========================================================================
     MASSE=4.500                    ! Masse en kilogramme
     FACTEUR_MASSE=1.0                   ! Tete adulte
     IF(TYPE_MANNEQUIN(36+K).EQ.12) MASSE=2.106915 ! i.e 4.65 LB x 0.4531 kg
     IF(TYPE_MANNEQUIN(36+K).EQ.12) FACTEUR_MASSE=2.106915/4.5
     G=9.80665                 ! Conversion de G en m/s**2
     CALL CLS(3,1)                  ! Effacer l'ecran
     CALL LOCATE(6,27,'Type de mannequin utilisÈ:')
     TYPE 299,MANQIN(TYPE_MANNEQUIN(36+K))
     CALL LOCATE(8,32,'Masse utilisÈe:')
     TYPE 399,MASSE
399 FORMAT(34X,F8.6,' kg')
299 FORMAT(36X,A8)
     CALL DELAIS(2.0)               ! Afficher pendant 2 sec.
C    ---------------------------------------------------------------------
C    Lire ‡ partir du numÈro de groupe le TITRE,AUTO,TCNO et CDATE
C    ---------------------------------------------------------------------

     IUNIT=UNIT(K,1)                ! Acc de la tete en X du groupe
     READ(IUNIT,REC=1)
```

```
     : ((TBL(I,J),J=1,3),FCLASS(I),LBL(1,I),LBL(2,I),I=1,50),
     : SAMPRT,PRETRG,NCHS,LCHN,ADRES,NVECS,NINTS,NDIFS,(IDUM(I),I=1,5),
     : (VTBL(I),I=1,10),(DTBL(I),I=1,10),(ITBL(I),I=1,10),
     : (WTBL(I),I=1,10),(PLBL(1,I),PLBL(2,I),I=1,30),
     : CDATE,ADATE,PROG,TCNO,AUTO,INGENR,TECHCN,CLIENT,TITRE,CONTRT,
     : IDUM,NTEXT,(TEXT,I=1,3000),(ICON(I),I=1,10),IBOITE,
     : (ALBL(1,I),ALBL(2,I),UNITS(I),I=1,50)

C    ------------------------------------------------------------------
C    Calcul de la force F: Y=Acc tete x (m/sec**2), Z=Force du cou x
C    La constante gravitationnelle G = 9.80665 m/s**2
C    ------------------------------------------------------------------

     IKL=CHAN(K,1)*2                       ! No du canal Acc tete x
     IUNIT=UNIT(K,1)                   ! UnitÈ logique de Acc tete x
     READ(IUNIT'IKL)(Y(I),I=1,2048)           ! 1/2 du canal
     READ(IUNIT'IKL+1)(Y(I),I=2049,4096)   ! 2/2 DU CANAL

     IKL=CHAN(K,4)*2                       ! No du canal COU FX
     IUNIT=UNIT(K,4)                   ! UnitÈ logique COU FX
     READ(IUNIT'IKL)(Z(I),I=1,2048)           ! 1/2 du canal
     READ(IUNIT'IKL+1)(Z(I),I=2049,4096)   ! 2/2 DU CANAL

     DO I=1,4096                    ! Boucler sur le nombre de pts
       Y(I)=MASSE*Y(I)*G                ! Multiplier l'acc par la masse
       F(I)=(Y(I)-Z(I))**2              ! Calculer la composante en X
     ENDDO                          ! Fin de la boucle
C    ------------------------------------------------------------------
C    Calcul de la force F: Y=Acc tete y (m/sec**2), Z=Force du cou y
C    ------------------------------------------------------------------

     IKL=CHAN(K,2)*2                       ! No du canal Acc tete y
     IUNIT=UNIT(K,2)                   ! UnitÈ logique de Acc tete y
     READ(IUNIT'IKL)(Y(I),I=1,2048)           ! 1/2 du canal
     READ(IUNIT'IKL+1)(Y(I),I=2049,4096)   ! 2/2 DU CANAL

     IKL=CHAN(K,5)*2                       ! No du canal COU FY
     IUNIT=UNIT(K,5)                   ! UnitÈ logique COU FY
C    IF(IGRP.EQ.2)IKL=CHAN(K,8)        ! No du canal HT COU FY
C    IF(IGRP.EQ.2)IUNIT=UNIT(K,8)           ! UnitÈ logique HT COU FY
     READ(IUNIT'IKL)(Z(I),I=1,2048)           ! 1/2 du canal
     READ(IUNIT'IKL+1)(Z(I),I=2049,4096)   ! 2/2 DU CANAL

     DO I=1,4096                    ! Boucler sur le nombre de pts
       Y(I)=MASSE*Y(I)*G                ! Multiplier l'acc par la masse
       F(I)=F(I)+(Y(I)-Z(I))**2         ! Calculer la composante en X+Y
     ENDDO                          ! Fin de la boucle

C    ------------------------------------------------------------------
C    Calcul de la force F: Y=Acc tete z (m/sec**2), Z=Force du cou z
C    ------------------------------------------------------------------

     IKL=CHAN(K,3)*2                       ! No du canal Acc tete z
     IUNIT=UNIT(K,1)                   ! UnitÈ logique de Acc tete z
     READ(IUNIT'IKL)(Y(I),I=1,2048)           ! 1/2 du canal
     READ(IUNIT'IKL+1)(Y(I),I=2049,4096)   ! 2/2 DU CANAL

     IKL=CHAN(K,6)*2                       ! No du canal COU FZ
     IUNIT=UNIT(K,6)                   ! UnitÈ logique COU FZ
C    IF(IGRP.EQ.2)IKL=CHAN(K,9)        ! No du canal HT COU FZ
```

```
C   IF(IGRP.EQ.2)IUNIT=UNIT(K,9)           ! UnitÈ logique HT COU FZ
    READ(IUNIT'IKL)(Z(I),I=1,2048)         ! 1/2 du canal
    READ(IUNIT'IKL+1)(Z(I),I=2049,4096)    ! 2/2 DU CANAL

    DO I=1,4096                   ! Boucler sur le nombre de pts
      Y(I)=MASSE*Y(I)*G               ! Multiplier l'acc par la masse
      F(I)=F(I)+(Y(I)-Z(I))**2        ! Calculer la compo. en X+Y+Z
    ENDDO                         ! Fin de la boucle

C   -------------------------------------------------------------------
C   La force rÈsultante est maintenant Ègale ‡
C   -------------------------------------------------------------------

    DO I=1,4096                   ! Boucler sur le nombre de pts
      F(I)=SQRT(F(I))             ! Calculer F rÈsultante
    ENDDO                         ! Fin de la boucle

    RETURN
    END

C***********************************************************************
C****DSCALE(CONTACT): SUBROUTINE TO SCALE Y-AXIS DATA FOR BARPLT
C       VERSION: 4.1 18-MAR-83   D. LABOCCETTA
C       Version: 4.2    07-MAI-92    A. Caron,ing
C       Version pour CONTACT
C                       ______________________Maximum
C                      /   ___________________Minimum
C                     /   /   ________________Echelle (+)
C                    /   /   /     _________Echelle (-)
C                   /   /   /   /  ______Temps du max
C                  /   /   /   /  /  ___Temps du min
C                 /   /   /   /  /  /
    SUBROUTINE DSCALE (Y,YMAX,YMIN,IMAX,IMIN,KMX,KMN,IDIV,IUNIT)
    INTEGER*2 ISCALE(15),DIVISE(15)
    REAL*4  Y(4096)
    DATA ISCALE/10,30,60,75,
  : 100,150,200,300,600,2000,3000,4500,
  : 10000,15000,20000/
    DATA DIVISE/4,3,4,3,4,3,4,3,4,4,3,3,4,3,4/
C-----------------------------------------------------------------------
C----Initialiser
C
    YMIN=999999.
    YMAX=-YMIN
C-----------------------------------------------------------------------
C----Evaluer le MAX et le MIN
C
20  DO 100 K=1,4000
      IF(YMAX.GE.Y(K))GO TO 30
        YMAX=Y(K)
        KMX=K
30    IF(YMIN.LE.Y(K))GO TO 100
        YMIN=Y(K)
        KMN=K
100 CONTINUE
C----------------------------------------------------------------------
C----Trouver l'echelle approprie
C
    YYY=YMAX
    IF(ABS(YMIN).GT.YYY)YYY=ABS(YMIN)
```

```
      DO 120 K=1,14
        SMAX=ISCALE(K)
        IDIV=DIVISE(K)
        IF(YYY.LT.SMAX)GO TO 125
120 CONTINUE
C----------------------------------------------------------------------
C----Finalement les resultats
C
125 IMAX=SMAX
      IMIN=-SMAX
C----------------------------------------------------------------------
C----Retour au programme principal
C
      RETURN
      END

C************************************************************************
C****IMPHIC: Sous-routine pour tracer sur imprimante le graphique qui a
C         servit pour calculer le HIC. Base sur la sous-routine UNSEUL
C         avec l'ajout de la sous-routine CANADA
C
C         Version: 1.0    30-JUL-86    A. Caron,ing
C         Version: 4.0    04-dec-89    M. Villeneuve, stagiaire
C         (Version pour le VAX/VMS)

      SUBROUTINE IMP_CONTACT(A,IMIN,IMAX,IDIV,IPAGE,
     :PRETRG,SAMPRT,TITRE,AUTO,TCNO,CDATE,ITTE,ITTD,IBL)
C------------------------------------------------------------------------
C    Variables locales
C------------------------------------------------------------------------
      REAL*4 A(4096),Y
      REAL XIL,XIS
      CHARACTER*22 MANNEQUIN(4),TITRE_MAN
      INTEGER     BUX1,BUX2,BUY1,BUY2
      LOGICAL*1 TITRE(32),AUTO(16),TCNO(6),CDATE(9)
C==========================================================================
C----Debut de la sous-routine
C
      XMIN=-PRETRG*SAMPRT/1.E6
      XMAX=(4000-PRETRG)*SAMPRT/1.E6
      YMIN=IMIN
      YMAX=IMAX
C--------------------------------------------------------------------------
C----Alors initialiser les variables.
C
      MANNEQUIN(1)='CHAUFFEUR/DRIVER      '
      MANNEQUIN(2)='PASSAGER/PASSENGER    '
      MANNEQUIN(3)='PASSAGER 1/PASSENGER 1'
      MANNEQUIN(4)='PASSAGER 2/PASSENGER 2'
      BUX1=XMIN
      BUX2=XMAX*1000.
      BUY1=YMIN
      BUY2=YMAX
      IFIRST=BUX1
      IF(BUX1.EQ.0)IFIRST=1
      FIRSTY  = BUY1
C--------------------------------------------------------------------------
C    Entete
C--------------------------------------------------------------------------
      CALL LNEXCL                    ! Passer de LN03 en EXCL
```

```
      IDRAP=0
      IF (TITRE(1).GE.65.AND.TITRE(1).LE.90) IDRAP=1 ! drapeau pour nsvac
      CALL FONT(5)
      CALL PORTR
      CALL PLOT(0.6,0.0,-3)
      CALL ENTETE (2.0,IDRAP)
      CALL FONT(2)

C-----------------------------------------------------------------------
C     Remplissage de l'entÍte
C-----------------------------------------------------------------------
      CALL SYMBOL(.57,5.5+(-0.47*IDRAP),0.07,TITRE,90.0,32)
      CALL SYMBOL(.57,8.5+(-0.6*IDRAP),0.07,TITRE,90.0,32)
      CALL SYMBOL(.85,4.5,0.09,AUTO,90.0,16)
      CALL SYMBOL(.85,8.5,0.09,TCNO,90.0,6)
      CALL SYMBOL(.85,1.5,0.09,CDATE,90.0,9)
C-----------------------------------------------------------------------
C----Initialiser l'imprimante et redefinir l'origine
C
      CALL FACTOR (0.75)
      CALL PLOT(8.9,2.25,-3)
C-----------------------------------------------------------------------
C----Axes   X & Y
C
      XLEN=10.0
      YLEN=6.0
      FIRSTV=BUX1
      DELTAX=(BUX2-BUX1)/XLEN
      DELTAY=(BUY2-BUY1)/YLEN
      IBOUC=6
      ZFAC=1.0
      IF(IDIV.EQ.4) THEN
         IBOUC=8
        ZFAC=0.75
        CALL FACTOR(1.0)
        CALL FACTOR(0.5625)
        YLEN=8.0
        DELTAY=(BUY2-BUY1)/YLEN
      ENDIF

      CALL AXIS(0.0,0.0,'Newton',6,YLEN,180.0,FIRSTY,DELTAY)
      CALL FACTOR(1.0)
      CALL FACTOR (0.75)
      YLEN=6.0
      DELTAY=(BUY2-BUY1)/YLEN
      CALL AXIS(0.0,0.0,'(msecs)',-7,XLEN,90.0,FIRSTV,DELTAX)
      CALL PLOT(-6.0,0.0,-3)

C-----------------------------------------------------------------------
C----Ecrire le temps de contact
C
      CALL SYMBOL(-.15,0.0,0.18,
     :'Temps de Contact/Contact Duration:',90.0,34)
      TEMP1=((FLOAT(ITTE))-PRETRG)/10.
      TEMP2=((FLOAT(ITTD))-PRETRG)/10.
      TEMPS_CONTACT=TEMP2-TEMP1
      CALL NUMBER(-.15,4.7,0.18,TEMPS_CONTACT,90.0,2)
C-----------------------------------------------------------------------
C-------Tracer la grille
C
```

```
      DO 118 IS=1,10
        XIS=IS
        CALL PLOT(0.0,XIS,3)
118     CALL PLOT(YLEN,XIS,2)
C
      DO 18 IL=0,IBOUC-1
        XIL=IL*ZFAC
        CALL PLOT(XIL,0.0,3)
18      CALL PLOT(XIL,XLEN,2)
C--------------------------------------------------------------------
C----Tracer T1 & T2
C
      CALL SYMBOL(-1.0,0.0,0.18,
     :'FORCE DE CONTACT VS TEMPS / CONTACT FORCE-TIME CURVE',90.0,52)
      CALL PLOT(-.95,0.0,3)
      CALL PLOT(-.95,8.0,2)
      TITRE_MAN=MANNEQUIN(IBL)
      CALL SYMBOL(-.45,0.0,0.18,%ref(TITRE_MAN),90.0,22)
      CALL SYMBOL(-.15,5.7,0.18,'Te:',90.0,3)
      CALL NUMBER(-.15,6.105,0.18,TEMP1,90.0,1)
      CALL SYMBOL(-.15,6.915,0.18,'msecs  Td:',90.0,10)
      CALL NUMBER(-.15,8.40,0.18,TEMP2,90.0,1)
      CALL SYMBOL(-.15,9.21,0.18,'msecs',90.0,5)
      XX=((ITTE-PRETRG)*SAMPRT/1.E6)*10./0.4000
      CALL SYMBOL(YLEN+.4,XX-.05,0.08,'Te',90.0,2)
      IZ=0
2002      IF(IZ.EQ.2) GOTO 2003
      IH=0
      CALL PLOT (0.0,XX,3)
      CALL DASHP (6.0,XX,.15)
      XX=((ITTD-PRETRG)*SAMPRT/1.E6)*10./0.4000
      IZ=IZ+1
      GOTO 2002
C--------------------------------------------------------------------
C----Tracer la courbe
C
2003      CALL SYMBOL(YLEN+.4,XX-.05,0.08,'Td',90.0,2)
      CALL PLOT(6.0,0.0,-3)
      K=1
      X=((K-PRETRG)*SAMPRT/1.E6)*10./0.4000
      Y=A(1)
      CALL PLOT(-1*(Y/DELTAY),X*(40/DELTAX),3)
      IK=0
      DO 202 K=1,4000
        X=((IK-PRETRG)*SAMPRT/1.E6)*10./0.4000
        Y=A(K)
        CALL PLOT(-1*(Y/DELTAY),X,2)
        CALL PLOT(-1*(Y/DELTAY),X,3)
        IK=IK+1
202 CONTINUE
      ZPAGE=IPAGE                  ! No du pied de page
      CALL FACTOR(1.0)             ! Revenir en 1 pour 1
      CALL FONT(3)                 ! Changer de caractËres
      CALL SYMBOL(-3.2,-.875,0.12,'-F',0.0,2)
      CALL NUMBER(999.,999.,0.12,ZPAGE,0.0,-1)
      CALL SYMBOL(999.,999.,0.12,'-',0.0,1)
      CALL CLRLIN(3,22)            ! Effacer les lignes 3-22
      CALL LOCATE(5,1,' ')         ! Pour rester en haut de l'Ècran
      CALL PLOT(0.0,0.0,10)            ! Changer de page
      RETURN
```

```
      END

C***************************************************************************
C****ENTETE:     Routine pour imprimer l'entete du CANADA
C          Version: 1.0  06-JUIN-89   J.M. Fiore
C***************************************************************************
      SUBROUTINE ENTETE (ORIENT,IFLAG)
C-------------------------------------------------------------------------
      REAL Y(2,11)
      DATA Y /7.5,10.2,3.05,3.8,5.9,7.5,5.96,7.6,0.56,0.56,3.11,3.9,
     :6.30,7.94,3.63,5.03,6.07,7.87,3.7,5.1,6.22,8.025/
      CALL CANADA (.25,.5,.195,1,1)
      CALL RECT(.65,.5,Y(ORIENT,1),.32,0.0,3)
      CALL PLOT(0.65,Y(ORIENT,2),3)
      CALL PLOT(.97,Y(ORIENT,2),2)
      CALL PLOT(0.65,Y(ORIENT,3),3)
      CALL PLOT(.97,Y(ORIENT,3),2)
      CALL FONT(2)
      CALL SYMBOL(.79,Y(ORIENT,5),.08,17HDate de collision,90.0,17)
      CALL SYMBOL(.91,Y(ORIENT,5),.08,13HDate impacted,90.0,13)
      CALL SYMBOL(.79,Y(ORIENT,6),.08,8HVehicule,90.0,8)
      CALL SYMBOL(.791,Y(ORIENT,6),.08,2H ',90.0,2)
      CALL SYMBOL(.91,Y(ORIENT,6),.08,7HVehicle,90.0,7)
      CALL SYMBOL(.79,Y(ORIENT,4),.08,6HT.C. N,90.0,6)
      CALL SYMBOL(.75,Y(ORIENT,7),.04,1Ho,90.0,1)
      CALL SYMBOL(.91,Y(ORIENT,4),.08,8HT.C. No.,90.0,8)
      CALL FONT(5)
      CALL SYMBOL(0.37,Y(ORIENT,8),.09,18HESSAI DE COLLISION,90.0,18)
      CALL SYMBOL(0.37,Y(ORIENT,9),.09,19HBARRIER IMPACT TEST,90.0,19)
      IF (IFLAG.EQ.0)THEN
      CALL SYMBOL(0.57,Y(ORIENT,10),.07,5HNSVAC,90.0,5)
      CALL SYMBOL(0.57,Y(ORIENT,11),.07,5HCMVSS,90.0,5)
      ENDIF
      CALL FONT(2)
      RETURN
      END

C***************************************************************************
C****CANADA:     Sous-routine pour imprimer la feuille d'erable du CANADA
C          Version: 1.0  07-JUIN-89   J.M. Fiore
C***************************************************************************
      SUBROUTINE CANADA (DEPX,DEPY,ZSIZE,IFILL,ITITRE)
C-------------------------------------------------------------------------
C     DEPX = POSITION DE DEPART EN X
C     DEPY = POSITION DE DEPART EN Y
C     ZSIZE = GROSSEUR DU SIGLE (en pouces)
C     IFILL = SIGLE PLEIN OU CONTOUR SEULEMENT (0=CONTOUR, 1=PLEIN)
C     ITITRE = 1->IMPRIME LE TITRE TRANSPORTS CANADA... 0->IMPRIME PAS
C-------------------------------------------------------------------------
      REAL XX(25),YY(25)
      DATA XX/3.5,-1.0,4.5,-2.5,1.5,-0.5,2.5,0.5,3.5,1.5,-0.3,3.3,0,
     :-3.3,0.3,-1.5,-3.5,-0.5,-2.5,0.5,-1.5,2.5,-4.5,1.0,-3.5/
      DATA YY/1.5,1.5,-0.5,2.5,0,3,-1.5,1.7,-4.7,0.8,-3.8,0,-1.0,
     :0,-3.8,0.8,-4.7,1.7,-1.5,3,0,2.5,-0.5,1.5,1.5/
C-------------------------------------------------------------------------
C     VALEURS DE DEFAULTS
C-------------------------------------------------------------------------
      IF (DEPX.EQ.0) DEPX=0.5
      IF (DEPY.EQ.0) DEPY=0.75
      IF (ZSIZE.EQ.0) ZSIZE=0.2
```

```
C-----------------------------------------------------------------------
      SIZE=ZSIZE*0.045
      IF (IFILL.EQ.1) call begpfl (.false.,.false.,0)
      CALL RECT (DEPX,DEPY,10*SIZE,22*SIZE,0.0,3)
      IF (IFILL.EQ.1) call endpfl
      X=DEPX+(2*SIZE)
      Y=DEPY+(21.5*SIZE)
      CALL PLOT(X,Y,3)
      IF (IFILL.EQ.1) call begpfl (.false.,.false.,0)
      DO 99 I=1,25
      CALL PLOT((XX(I)*size)+X,(YY(I)*size)+Y,2)
      x=x+(xx(i)*size)
      y=y+(yy(I)*size)
99    CONTINUE
      IF (IFILL.EQ.1) call endpfl
      IF (IFILL.EQ.1) call begpfl (.false.,.false.,0)
      CALL RECT (DEPX,DEPY+(33*SIZE),10*SIZE,22*SIZE,0.0,3)
      IF (IFILL.EQ.1) call endpfl
C-----------------------------------------------------------------------
      IF (ITITRE.NE.1) GOTO 999
      CALL FONT(2)
      HH=DEPX+(10*SIZE)
      GG=DEPY+(60*SIZE)
      CALL SYMBOL(HH,GG,8*SIZE,20HTransports Canada   ,90.0,20)
      CALL SYMBOL(999.,999.,8*SIZE,16HTransport Canada,90.0,16)
      HH=DEPX+(21*SIZE)
      CALL SYMBOL(HH,GG,8*SIZE,19HC.E.V.A.           ,90.0,19)
      CALL SYMBOL(999.,999.,8*SIZE,8HM.V.T.C.,90.0,8)
999   CONTINUE
C-----------------------------------------------------------------------
      RETURN
      END

C=======================================================================
C     SOUS-ROUTINE SERVANT ¿ …VALUER TOUS LES Te et les Td possibles
C     (jusqu'‡ 5 recherche)
C
C     Version: 1.0     8-Mai-92     Alain Caron, ing
C=======================================================================
      SUBROUTINE TEMPS_ENGAGE(Y,ITE,ITD)

C-----------------------------------------------------------------------
C     Variables locales
C-----------------------------------------------------------------------
      REAL*4 Y(4096)
      INTEGER ITE(500),ITD(500)
      REAL FACTEUR_MASSE
      COMMON /FACCOM/ FACTEUR_MASSE

C-----------------------------------------------------------------------
C     DÈbut de la sous-routine
C-----------------------------------------------------------------------
      ISTART=1              ! Point de dÈpart pour la recherche

      DO 1 I=1,500          ! Limiter les recherche ‡ 500
      CALL CHERCHE_500(Y,ISTART,IT500)! Chercher le no de l'Èchantillon
      IF(IT500.EQ.0) GOTO 2          ! Plus de recherche possible
      CALL LIMITE_INF(Y,IT500,ITINF)   ! Chercher la limite infÈrieure
      ITE(I)=ITINF          ! Sauve-garder la valeur
      CALL LIMITE_SUP(Y,IT500,ITSUP)     ! Chercher la limite supÈrieur
```

```
      ITD(I)=ITSUP                  ! Sauve-garder la valeur
      ISTART=ITSUP                  ! Nouveau dÈpart de recherche
1     CONTINUE                 ! Fin des recherches

2     RETURN
      END

C==========================================================================
C     Sous-routine utilisÈe par TEMPS_ENGAGE, recherche 500 N
C
C     Version: 1.0       8-Mai-92Alain Caron, ing
C==========================================================================
      SUBROUTINE CHERCHE_500(Y,ISTART,IT500)

C--------------------------------------------------------------------------
C     Variables locales
C--------------------------------------------------------------------------
      REAL*4 Y(4096)
      INTEGER IT500
      REAL FACTEUR_MASSE,FC
      COMMON /FACCOM/ FACTEUR_MASSE

C--------------------------------------------------------------------------
C     DÈbut de la sous-routine
C--------------------------------------------------------------------------
      FC=FACTEUR_MASSE          ! Tenir compte du rapport de masse
      DO 1 I=ISTART,4000        ! Boucle de recherche du 500 N
        IF(Y(I).LT.500*FC) GOTO 1   ! Plus petit que 500 boucler ‡ nouveau
          IT500=I              ! Plus grand ou Ègal ‡ 500 N
          RETURN               ! Retourner le no de l'Èchantillon
1     CONTINUE                 ! Fin de la boucle de recherche
      IT500=0                  ! Valeur de dÈfaut si rien trouvÈ

      RETURN
      END

C==========================================================================
C     Sous-routine utilisÈe par TEMPS_ENGAGE, recherche 500 N
C
C     Version: 1.0       8-Mai-92Alain Caron, ing
C==========================================================================
      SUBROUTINE LIMITE_INF(Y,ISTART,ITINF)

C--------------------------------------------------------------------------
C     Variables locales
C--------------------------------------------------------------------------
      REAL FACTEUR_MASSE,FC
      COMMON /FACCOM/ FACTEUR_MASSE
      REAL*4 Y(4096)

C--------------------------------------------------------------------------
C     DÈbut de la sous-routine
C--------------------------------------------------------------------------

      FC=FACTEUR_MASSE          ! Tenir compte du rapport de masse
      DO 1 I=ISTART,1,-1        ! Boucle de recherche du 500 N
        IF(Y(I).GT.200*FC) GOTO 1   ! Plus grand  ‡ 200 N boucler ‡ nouveau
          ITINF=I              ! Plus petit ou Ègal que 200
          RETURN               ! Retourner le no de l'Èchantillon
1     CONTINUE                 ! Fin de la boucle de recherche
```

```
      RETURN
      END

C===========================================================================
C     Sous-routine utilisÈe par TEMPS_ENGAGE, recherche 500 N
C
C     Version: 1.0         8-Mai-92Alain Caron, ing
C===========================================================================
      SUBROUTINE LIMITE_SUP(Y,ISTART,ITSUP)

C-------------------------------------------------------------------------
C     Variables locales
C-------------------------------------------------------------------------
      REAL*4 Y(4096)
      REAL FACTEUR_MASSE,FC
      COMMON /FACCOM/ FACTEUR_MASSE

C-------------------------------------------------------------------------
C     DÈbut de la sous-routine
C-------------------------------------------------------------------------

      FC=FACTEUR_MASSE           ! Tenir compte du rapport de masse
      DO 1 I=ISTART,4000         ! Boucle de recherche du 500 N
        IF(Y(I).GT.200) GOTO 1 ! Plus grand que 200 boucler ‡ nouveau
          ITSUP=I                ! Plus petit ou Ègal ‡ 200 N
          RETURN                 ! Retourner le no de l'Èchantillon
1     CONTINUE                   ! Fin de la boucle de recherche
      ITSUP=4000                 ! Valeur de dÈfaut si rien trouvÈ

      RETURN
      END

C     ================================================================
C     : HICSUB : s.-r. to evaluate "sup-hic" for head accelerations.:
C     :   actual hic number computation is performed by subroutine  :
C     :   shic on both the driver and passenger head accelerations. :
C     :   output is to file 'BARHIC.RPT' and terminal.              :
C     :                                                             :
C     :     Version : 2.0      17-FEB-83       D. Laboccetta        :
C     :     Version : 3.0      08-OCT-87       Alain Caron,ing      :
C     :     Version : 4.0      04-NOV-89     Marc Villeneuve,stag.  :
C     :                         (Version pour le VAX/VMS)           :
C     :     Version : 4.1    08-Mai-92    Alain Caron,ing           :
C     :                         (Version pour CONTACT)              :
C     ================================================================
      SUBROUTINE HICSUB(KKK,TABT1,TABT2,TABHIC,IS,IBOUK,IUNIT,INT,
     :ITTE)
C-----------------------------------------------------------------------
C     Variables Globales
C-----------------------------------------------------------------------
      REAL*8 LBL(2,50),PLBL(2,30),ALBL(2,50),F1,F2,A1,A2
      REAL*4 TBL(50,3),VTBL(10),WTBL(10),UNITS(50)
      INTEGER*2 ITBL(10),DTBL(10),FCLASS(50),
     : ADRES,IDUM(78),ICON(10),IBOITE
      LOGICAL*1 ADATE(9),CDATE(9),PROG(6),TCNO(6),TSTFIL(14),
     :       AUTO(16),INGENR(16),TECHCN(16),CLIENT(32),
     :       TITRE(32),CONTRT(16),TESTXT,IBYTE(20),DBYTE(20),
     :       VBYTE(40)
      EQUIVALENCE (ITBL(1),IBYTE(1)),(DTBL(1),DBYTE(1)),
```

```
     :            (VTBL(1),VBYTE(1))
       INTEGER*2  HICCHN,PULTIM,PULPTS,HICT1,HICT2
       REAL*8        TABHIC(4,3),TABT1(4,3),TABT2(4,3)
       LOGICAL*1  HICFLG
       CHARACTER*1   COMD
       CHARACTER*80 M                ! Pour faire la grille
       COMMON /HICDAT/ HICCHN,PULTIM,PULPTS,HICT1,HICT2,
     :            SUPHIC,AMPLT1,AMPLT2,AMPMAX,AMPBAR
       COMMON /OUTBUF/ IOP,A(4096)
       PARAMETER BELL=7
C------------------------------------------------------------------
C----Initialisations
C
       CALL ERRSET(63,.TRUE.,.FALSE.,.TRUE.,.FALSE.,)
       DONE=.FALSE.                  ! Flag -> le calcul est fait
       IF (KKK.EQ.0) GO TO 999            ! Sortir
       READ(IUNIT'1)
     : ((TBL(I,J),J=1,3),FCLASS(I),LBL(1,I),LBL(2,I),I=1,50),
     : SAMPRT,PRETRG,NCHS,LCHN,ADRES,NVECS,NINTS,NDIFS,(IDUM(I),I=1,5),
     : (VTBL(I),I=1,10),(DTBL(I),I=1,10),(ITBL(I),I=1,10),
     : (WTBL(I),I=1,10),(PLBL(1,I),PLBL(2,I),I=1,30),
     : CDATE,ADATE,PROG,TCNO,AUTO,INGENR,TECHCN,CLIENT,TITRE,CONTRT,
     : IDUM,NTEXT,(TESTXT,I=1,3000),(ICON(I),I=1,10),IBOITE,
     : (ALBL(1,I),ALBL(2,I),UNITS(I),I=1,50)
       DTIME=SAMPRT*1.E-6                 ! Base de temps
C-----------------------------------------------------------
C    Ajuster les titres
C-----------------------------------------------------------
520    KLBL=NCHS+1
         IF(NVECS.EQ.0)GO TO 1145           ! Pour les vecteurs
         DO 1140 K=1,NVECS                 ! Boucler sur le nbre de vec.
           LBL(1,KLBL)=PLBL(1,K)           ! Premiere 1/2 du titre
           LBL(2,KLBL)=PLBL(2,K)           ! Seconde 1/2 du titre
1140          KLBL=KLBL+1                  ! Incrementer le no du canal

1145         IF(NDIFS.EQ.0)GO TO 1155        ! Pour les differences
         DO 1150 K=1,NDIFS                 ! Boucler sur le nombre de mom.
           LBL(1,KLBL)=PLBL(1,K+10)            ! Premiere 1/2 du titre
           LBL(2,KLBL)=PLBL(2,K+10)            ! Seconde 1/2 du titre
1150          KLBL=KLBL+1                  ! Incrementer le no du canal

1155         IF(NINTS.EQ.0)GO TO 127         ! Pour les integrales
         DO 1160 K=1,NINTS                 ! Boucler sur le nbre d'int.
           LBL(1,KLBL)=PLBL(1,K+20)            ! Premiere 1/2 du titre
           LBL(2,KLBL)=PLBL(2,K+20)            ! Seconde 1/2 du titre
1160          KLBL=KLBL+1                  ! Incrementer le no du canal
C------------------------------------------------------------------
C----L'espace est libre utilisons-le
C
127 CALL CLRLIN(13,22)               ! Effacer les lignes 3-22
       M(1:29)='***HIC calcul du canal yyy***'   ! DÈfinir M
       ENCODE(3,130,M(24:26)) KKK            ! InsÈrer KKK dans M
       CALL EFFET(2)                 ! Haute intensitÈ
       CALL LOCATE(13,25,M(1:29))        ! …crire M
       CALL EFFET(3)                 ! VidÈo normal
       CALL DELAIS(1.0)              ! Attendre 2 secondes
C------------------------------------------------------------------
C----Lire les donnees du canal
C
       HICFLG=0                   ! Initialiser le flag de HIC
```

```
      ITUK=KKK+KKK                    ! No du record du 1/2 canal
      ITUKP1=ITUK+1                   ! Numero canal -> no de record
C---------------------------------------------------------------------
C     Calcul du HIC  intervalle=Td-Te
C---------------------------------------------------------------------
      READ(IUNIT'ITUK)(A(I),I=1,2048)          ! Lire les donnees du...
      READ(IUNIT'ITUKP1)(A(I),I=2049,LCHN)     ! ...canal a nouveau
      CALL HT1T2(INT,ITTE)               ! Calcul selon Te et Td
      TI1=HICT1*DTIME                    ! T1 exprimÈ en sec
      TI2=HICT2*DTIME                    ! T2 exprimÈ en sec
      TABT1(IS,1)=TI1                 ! Sauvegarder les donnÈes
      TABT2(IS,1)=TI2                 ! Sous forme de tableau
      TABHIC(IS,1)=SUPHIC                ! Pour impression futur

C     ------------------------------------------------------
C     Faire une grille
C     ------------------------------------------------------
400   CALL LOCATE(16,1,' ')              ! Pour Ècrire sur la ligne 13
      IF(INT.LE.10) GOTO 303             ! Afficher le message d'erreur
      WRITE(5,200,ERR=303)SUPHIC,TI1,TI2,
     :          AMPLT1,AMPLT2,AMPMAX,AMPBAR      ! Afficher ‡ l'Ècran
      GOTO 304                        ! Dessiner le cadre tout autour
303   CALL LOCATE(15,16,
     :'Erreur: L''intervalle de recherche du HIC > Td-Te')
      CALL DELAIS(2.0)                ! Afficher pendant 2 sec.
      GOTO 999                        ! Retour au programme principal
304   CALL SETCAR(0,3)                ! CaractËres graphiques
     M='lqqqqqqqqqqwqqqqqqwqqqqqqqwqqqqqqqwqqqqqqqwqqqqqqqwqqqqqqqqqk'
      CALL LOCATE(16,10,M)               ! Ligne blanche haut de la boite
      CALL LOCATE(17,10,'x')             ! SÈparateurs dans la boite
      CALL LOCATE(17,21,'x')
      CALL LOCATE(17,28,'x')
      CALL LOCATE(17,36,'x')
      CALL LOCATE(17,44,'x')
      CALL LOCATE(17,52,'x')
      CALL LOCATE(17,60,'x')
      CALL LOCATE(17,70,'x')
     M='tqqqqqqqqqqnqqqqqqnqqqqqqqnqqqqqqqnqqqqqqqnqqqqqqqnqqqqqqqqqu'
      CALL LOCATE(18,10,M)               ! Ligne blanche milieu boite
      CALL LOCATE(19,10,'x')             ! SÈparateurs dans la boite
      CALL LOCATE(19,21,'x')
      CALL LOCATE(19,28,'x')
      CALL LOCATE(19,36,'x')
      CALL LOCATE(19,44,'x')
      CALL LOCATE(19,52,'x')
      CALL LOCATE(19,60,'x')
      CALL LOCATE(19,70,'x')
     M='mqqqqqqqqqqvqqqqqqvqqqqqqqvqqqqqqqvqqqqqqqvqqqqqqqvqqqqqqqqqj'
      CALL LOCATE(20,10,M)               ! Ligne blanche bas de boite
      CALL DELAIS(2.0)                ! Afficher pendant 2 sec
      CALL SETCAR(0,2)                ! CaractËres normaux

C---------------------------------------------------------------
C----Les formats
C
2     FORMAT(I2)
130   FORMAT(I3)
200   FORMAT(11X'HIC number',5X,'T1',6X,'T2',6X,'A1',6X,'A2',6X,'AM'
     :       ,2X,'A MOYEN'//10X,F10.1,2F8.4,0P4F8.2)
201   FORMAT(11X'HIC number',5X,'T1',6X,'T2',6X,'A1',6X,'A2',6X,'AM'
```

```
    :       ,2X,'A MOYEN'//10X,F10.1,2F8.4,' Erreur',0P3F8.2)
999 RETURN                          ! Retour a la question initial.
    END

C************************************************************************
C****HT1T2:  Sous-routine pour calculer le HIC avec un interval fixe
C          Idee original de Tim Bowden,Ph.D (D.C.I.E.M)
C
C    Version: 1.0        14-JUL-86    Alain Caron,ing
C    Version: 1.1        14-NOV-86    Alain St-Pierre,sta
C
C    La version 1.1 possede une nouvelle possibilite pour le calcul du HIC.
C    Il s'agit du calcul du hic pour un intervalle MAXIMUM specifie par
C    l'usager.
C
C    Version: 2.0        13-MAI-92    Alain Caron, ing
C
C    La version 2.0 cherche toujours un HIC maximum pour un intervalle
C    maximal donnÈ ‡ la diffÈrence avec une la restriction de chercher
C    entre les no d'Èchantillon correspondant ‡ Te et Td.
C
C***************************************************************************
    SUBROUTINE HT1T2(INTMAX,ITTE)
    DOUBLE PRECISION SHICN
    INTEGER*2 HICCHN,PULTIM,PULPTS,HICT1,HICT2,IPLACE,HICPTR,POSI
    LOGICAL*1 HICFLG
    COMMON /HICDAT/ HICCHN,PULTIM,PULPTS,HICT1,HICT2,
   :            SUPHIC,AMPLT1,AMPLT2,AMPMAX,AMPBAR
    COMMON /OUTBUF/ IOP,A(4096)
C===========================================================================
C----Debut de la sous-routine
C----Taux d'echantillonnage
C
    SAMPRT=100.0                    ! Sampling Rate
    DT=SAMPRT*1.E-6                      ! Sampling Rate en misec
    ISORT=0                         ! Intervalle max atteint
    IF (INTMAX.EQ.1000) GOTO 2029       ! Option Methode CEVA
C-----------------------------------------------------------------------------
C----On desire une recherche du plus grand HIC selon une largeur d'intervalle
C   fixe par l'usager
      IM=0                      ! On commence ‡ chercher ‡ ITTE
      DELT=INTMAX*DT                ! Convertir l'intervalle en sec
      IMAX=INTMAX                   ! Intervalle MAXIMUM
      GOTO 2030                     ! Aller calculer l'aire
C-----------------------------------------------------------------------------
C----Chercher un  interval  pour  un maximum en acceleration integre. Puisque
C   l'intervalle  de  temps  est constant, ceci nous donnera automatiquement
C   le  HIC  maximum.  Initialisons  la  valeur de l'integrale a la premiere
C   valeur d'intervalle de largeur INT. Puisque le maximum de l'acceleration
C   est lui-meme un resultat, on le trouve du meme coup.
C
2029     IMAX=1000                  ! Int. MAX. pour Meth. CEVA
2030     CONTINUE                   ! Option Methode CEVA
      TTM=0.0                   ! Le HIC max intermediaire
      INT=9                  ! INT-1 par defaut (1 msec)
2031     INT=INT+1                  ! IncrÈmenter int. de recherche
    IM=0
    DELT=INT*DT                     ! Convertir l'intervalle en sec
2032     AM=0.                      ! Initialiser Ampli max
    TM=0.                     ! Initialiser la somme
```

```
      RM=ABS(A(ITTE))                    ! DÈbut la recherche ‡ Te
      DO 2 I=ITTE+1,ITTE+INT             ! Calculer la surf sous la courb
        RC=A(I+IM)                    ! RC = ampli du pt suivant
        SC=TM+.5*(RC+RM)                 ! SC = aire sous la courbe
        TM=SC                      ! TM = retient la derniere aire
        RM=RC                      ! Le nouveau dÈpart = 2ieme pt.
2     CONTINUE
C-------------------------------------------------------------------------
C----Calculer l'integrale pour toutes intervalles subsequentes en comparant
C    avec la valeur precedente.
C    Ici on cherche l'aire maximale pour un mÍme intervalle. Ce qui donnera
C    forcÈment le HIC max pour un INT fixe puisque c'est le plus grand rapport
C    TM/INT qui donnera le plus grand HIC.

      T=TM                         ! Integrale initiale
      I=ITTE-1                  ! Borne inf init de l'integrale
20    I=I+1                        ! Incrementer a coup de 1
      J=I+INT                      ! Borne sup de l'integrale
      IF(J.GT.ITTE+IMAX) GO TO 30            ! Allez calculer le HIC
      TS=.5*(A(J)+A(J+1))             ! DÈplacer l'aire vers la droite
      TA=.5*(A(I)+A(I+1))             ! En add nouvelle ampli - prece.
      T=T+TS-TA                    ! Nouvelle integrale
      IF (T.LE.TM) GO TO 20              ! Verifier si le HIC serait sup
      TM=T                         ! Si oui on garde cette valeur
      IM=I+1                       ! Re-ajuste les bornes
      GO TO 20                     ! Chercher l'optimum
C-------------------------------------------------------------------------
C----Le maximum TM a ete trouve a IM.
C
30    TI1=IM*DT                    ! Le temps T1
      TI2=TI1+DELT                    ! Le temps T2
      AMPBAR=TM/INT                      ! La valeur moyenne
      SHICN=(AMPBAR**2.5)*DELT           ! Le HIC
      SUPHIC=SHICN
      IF(IM.EQ.0) IM=ITTE             ! Cas des interv. trop courts
      AMPLT1=A(IM)                    ! Amplitude a T1
      AMPLT2=A(IM+INT)                ! Amplitude a T2
      HICT1=IM                     ! T1 en terme d'echantillon
      HICT2=IM+INT                    ! T2 en terme d'echantillon
      PULTIM=0
      PULPTS=INT                      ! L'intervalle
      IF(ISORT.EQ.1) GO TO 999
C------------------------------------------------------------------------
C----Option Methode CEVA et Int. MAXIMUM.
C
      IF(SUPHIC.GT.TTM) THEN                 ! Comparons HIC cour. vs HICMAX
        IINT=INT                   ! Enreg. INT du nouveau HICMAX
        TTM=SUPHIC                    ! Enregistrer nouveau HICMAX
        ENDIF                   ! Fin de comparaison
      IF (INT.LT.IMAX) GO TO 2031        ! IMAX pas att.,cherche encore
      INT=IINT                     ! Sinon rappeller INT du MAX
      DELT=INT*DT                     ! Convertir l'intervalle en sec
      IM=0
      ISORT=1                         ! Flag pour sortir
      GOTO 2032                    ! Recalculer le HICMAX

999   RETURN
      END

C*************************************************************************
```

```
C****CHECK:  Sous-routine pour verifier si on est en mode automatique et si
C         oui alors ouvrir les fichier d'Eng. Units concernÈs.
C         Version permettant d'avoir des unitÈs logiques diffÈrentes
C         Version: 1.1    25-AUG-87
C         Version: 2.0    24-nov-89     Marc Villeneuve, Stagiaire
C                                 PremiËre version du VAX/VMS
C         Version: 2.1    29-oct-90     pour le TTI
C         Version: 2.2    01-mai-92     pour CONTACT
C         Version: 2.3    02-sep-92     Traite maintenant 4 boites
C
C        On cherche les titres suivants:
C
C    CHAUFFEUR TETE X   PASSAGER TETE X   PASS #1 TETE X   PASS #2 TETE X
C    CHAUFFEUR TETE Y   PASSAGER TETE Y   PASS #1 TETE Y   PASS #2 TETE Y
C    CHAUFFEUR TETE Z   PASSAGER TETE Z   PASS #1 TETE Z   PASS #2 TETE Z
C    CHAUFFEUR COU FX   PASSAGER COU FX   PASS #1  COU FX  PASS #2  COU FX
C    CHAUFFEUR COU FY   PASSAGER COU FY   PASS #1  COU FY  PASS #2  COU FY
C    CHAUFFEUR COU FZ   PASSAGER COU FZ   PASS #1  COU FZ  PASS #2  COU FZ
C    CHAU HT COU FX     PASS HT COU FX    PAS1 HT COU FX   PAS2 HT COU FX
C    CHAU HT COU FY     PASS HT COU FY    PAS1 HT COU FY   PAS2 HT COU FY
C    CHAU HT COU FZ     PASS HT COU FZ    PAS1 HT COU FZ   PAS2 HT COU FZ
C    R CHAUFFEUR TETE   R PASSAGER TETE   R PASS #1 TETE   R PASS #2 TETE
C
C**************************************************************************
      SUBROUTINE CHECK(NCAN,IGO)
C     ----------------------------------------------------
C     Variables locales
C     ----------------------------------------------------
      REAL*8 CHAINE(80)
      CHARACTER*16 CHERCH,TROUVE
      CHARACTER*80 MESS
      DATA CHAINE /
     1'CHAUFFEU','R TETE X','CHAUFFEU','R TETE Y','CHAUFFEU','R TETE Z',
     1'CHAUFFEU','R COU FX','CHAUFFEU','R COU FY','CHAUFFEU','R COU FZ',
     1'CHAU HT ','COU FX  ','CHAU HT ','COU FY  ','CHAU HT ','COU FZ  ',
     2'PASSAGER',' TETE X ','PASSAGER',' TETE Y ','PASSAGER',' TETE Z ',
     2'PASSAGER',' COU FX ','PASSAGER',' COU FY ','PASSAGER',' COU FZ ',
     2'PASS HT ','COU FX  ','PASS HT ','COU FY  ','PASS HT ','COU FZ  ',
     3'PASS #1 ','TETE X  ','PASS #1 ','TETE Y  ','PASS #1 ','TETE Z  ',
     3'PASS #1 ',' COU FX ','PASS #1 ',' COU FY ','PASS #1 ',' COU FZ ',
     3'PAS1 HT ','COU FX  ','PAS1 HT ','COU FY  ','PAS1 HT ','COU FZ  ',
     4'PASS #2 ','TETE X  ','PASS #2 ','TETE Y  ','PASS #2 ','TETE Z  ',
     4'PASS #2 ',' COU FX ','PASS #2 ',' COU FY ','PASS #2 ',' COU FZ ',
     4'PAS2 HT ','COU FX  ','PAS2 HT ','COU FY  ','PAS2 HT ','COU FZ  ',
     R'R CHAUFF','EUR TETE','R PASSAG','ER TETE ','R PASS #','1 TETE  ',
     R'R PASS #','2 TETE  '/
      PARAMETER BELL=7
      INTEGER*2 IDUM(78),ICH,IUN,NCAN,JCAN(40)
      INTEGER*2 POSI_MANNEQUIN(40),TYPE_MANNEQUIN
      COMMON /CANCOM/ ICH(40),IUN(40),TYPE_MANNEQUIN(40)
      DATA POSI_MANNEQUIN /2,2,2,2,2,2,2,2,2,3,3,3,3,3,3,3,3,3,
     :4,4,4,4,4,4,4,4,4,5,5,5,5,5,5,5,5,5,2,3,4,5/
      CHARACTER*1 COMD,DOT
      CHARACTER*14 FICHE,DOSSIE,DOSS1,DOSS2,DOSS3,DOSS4 ! 4 Boites
      COMMON /DOSCOM/DOSSIE(4)                    ! 4 Boites
      EQUIVALENCE (TSTFIL(1,1),DOSS1),(TSTFIL(1,2),DOSS2),
     :(TSTFIL(1,3),DOSS3),(TSTFIL(1,4),DOSS4)              ! 4 Boites
      EQUIVALENCE (DOSS1,DOSSIE(1)),(DOSS2,DOSSIE(2)),
     :(DOSS3,DOSSIE(3)),(DOSS4,DOSSIE(4))                  ! 4 Boites
      DATA DOT /'.'/
```

```
      LOGICAL*1 TSTFIL(14,4)                      ! 4 Boites

C     ------------------------------------------------------------
C     DÈclarations des variables de lecture du fichier CHECK.CFG
C     ------------------------------------------------------------

      INTEGER     BOITE,CONTACT
      CHARACTER*9 BOX1,BOX2,BOX3,BOX4

C     ----------------------------------------------------
C     Variables Globales
C     ----------------------------------------------------
      REAL*8  LBL(2,50),PLBL(2,30),ALBL(2,50)
      REAL*4  VTBL(10),WTBL(10)
      INTEGER*2  ADRES,ITBL(10),DTBL(10),IBOITE
      LOGICAL*1  CDATE(9),ADATE(9),AUTO(16),IBYTE(20),DBYTE(20),
     :           VBYTE(40),PROG(6),TCNO(6),
     :           BAUTO(16),BTCNO(6)
      EQUIVALENCE (ITBL(1),IBYTE(1)),(DTBL(1),DBYTE(1)),
     :         (VTBL(1),VBYTE(1))
      REAL*4 TBL(50,3),UNITS(50),ZTC
      INTEGER*2 FCLASS(50),ICON(10)
      LOGICAL*1 INGENR(16),TECHCN(16),CLIENT(32),
     :     TITRE(32),CONTRT(16),TEXT

      CHARACTER*80 COM80
      CHARACTER*250 NOMESS,COMMDE
C     --------------------------------------------------------------------
C     Debut de la sous-routine
C     --------------------------------------------------------------------
      CALL ERRSET(29,.TRUE.,.FALSE.,.TRUE.,.FALSE.,)
      CALL ERRSET(30,.TRUE.,.FALSE.,.TRUE.,.FALSE.,)
      DOSS1(10:14)='.ENG '
      DOSS2(10:14)='.ENG '
      DOSS3(10:14)='.ENG '
      DOSS4(10:14)='.ENG '

C     --------------------------------------------------------------------
C     Effacer l'Ècran et afficher le titre du programme
C     --------------------------------------------------------------------
      CALL CLEAR                    ! Effacer complËtement l'Ècran
      CALL TITCAR('CONTACT (V1.1:Automatique)') ! Mettre un titre

C     --------------------------------------------------------------------
C     VÈrifier si un fichier CONTACT.X existe et si oui l'effacer.
C     IdÈe de commande.com de Yves Gaudreau (Ao˚t 90).
C     --------------------------------------------------------------------
      DO J=1,80                     ! initialisation a blancs
         COM80(J:J) = ' '           ! Texte pour FUNMCR
      ENDDO                         ! Fin de la boucle
      DO I=1,250                    ! initialisation a blancs
         NOMESS(I:I) = ' '          ! Texte du Commande.com
         COMMDE(I:I) = ' '          ! Texte effacer BARFIX.X
      ENDDO                         ! Fin de la boucle
      OPEN(UNIT=97,FILE='COMMANDE.COM',STATUS='NEW',
     :ACCESS='SEQUENTIAL',FORM='FORMATTED',RECL=252)
      NOMESS(1:35) = 'SET MESSAGE/NOTEXT/NOIDENTIFICATION'
      NOMESS(36:57) = '/NOFACILITY/NOSEVERITY'
      COMMDE(1:15) = 'DEL CONTACT.X;*'
      WRITE (UNIT=97,FMT=100) NOMESS        ! Insc. nomess ds Commande.com
```

```
      WRITE (UNIT=97,FMT=100) COMMDE        ! Effacer les CONTACT.X
      COMMDE(1:17) = 'DEL CONTACT.LOG;*'
      WRITE (UNIT=97,FMT=100) COMMDE        ! Effacer les CONTACT.LOG
      COMMDE(1:17) = 'DEL *.CNT;*      '
      WRITE (UNIT=97,FMT=100) COMMDE        ! Effacer les XXXXXXX.CNT
      COMMDE(1:17) = 'DEL CONTACT.DAT;*'
      WRITE (UNIT=97,FMT=100) COMMDE        ! Effacer les CONTACT.DAT
100   FORMAT('$ ',A250)                 ! 2 + 250 = 252 caractËres
      CLOSE(UNIT=97,DISPOSE='KEEP')         ! Fwermer pour exÈcuter
      COM80(1:9) = '@COMMANDE'      ! Composition du FUNMCR
      CALL FUNMCR(COM80)            ! ExÈcution de Commande.com
      DO J=1,80                 ! initialisation a blancs
         COM80(J:J) = ' '
      ENDDO                     ! Fin de la boucle
      COM80(1:21) = 'DELETE COMMANDE.COM;*'   ! Effacer Commande .com
      CALL FUNMCR(COM80)            ! ExÈcuter l'effacement

C     -------------------------------------------------------------------
C     Lire le contenu du fichier du CEVA
C     -------------------------------------------------------------------
      CALL READ_CHECK(BOITE,BOX1,BOX2,BOX3,BOX4,'CONTACT',CONTACT,IGO)
       IF(IGO.EQ.0) STOP'CONTACT fonctionne en automatique seulement'
      IF(CONTACT.EQ.0) STOP 'CONTACT non-demandÈ'! Stopper pas CONTACT

      NBFICH=BOITE                  ! Nombre de fichier ‡ lire
      DOSS1(1:9) = BOX1             ! Premier dossier Boite #1
      DOSS2(1:9) = BOX2             ! DeuxiËme dossier Boite #2
      DOSS3(1:9) = BOX3             ! TroisiËme dossier Boite #3
      DOSS4(1:9) = BOX4             ! TroisiËme dossier Boite #4
      CALL FUNMCR('REPLY /NONOTIFY/TERM=(OPA0) "DEBUT DE CONTACT"')
      IFOIS=1                   ! Commencer avec le fichier 1
      ITEM=0                    ! Pour TEMOIN
      CALL ASSIGN(66,'CONTACT.LOG')         ! Ouvrir le fichier LOG
      NCAN=0                    ! Nombre de canaux ‡ traiter
      IUNIT=24                  ! UnitÈ logique de dÈpart + 1
511   IW=1                      ! Au dÈbut on cherche le 1e
5511     IF(ICH(IW).NE.0) THEN              ! …viter recherche inutile
        IW=IW+1                 ! Chercher le prochain
        IF(IW.GT.40) RETURN           ! Tous trouvÈs
        GOTO 5511                   ! VÈrifier si dÈj‡ trouvÈ
      ENDIF                     ! Fin du test
      IUNIT=IUNIT-1                 ! UnitÈ logique de dÈpart
      IBOUK=IFOIS                   ! Faire correspondre le LUN
899     IF(IBOUK.EQ.1) CALL ASSIGN(IUNIT,DOSS1,14)
        IF(IBOUK.EQ.2) CALL ASSIGN(IUNIT,DOSS2,14)
        IF(IBOUK.EQ.3) CALL ASSIGN(IUNIT,DOSS3,14)
        IF(IBOUK.EQ.4) CALL ASSIGN(IUNIT,DOSS4,14)
        DEFINE FILE IUNIT(1,4096,U,IIP)       ! DÈfinir la zone mÈmoire
C     ---------------------------------------------------
C     Lire le contenu du fichier du CEVA
C     ---------------------------------------------------
        READ(IUNIT,REC=1,ERR=7)((TBL(I,J),J=1,3),
     :  FCLASS(I),LBL(1,I),LBL(2,I),I=1,50),
     :   SAMPRT,PRETRG,NCHS,LCHN,ADRES,NVECS,NINTS,NDIFS,
     :  (IDUM(I),I=1,5),(VTBL(I),I=1,10),(DTBL(I),I=1,10),
     :  (ITBL(I),I=1,10),(WTBL(I),I=1,10),(PLBL(1,I),PLBL(2,I),
     :  I=1,30),CDATE,ADATE,PROG,TCNO,AUTO,INGENR,TECHCN,CLIENT,
     :  TITRE,CONTRT,IDUM,NTEXT,(TEXT,I=1,3000),(ICON(I),I=1,10),
     :  IBOITE,(ALBL(1,I),ALBL(2,I),UNITS(I),I=1,50)
        CALL CLOSE(IUNIT)             ! Fermer pour ouvrir ‡ nouveau
```

```
C   ---------------------------------------------------
C   Maintenant ouvrir le fichier EU selon le nombre de canaux
C   ---------------------------------------------------
      IF(IBOUK.EQ.1) CALL ASSIGN(IUNIT,DOSS1,14)
      IF(IBOUK.EQ.2) CALL ASSIGN(IUNIT,DOSS2,14)
      IF(IBOUK.EQ.3) CALL ASSIGN(IUNIT,DOSS3,14)
      IF(IBOUK.EQ.4) CALL ASSIGN(IUNIT,DOSS4,14)
      NRECS=(NCHS+NVECS)*2+1           ! Le nbre de record CEVA
      DEFINE FILE IUNIT(NRECS,4096,U,IIP)   ! Ouvrir correctement le CEVA

C   ---------------------------------------------------
C   Afficher l'etiquette du fichier
C   ---------------------------------------------------

      CALL CLRLIN(9,12)             ! Effacer ‡ partir de 10
      CALL BOX(7,4,70,3)                 ! Dessiner une boÓte
      MESS(1:30)='Fichier: xxxxxxxxxxxxxx ouvert'
      MESS(31:63)= ', contenant yyy canaux de donnÈes'
      MESS(10:23)=DOSSIE(IBOUK)          ! InsÈrer le nom du canal
      ENCODE(3,6,MESS(43:45)) NCHS           ! et le numÈro dans le msg
      CALL LOCATE(7,8,MESS(1:63))        ! …crire le msg
      WRITE(66,707) MESS                 ! …crire dans le log
      CALL EFFET(2)                 ! Haute intensitÈ
      CALL LOCATE(7,17,MESS(10:23))      ! RÈÈcrire le nom du canal
      CALL LOCATE(7,50,MESS(43:45))      ! RÈÈcrire le numÈro
      CALL EFFET(3)                 ! VidÈo normal
      IF (ITEM.EQ.0) ITEM=NBFICH           ! Pour TEMOIN (1 seule fois)
      CALL TEMOIN(1,ITEM,15,IBOUK,ZSAUT) ! Afficher un tÈmoin indiquant ‡
                              ! quel fichier on est rendu.
C   ---------------------------------------------------------
C   Mode automatique de recherche des canaux
C   ---------------------------------------------------------
519 ENCODE(16,201,CHERCH) CHAINE(2*IW-1),CHAINE(2*IW)
    DO 51 I=1,NCHS+NVECS              ! Boucler sur les canaux extras
      IF(I.LE.NCHS) THEN
        ENCODE(16,201,TROUVE) LBL(1,I),LBL(2,I) ! Lire titre acquisition
      ELSE
         ENCODE(16,201,TROUVE) PLBL(1,I-NCHS),PLBL(2,I-NCHS)! titre vecteur
      ENDIF
      IF(TROUVE.NE.CHERCH) GOTO 51         ! Pas encore trouvÈ
      GOTO 53                      ! Oui on a trouvÈ
51  CONTINUE                      ! Fin de la boucle de recherche
    MESS(1:40)='                                    ' ! Vider MESS
    MESS(41:80)='                                   '      !
    MESS(29:76)='CONTACT-XXXXXXXXXXXXXXXX introuvable; fichier Y"    '
    MESS(37:52)=CHERCH               ! InsÈrer CHERCH dans MESS
    ENCODE(1,4,MESS(75:75)) IFOIS
C   CALL FUNMCR(MESS)                ! Envoyer msg ‡ la CONSOLE
    WRITE(66,707) MESS               ! Inscrire le message dans LOG
707 FORMAT(1X,A80)                   ! Format du message
    KKK=0                        ! Flag pour dire aucun canal
520 IW=IW+1                          ! Chercher le 2e
    IF(IW.GT.40) GOTO 1016           ! Seulement 40 titres a chercher
    IF(ICH(IW).EQ.0) GOTO 519        ! Encoder et chercher
    GOTO 520                     ! Le suivant
53  ICH(IW)=I                    ! On connait le canal
    IUN(IW)=IUNIT                    ! Enregistrer le LUN
    TYPE_MANNEQUIN(IW)=ICON(POSI_MANNEQUIN(IW))
    MESS(1:43)='------------------------------------->  '
    MESS(44:80)='XXXXXXXXXXXXXXXX. Canal# YY. Fic# YY"'
```

```
      MESS(44:59)=TROUVE             ! RÈÈcrire le message
      ENCODE(2,5,MESS(69:70)) I      ! avec les mÍmes donnÈes
      ENCODE(2,5,MESS(78:79)) IFOIS      !
      WRITE(66,707) MESS
C     CALL FUNMCR(MESS)              ! et l'envoyer ‡ la CONSOLE

      KKK=I                    ! Variable de test
      NCAN=NCAN+1                    ! Nombre de canaux de trouver
      JCAN(NCAN)=IUNIT
      GOTO 520                 ! ALLER pour le 2e
1016      NBFICH=NBFICH-1                  ! Reduire le nombre de fichier
      IF(NBFICH.EQ.0.AND.KKK.EQ.0.AND.NCAN.EQ.0) THEN      ! Fin de la recherche
        MESS(1:40)='                              ' ! Vider MESS
        MESS(41:80)='                              '
        MESS(1:33)='Durant sa recherche de titres CON'
        MESS(34:70)='TACT: A rien trouve a calculer       '
        WRITE(66,707) MESS
        STOP'--ARRET sur manque de donnÈes ' ! Aucun canal ds aucun fichier
      ENDIF                    ! Fin du test
      IF(NBFICH.EQ.0.AND.NCAN.NE.0) GOTO 777   ! Certains canaux sont non-util.
        IFOIS=IFOIS+1          ! Le numero de la recherche
        GOTO 511               ! Retour pour 2e recherche
C     ----------------------------------------------------------
C     …crire l'entÍte
C     ----------------------------------------------------------
777 IGO=1
778 CALL PLOTS(0.0,0.0,0)            ! Initialisation de LASERPLOT
      ierr = usrfil('CONTACT.X')     ! Nom du fichier ‡ produire
      CALL LNEXCL                    ! Changer le mode d'imprimante
      RETURN                         ! On a nos valeurs
C     ---------------------------------------------------
C     Il y a eu un erreur durant la lecture du fichier du type LOCKED
C     ---------------------------------------------------
7     CALL ERRTST(30,J)              ! Tester s'il s'agit d'un err 30
      GOTO (20,30),J                 ! J=1 -> Locked, J=2 -> Inconnu
20    CALL CLOSE(4-IBOUK)            ! Fermer le fichier actif
      CALL FUNMCR('UNLOCK *.*')
      GOTO 899                 ! Allez chercher 1 autre fichier
C     ---------------------------------------------------
C     Erreur d'un type inconnu
C     ---------------------------------------------------
30    CALL CLOSE(IUNIT)              ! Fermer le fichier actif
      CALL CLS(6,1)                  ! Effacer a partir de (6,1)
898 STOP'-- CONTACT Avorte sur Automatique' ! Erreur inconnu
C     ---------------------------------------------------
C     Le fichier CHECK.CHK n'existe pas
C     ---------------------------------------------------
10    IGO=0
      STOP'--CONTACT doit Ítre utilisÈ en automatique seulement'
C     ---------------------------------------------------
C     Les formats
C     ---------------------------------------------------

2     FORMAT(1X,I1)
3     FORMAT(1X,A14)
5     FORMAT(I2)
4     FORMAT(I1)
6     FORMAT(I3)
201 FORMAT(2A8)
      END
```

# Annex J
(informative)

# AO/C1/C2 upper neck injury probabilities and injury cost

## J.1 Introduction

### J.1.1 Background

ISO 13232-5:1996 provided a method to assess the probability of various AIS injury severities for the following body regions:

- head (closed skull brain),
- chest (thorax),
- abdomen,
- lower extremities (femur fracture, tibia fracture, and knee dislocation).

The AIS probabilities were calculated based on objective measurements of injury assessment variables sensed and recorded in the Motorcyclist Anthropometric Test Device (MATD). These measurements could be from either full-scale tests or calibrated computer simulations.

There is a need and desire to evaluate injuries for all critical body regions, and for motorcyclists this includes in particular the cervical spine. ISO 13232:1996 provided for the measurement of upper neck forces and moments by a load cell near the upper neck joint of the MATD. Neck injury indices (NII) were calculated from these measurements. However, these previous NII;

- did not provide an indication of AIS injury severity level,
- did not provide an indication of injury probability, and
- in general (it has been observed) tended to over predict the number and likelihood of neck injuries.

Specifically, an investigation of the 501 LA/Hannover motorcycle impact configurations defined in ISO 13232-2:1996, using a simulation calibrated according to ISO 13232-7:1996, (Kebschull, et al., 1998), indicated that in approximately 30 percent of the impacts one or more of the NII exceeded a value of 1.0 (a value which is "interpreted as likely neck fracture or dislocation; with significant likelihood of spinal cord damage, which, at the C1/AO location has a fatal propensity," ISO 13232-5:1996, H.3.8.

However, the actual injury data for 498 LA/Hannover accidents with relative normal closing velocity < 121 km/h[3], which are presented in ISO 13232-2:1996, Annex C, indicate that only 2 percent of those accidents were non-fatal accidents in which neck rupture, dislocation, or fracture injuries were observed. For the fatal accidents, detailed head-neck autopsies were not done, so the occurrence of neck injuries among the fatal sample is unknown. However, if in the worst case, all of the fatal LA/Hannover accidents were assumed to involve neck injury, this would only account for an additional 3 percent of the accidents. If added to the non-fatal accidents in which there were neck injuries, this would correspond to a total maximum of 5 percent of real motorcycle accidents where some

3) Three of the 501 LA/Hannover cases had a relative normal closing velocity > 121 km/h. These 3 cases were excluded from further neck injury analysis because they were higher speeds than observed in the available USC fatal data and would therefore be outside the domain of validity of the resulting neck injury criteria.

level of neck injury was either observed or might be assumed. This is a much lower frequency of occurrence than suggested by the NIIs and related methodologies of ISO 13232:1996, in the example results previously noted.

Note that for other body regions (e.g., head, chest, abdomen, lower extremities), the calibrated simulation of Kebschull, et al., (1998), produces approximately the correct distribution of injury severities, in comparison with the real accident data.

These example results indicated the need for a more consistent and comprehensive set of neck injury probability relationships in ISO 13232:2002.

In addition, recently, the University of Southern California (USC) published a study involving the neck dissections of 304 fatally injured motorcycle riders (Thom, et al., 1995). The location, type, AIS severity level, and force direction were determined for each neck injury. A subset involving 67 of these accidents, which corresponded most closely with the 498 LA/Hannover cases with relative normal closing velocity $\leq$ 121 km/h in ISO 13232 in terms of typology, was recently further analyzed by the Head Protection Research Laboratory (HPRL) (Smith, 2002), and are summarized subsequently.

### J.1.2 Objectives for the neck injury probability analysis

The objective of the analysis described herein was to develop a probabilistic, objective injury criterion that would be:

- consistent with the form of the injury criteria for the other body regions in ISO 13232-5,
- based on the force and moment time histories from both computer simulations and full scale tests ISO 13232-4, ISO 13232-6, ISO 13232-7,
- suitable for predicting AIS 1 to 6 level injuries to the AO/C1/C2 region of the cervical spine,
- consistent with the frequency distributions of:
  - neck injury severities observed in the 485 non-fatal LA/Hannover motorcycle accidents and 67 USC fatal motorcycle accidents with relative normal closing velocity $\leq$ 121 km/h;
  - AO/C1/C2 neck injury severities and directions observed in the 67 USC motorcycle fatal accidents;
  - peak AO forces and moments observed in calibrated computer simulations of the 498 LA/Hannover accidents and 67 USC fatal motorcycle accidents, assuming the baseline helmet and OV were present in all cases, and a GPZ 500 motorcycle was the subject motorcycle in all cases.

## J.2 Databases

The desired injury probability curves will be based on injury data from Los Angeles, Hannover, and USC motorcycle accident databases. These databases are summarized in Table J.1. The LA and Hannover data are listed in Tables C.2 and C.3 of ISO 13232-2. The USC data is described in Thom, et al., (1995).

**Table J.1 — Summary of Accident Databases**

| Sample Criteria | | Database | | |
|---|---|---|---|---|
| | | LA | Hannover | USC |
| Accident | Reporting criteria | Police reported | Police reported | Police reported |
| | Number of vehicles | 2 | 2 | 2 |
| | Accident configurations | All, except untestable configurations | All, except untestable configurations | All, except runover/snag |
| | Investigation method | On scene, in-depth | On scene, in-depth | On scene, in-depth, including in-depth medical autopsies, including neck dissections |
| Subject vehicle | | Motorcycle with seated, solo rider | Motorcycle with seated, solo rider | Motorcycle with solo rider |
| Person | | Rider | Rider | Rider |
| | Injury severity | Injured or killed | Injured or killed | Death within 10 days |
| Other vehicle | | Passenger car | Passenger car | Passenger car |
| Region | | Los Angeles | Hannover | Los Angeles County |
| Time period | | 1976-1977 | 1980-1985 | August 1978-March 1981 |
| Sample size | | 501 | | 67 |
| Relative normal closing velocity ≤ 121 km/h | | 498 | | 67 |
| | Non fatal neck injuries | ≤ 2%[a] | | 92,5%[b] |
| | Fatal neck injuries | Unknown, but ≤ 3% | | 7,5% |
| | Fatal (all causes) | 3% | | 100% |
| Comment | | No neck dissections,<br>Neck injuries for fatal cases unknown | | Detailed information about neck injuries |
| Reference | | Part 2, Table C.2 | Part 2, Table C.3 | Smith, 2002 |

[a] Ruptures, dislocations, and fractures

[b] The fatal sample indicates that nearly all of these motorcycle fatal accidents involve non-fatal neck injuries. This confirms the assumption stated previously that the 3 percent of LA/Hannover accidents which were fatal all involved some (i.e., non-fatal) levels of neck injury.

## J.3 Technical Approach

The desired AO/C1/C2 neck injury probabilities were determined by fitting the distributions of neck forces and moments predicted by ISO 13232 calibrated computer simulations to the accident databases described in subclause J.2. This subclause describes the assumptions and methods that were used.

### J.3.1 Assumptions

The analysis methods and resulting neck injury criteria were based on various assumptions, which are described in this subclause.

#### J.3.1.1 Basic assumptions

Basic assumptions for this analysis were that:

- A neck injury criteria is sought that would be applicable to a majority of motorcycle-car crashes. However, the range of crash conditions in the available accident databases limits the domain of validity of the injury criteria. The neck injury criteria is not applicable to high speed crashes with relative normal closing velocity greater than 121 km/h.

- The distribution of neck injury severities in the 67 USC fatal accidents are the same as the distribution of neck injury severities in the 13 fatal LA/Hannover accidents, with relative normal closing velocities less than or equal to 121 km/h.

- The distribution of neck forces and moments predicted by computer simulations (based on ISO 13232 computer simulations) of 67 USC fatal motorcycle accidents with a GPZ 500 motorcycle and a helmeted rider, are the same as those which occurred in the 67 USC fatal motorcycle accidents, and that these distributions are representative of all fatal motorcycle accidents.

- The distribution of forces and moments predicted by the 498 ISO 13232 calibrated computer simulations with a GPZ 500 motorcycle and a helmeted rider are the same as those which occurred in the 498 LA/Hannover injury accidents, and that these distributions are representative of all injurious motorcycle accidents.

These assumptions are based on the underlying assumption that neck forces and moments and resulting injury severity are independent of helmet use. This topic is discussed in Hurt, et al., (1981).

### J.3.1.2 Assumed Mathematical Model

It is further assumed that the probability of a maximum $AIS_{AO/C1/C2} \geq k$ neck injury is related to an objective injury index $NII_{max}$ as follows:

$$P\left(MAIS_{A0/C1/C2} \geq k \middle| NII_{\max} = x\right) = 1 - e^{-\left(\left(\frac{x-\gamma_k}{\eta_k}\right)^{3,5}\right)} \quad (1)$$

where $\gamma_k$ and $\eta_k$ are injury risk distribution coefficients to be determined. It is further assumed that this distribution approximates a normal distribution with mean $\mu_k$, and standard deviation $\sigma_k$, according to the equations from SAE AE-9 (1987) and Råde: and Westergren (1990).

$$\mu_{\max} = \gamma_k + 0{,}8997\eta_k \quad (2)$$

$$\sigma_k = 0{,}2847\eta_k \quad (3)$$

The objective injury index $NII_{max}$ is defined as follows:

$$NII_{\max} = \max_t NII(t) \quad (4)$$

where

$$NII(t) = \max\left(\left(\left(\frac{F_C(t)}{F_C^*} + \frac{F_T(t)}{F_T^*} + \left(\left(\frac{M_X(t)}{M_X^*}\right)^2 + \left(\frac{M_E(t)}{M_E^*} + \frac{M_F(t)}{M_F^*}\right)^2\right)^{1/2}\right)^2 + \left(\frac{M_Z(t)}{M_Z^*}\right)^2\right)^{1/2}, \alpha\left|\frac{F_C(t)}{F_C^*} + \frac{F_T(t)}{F_T^*}\right|\right) \quad (5)$$

and where

$F_C$ is the neck axial compression force[4], $F_C = -min(F_Z,0)$;

$F_T$ is the neck axial tension force, $F_T = max(F_Z,0)$;

$M_X$ is the neck lateral flexion moment;

$M_E$ is the neck extension moment[4], $M_E = -min(M_Y,0)$;

$M_F$ is the neck flexion moment, $M_F = max(M_Y,0)$;

$M_Z$ is the neck torsion moment;

$F_I^*$ and $M_I^*$ are force and moment normalizing coefficients, to be determined for $I = \{C,T,X,E,F,Z\}$;

$\alpha$ is a coefficent representing increased injury potential for axial forces relative to the injury potential for combined forces and moments, also to be determined.

The objective injury index defined by equations (4) and (5) was adapted from the generalized stress ratio method for estimating the strength of materials under combined loading conditions described in many references, for example, Shanley and Ryder (1937), Bruhn (1973), and US Department of Defense MIL-HDBK-5D (1983), and assuming that the generalized exponent has a value of either 1 or 2[5][6][7]. Neck shear forces are not included in this model because shear motions were observed in all of the 64 cases in the USC fatal accident database with AO/C1/C2 neck injuries. As a result there is insufficient information in this database to identify an injury criteria based on shear force[8].

Equation (5) can be re-expressed in terms of the neck force and moment components as follows:

$$NII^2(t) = \left( NII_C(t) + NII_T(t) + \left( NII_X^2(t) + \left( NII_E(t) + NII_F(t) \right)^2 \right)^{1/2} \right)^2 + NII_Z^2(t) \quad (6)$$

4) Note neck axial compression force and extension moment and the corresponding coefficients in table J.5 are defined in this annex as positive values. The axial compression force and extension moment and the corresponding coefficients in subclause 5.8.1 are defined with the opposite sign.

5) Published references (e.g., US Department of Defense MIL-HDBK-5D (1983), pages 1-29) indicate that for various materials, the exponents in equation (5) in general can have real values in the range of n=1 to 3, as indicated in Figures 1.5.3.5 of US Department of Defense MIL-HDBK-5D (1983), and elsewhere. This assumes that biological material such as ligaments and vertebral facets exhibit material characteristics analogous to those for metallic materials, for example.

6) For strength of materials, in general, bending and axial stresses are considered to be linearly additive (i.e., $n$=1); moments about orthogonal axes are considered to be resultants (i.e., n=2); and combinations of shear (i.e., torsion) and axial stress are considered to be resultants. Equations C4.11, C4.16, and C4.16 in Bruhn (1973), are examples of stress ratios for these types of interactions.

7) Equation (5) allows for asymmetric (e.g., extension-flexion, tension-compression) strengths, and strengths in each direction which are independent of the strengths in the other directions, which would be appropriate for complex structures such as the human neck.

8) Possible explanations of this are that neck shear motion may be uniformly associated with motorcycle (and perhaps all motor vehicle) neck injuries; or alternatively, that shear motion is a dependent variable, resulting from the other combined motions that are present (e.g., bending, torsion, and compression-tension).

where

$$NII_I(t) = \begin{cases} \left(\dfrac{F_I(t)}{F_I^*}\right) \text{for } I = \{C,T\} \\ \left(\dfrac{M_I(t)}{M_I^*}\right) \text{for } I = \{X,E,F,Z\} \end{cases} \quad (7)$$

It is furthermore assumed that if a maximum AIS AO/C1/C2 $\geq$ k injury does occur, then the injuries are associated with the neck force and/or moment directions, $I$, which satisfy the equation:

$$NII_I(t_{\text{max}}) \geq Q_k^* \mu_k \quad (8)$$

where $t_{max}$ is defined such that:

$$NII(t_{\text{max}}) = NII_{\text{max}} \quad (9)$$

The $Q_k^*$ coefficients are also to be determined.

#### J.3.1.3 Additional assumptions

It is further assumed that:

- the forces in the new MATD dummy neck (Withnall, 1999) are those which are relevant and correlated with human injuries. The new MATD neck dynamic response in three axes has been validated against volunteer human response corridors as documented in Withnall (1999). This approach for developing neck injury criteria has been commonly used by others in the past;
- the simulated dynamic response of the new MATD neck correlates strongly with the dynamic response from full-scale tests as noted in Van Auken, et al., (2001);
- the distributions of neck forces and moments from calibrated computer simulations of a GPZ 500 and helmeted rider for the 67 USC fatal accident cases are assumed to correspond to the distributions of the observed injury severities and motions;
- the coefficients that describe the relative distribution of injuries by direction ( $F_C^*, F_T^*, M_X^*, M_E^*, M_F^*, M_Z^*$, and $Q^*$ ) are assumed to be the same for both fatal and non-fatal motorcycle accidents, and for all injury severity levels;
- $F_C^*, F_T^*, M_X^*, M_E^*, M_F^*$, and $M_Z^*$ have positive values, which are assumed to be less than the overall maximum values for $F_C, F_T, M_X, M_E, M_F$, and $M_Z$ that occur in the computer simulations of the 67 USC fatal cases, because observed injuries were previously associated with each of these axes;
- the $\alpha$ coefficient that describes the injury potential for axial forces relative to the injury potenial for combined forces and moments may be different in the LA/Hannover and fatal USC motorcycle accidents. It is furthermore assumed that there were no injuies in the fatal USC motorcycle accidents resulting from only axial forces and that $\alpha$ =1.
- the overall probabilities of neck injury in fatal and non-fatal subsamples of motorcycle accidents may be different (i.e., the intercept value $\mu_k$ for riders in fatal accidents may be different from $\mu_k$ for injured riders);
- the standard deviation of the injury risk, $\sigma_k$, which is related to the slope of the probability of injury vs. injury index curve, is the same for all AIS injury severity levels (i.e., failure mechanism has similar mechanics at all AIS levels, e.g., similar to ISO 13232-5 thoracic compression injury probability). This assumption eliminates the

possibility of overlapping injury risk curves (e.g., the probability of an AIS 3+ injury greater than the probability of an AIS 2+ injury for a given injury index value);

— the coefficient of variation (standard deviation divided by the mean) of the AIS $\geq$ 3 injury risk curve is 0.2 (i.e., $\sigma_3/\mu_3$ =0.2). This assumption is based on results for neck extension moment and tension in Mertz and Prasad (2000);

— the probability of $AIS \geq 3$ injury due to a 4.17 kN tension only force is 0.03 based on AAMA (1998).

— "Direction of force" corresponds to "direction of motion" for each neck injury observed in the USC fatal accidents, which was based on detailed reconstruction of rider and in particular head and neck kinematics.

### J.3.2 Methods

The coefficients for the assumed mathematical model described in subclause J.3.1.2 were identified in two steps. First, the values for $F_I^*, M_I^*,$ and $Q_k^*$ were estimated by fitting the distribution of neck injury severities and direction components, which are predicted by the model from computer simulations of the 67 USC fatal accidents, to the observed distribution of injury severities and directions observed in the USC 67 fatal accident database. Then, the values for $\mu_k$ were estimated by fitting the distribution of neck injury indices predicted by the model from the computer simulations of the 498 generic LA/Hannover cases to the distribution of injury severities in Table J.3. The values for $\gamma_k$ and $\eta_k$ were then calculated from $\mu_k$ and $\sigma_k$ assuming that $\sigma_k$ = 0.2 $\mu_3$.

#### J.3.2.1 Distribution of Neck Injuries by Injury Severity and Direction

The distribution of neck injuries in the USC fatal accident database can be described by the frequencies with which the contributing directions occur by injury severity level. Let $n_{k,c,t,x,e,f,z}$ be the number of riders in the USC fatal accident database according to the AO/C1/C2 neck injury severity and axis/direction, where the subscripts $c$, $t$, $x$, $e$, $f$, $z$ are either 0 or 1 as follows:

$I$ = 1 if the rider had an $MAIS_{AO/C1/C2} \geq k$ injury, and the injury was associated with directions $F_I$ and $M_I$.

$I$ = 0 otherwise.

Note that $n_{k,0,0,0,0,0,0}$ is the number of riders with $MAIS_{AO/C1/C2} < k$ injuries. Values of $n_{k,0,0,0,0,0,0}$ for the USC fatal accident database are listed in Table J.2. Also note that the total number of cases in the fatal accident database is:

$$n_{total} = \sum_{c=0}^{1}\sum_{t=0}^{1}\sum_{x=0}^{1}\sum_{e=0}^{1}\sum_{f=0}^{1}\sum_{z=0}^{1} n_{k,c,t,x,e,f,z} \qquad (10)$$

which is a constant for all injury severity levels k ($n_{total}$ = 67).

**Table J.2 — Distribution of neck AO/C1/C2 injuries in the USC fatal motorcycle accident database**

| k | Number of Cases with $MAIS_{AO/C1/C2}$ = k | Number of Cases with $MAIS_{AO/C1/C2}$ < k ($n_{k,0,0,0,0,0,0}$) |
|---|---|---|
| 0 | 3 | 0 |
| 1 | 0 | 3 |
| 2 | 9 | 3 |
| 3 | 39 | 12 |
| 4 | 0 | 51 |

| k | Number of Cases with $MAIS_{AO/C1/C2}$ = k | Number of Cases with $MAIS_{AO/C1/C2}$ < k ($n_{k,0,0,0,0,0,0}$) |
|---|---|---|
| 5 | 11 | 51 |
| 6 | 5 | 62 |

In a similar manner, let $m_{k,c,t,x,e,f,z}$ be the number of computer simulations where AO/C1/C2 neck injury is indicated, where the subscripts $c, t, x, e, f, z$ are either 0 or 1 as follows:

I = 1 if $NII_{\max} \geq S_k$ and $NII_I(t_{\max}) \geq Q_k{}^* S_k$

I = 0 otherwise.

The total number of computer simulation cases is:

$$m_{total} = \sum_{c=0}^{1}\sum_{t=0}^{1}\sum_{x=0}^{1}\sum_{e=0}^{1}\sum_{f=0}^{1}\sum_{z-0}^{1} m_{k,c,t,x,e,f,z} \tag{11}$$

which is also a constant for all injury severity levels k (e.g., $m_{total}$ = 67).

The injury criteria coefficients $F_I^*, M_I^*,$ and $Q_k^*$ , and $S_k$ were selected to minimize the difference between the distributions of predicted and observed injuries. Specifically, the coefficients $S_k F_I^*, S_k M_I^*,$ and $Q_k^*$ were determined by the numerical searches described in Annex M to minimize the difference function $J$,

$$J = \sum_{k=1}^{6} J_k \tag{12}$$

where

$$J_k = \sum_{c=0}^{1}\sum_{t=0}^{1}\sum_{x=0}^{1}\sum_{e=0}^{1}\sum_{f=0}^{1}\sum_{z=0}^{1}\left(\frac{n_{k,c,t,x,e,f,z}}{n_{total}} - \frac{m_{k,c,t,x,e,f,z}}{m_{total}}\right)^2 \tag{13}$$

and where

$m_{k,0,0,0,0,0,0}$ is $n_{k,0,0,0,0,0,0}$;

$S_1$ is 1;

$Q_k^*$ is the largest value that satisfies $NII_I(t_{\max}) \geq Q_k^* S_k$ for at least one direction, $I$, for each of the cases that satisfy $NII_{\max} \geq S_k$ .

The constraint that $m_{k,0,0,0,0,0,0,0}$ = $n_{k,0,0,0,0,0,0,0}$ was imposed in order to facilitate the model coefficient identification process. With this constraint, $S_k$ can be directly calculated from the $F_I^*$ and $M_I^*$ coefficients, thus eliminating one coefficient from the model coefficient search. The constraint that $S_1$ = 1 was chosen in order to uniquely define the absolute magnitude of the $F_I^*$ and $M_I^*$ coefficients.

### J.3.2.2 Distribution of Neck Injuries by Severity

The relationship between the neck injury index, $NII_{max}$, and the injury severity level was determined by fitting the distribution of the neck injury indices from computer simulations of the 498 ISO generic accident cases, to the distribution neck injuries in the 498 LA/Hannover accident database listed in Table J.3. The distribution of LA/Hannover cases in Table J.3 was estimated using the data and methods in Annex K.

**Table J.3 — Distribution of neck AO/C1/C2 injuries in the LA/Hannover database**

| k | Estimated Number of Cases with $MAIS_{AO/C1/C2}$ = k (from column 9 of Table K.1) | Estimated Number of Cases with $MAIS_{AO/C1/C2}$ < k $n_k$ | 95% Confidence Limits for mk such that $\chi^2 \le 3.84$ (Equation 15) | |
|---|---|---|---|---|
| | | | $m_k^-$ | $m_k^+$ |
| 0 | 479 | 0 | - | - |
| 1 | 4 | 479 | 466 | 489 |
| 2 | 3 | 483 | 471 | 491 |
| 3 | 9 | 486 | 475 | 493 |
| 4 | 0 | 495 | 488 | - |
| 5 | 2 | 495 | 488 | - |
| 6 | 1 | 497 | 492 | - |

For each injury severity level k, the numbers of LA/Hannover cases with $MAIS_{AO/C1/C2} \ge k$ injuries and computer simulation cases with $NII_{max} \ge \mu_k$ can be expressed according Table J.4, where $\mu_k$ and $m_k$ are to be determined. If $NII_{max}$ is sorted such that $NII_{max,i} \le NII_{max,i}$ + 1, for $i$ = 1 to 497, then the values for $\mu_k$ can be calculated from $m_k$ according to the equation:

$$\mu_k = \sqrt{NII_{\max,m_k} NII_{\max,m_k+1}} \tag{14}$$

**Table J.4 — Number of cases with observed and predicted injuries**

| | Number of Cases | |
|---|---|---|
| | $MAIS_{AO/C1/C2} \ge k$ (LA/Hannover database) | $NII_{max} \ge \mu_k$ (computer simulations) |
| No | $n_k$ | $m_k$ |
| Yes | 498 – $n_k$ | 498 – $m_k$ |
| Total | 498 | 498 |

The best estimate of $\mu_k$, for k = 1 to 6, corresponds to $m_k = n_k$, the number of cases with $MAIS_{AO/C1/C2} < k$ listed in the third column of Table J.3. As a result, the distribution of $MAIS_{AO/C1/C2}$ injuries predicted by the 498 computer simulations will match the distribution of neck injuries observed in the LA/Hannover database (Figure J.5).

The 95% confidence intervals for $\mu_k$ can be considered the range of values for $\mu_k$ such that the portion of cases with $NII_{max} \ge \mu_k$ is not statistically significantly different than the portion of cases with $MAIS_{AO/C1/C2} \ge k$. This condition is satisfied for $m_k^- \leq m_k \leq m_k^+$ such that $\chi^2 \leq 3{,}84$, where $\chi^2$ is calculated according to the following equation from Box, et al., (1978).

$$\chi^2 = \frac{\left(n_k\left(498 - m_k\right) - m_k\left(498 - n_k\right)\right)^2\left(2 \times 498\right)}{\left(n_k + m_k\right)\left(498 = n_k + 498 - m_k\right)\left(498\right)^2} \tag{15}$$

Values for $m_k^-$ and $m_k^+$ that satisfy this condition are listed in the last two columns of Table J.3. The upper confidence limits for $\mu_4$, $\mu_5$, and $\mu_6$ are undefined.

## J.4 Resulting MATD neck injury criteria

The results of the injury criteria analysis for the new MATD neck from Withnall, (1999), are described in this clause.

### J.4.1 MATD neck injury direction coefficients

The injury direction coefficients were identified according to the methods described in subclause J.3.2.1. The resulting fit was J = 462/67$^2$ = 0,103 for the coefficient values listed in Tables J.5 and J.6. Table J.7 lists the number of observed and predicted injuries by injury severity and direction, which summarizes the fit to the 64 individual bins. The correlation between the predicted and observed bin counts ($m_{k,c,t,x,e,f,z}$ and $n_{k,c,t,x,e,f,z}$), excluding the non injury cases, was $r^2$=0,56.

**Table J.5 — Force and moment normalizing coefficients for the new MATD neck**

| Coefficient | Estimated Value | |
|---|---|---|
| $F_C^*$ | 6,53 | kN |
| $F_T^*$ | 3,34 | kN |
| $M_X^*$ | 62,66 | Nm |
| $M_E^*$ | 58,0 | Nm |
| $M_F^*$ | 204,2 | Nm |
| $M_Z^*$ | 47,1 | Nm |

**Table J.6 — Injury threshold coefficients for the 67 USC fatal cases with the new MATD neck**

| $k$ | $S_k$ | $Q_k^*$ |
|---|---|---|
| 1 | 1 | 0,619 |
| 2 | 1,00 | 0,619 |
| 3 | 1,50 | 0,650 |
| 4 | 3,74 | 0,594 |
| 5 | 3,74 | 0,594 |
| 6 | 5,20 | 0,564 |

**Table J.7 — Comparison of number of observed and predicted injuries by injury severity and direction**

| **Number of cases in the USC fatal motorcycle accident database with $MAIS_{AO/C1/C2} \geq k$ and indicated direction** | | | | | | | **Number of computer simulations of the USC fatal cases with $NII_{max} \geq S_k$ and $NII_I(t_{\max}) \geq Q_k^* S_k$** | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Direction | $k$ | | | | | | $I$ | $k$ | | | | | |
| | 1 | 2 | 3 | 4 | 5 | 6 | | 1 | 2 | 3 | 4 | 5 | 6 |
| Compression | 5 | 5 | 4 | 0 | 0 | 0 | $C$ | 8 | 8 | 1 | 0 | 0 | 0 |
| Tension | 18 | 18 | 16 | 4 | 4 | 0 | $T$ | 12 | 12 | 11 | 1 | 1 | 0 |
| Bending | 42 | 42 | 35 | 11 | 11 | 2 | $X$ | 42 | 42 | 30 | 7 | 7 | 1 |
| Extension | 33 | 33 | 29 | 8 | 8 | 4 | $E$ | 28 | 28 | 23 | 6 | 6 | 2 |
| Flexion | 20 | 20 | 17 | 4 | 4 | 0 | $F$ | 16 | 16 | 10 | 0 | 0 | 0 |
| Torsion | 20 | 20 | 17 | 7 | 7 | 2 | $Z$ | 28 | 28 | 16 | 5 | 5 | 2 |
| All | 64 | 64 | 55 | 16 | 16 | 5 | - | 64 | 64 | 55 | 16 | 16 | 5 |

The shape and step-wise fit of the $NII_{max}$ criteria to the USC data is illustrated in Figure J.1. There are six scatter plots, one for each pair of $F_z$, $M_x$, $M_y$, and $M_z$ axes. The numbers in each scatter plot are the maximum $AIS_{AO/C1/C2} = k$ predicted by $NI_{max} \geq S_k$ computed from the forces and/or moments at $t_{max}$, using the coefficients listed in Tables J.5 and J.6, for injuries associated with the forces and moments on the plot. For example, the graph in the upper left corner is a scatter plot of injuries that were only associated with tension $\left(NII_T(t_{\max}) \geq Q_k^* S_k\right)$, compression $\left(NII_C(t_{\max}) \geq Q_k^* S_k\right)$, and/or lateral bending $\left(NII_X(t_{\max}) \geq Q_k^* S_k\right)$ motion vs $F_z$ and $M_x$. Envelopes of constant $NII_{max} = S_k$ are also shown each plot, corresponding to the $S_k$ values in Table J.6. The envelopes separate out the injuries by AIS level as intended.

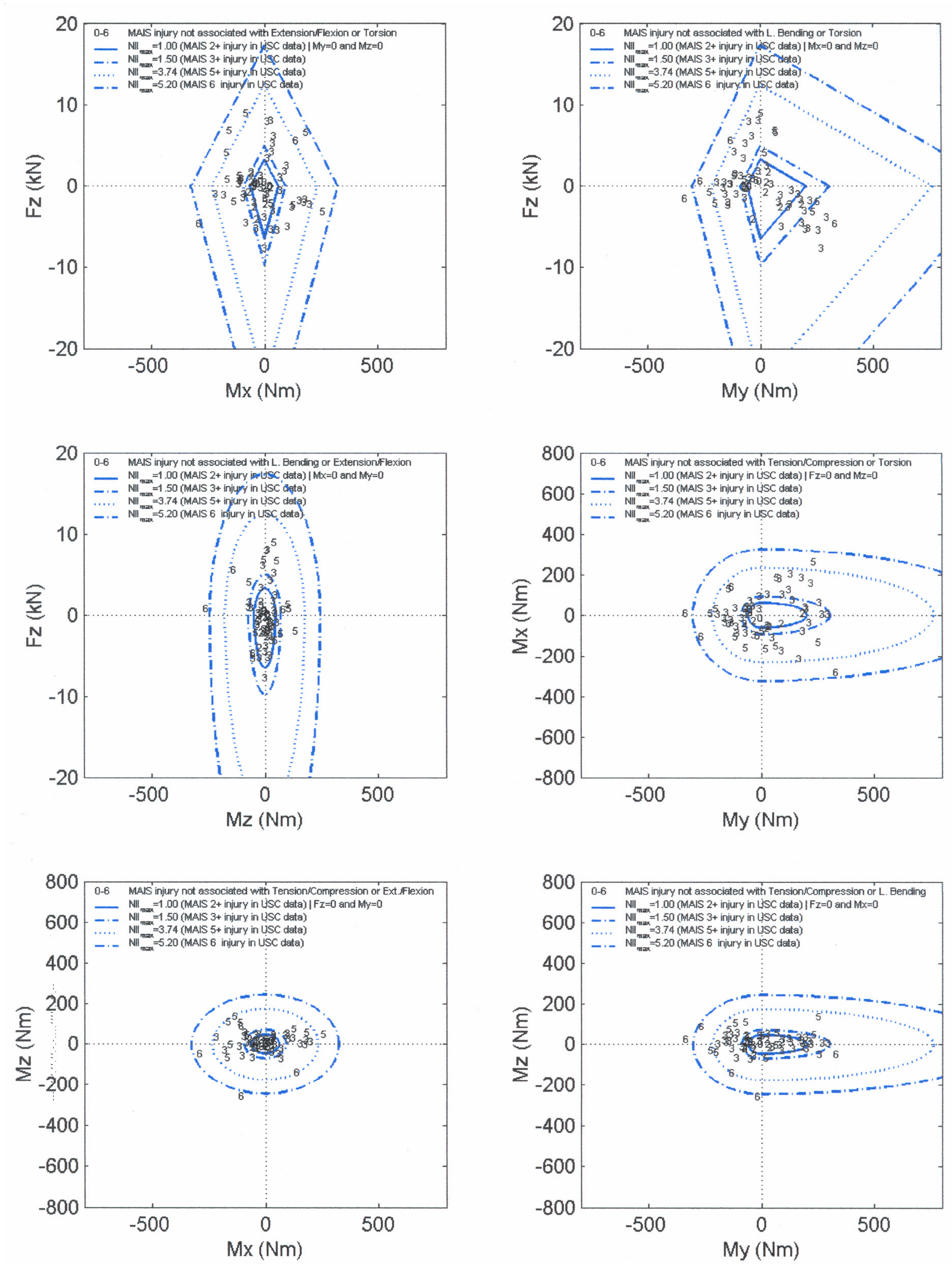


**Figure J.1 — Forces and moments at $t_{max}$ from computer simulations of 67 USC fatal cases and the best step-wise fit envelopes of constant $NII_{max}$, providing the basis for the envelope shape**

### J.4.2 MATD neck injury risk (probability) coefficients

The injury severity coefficients were identified from the LA/Hannover data according to the methods described in subclause J.3.2.2. Curves illustrating 50% probability of MAIS injury boundaries for the 498 LA/Hannover cases are illustrated in Figure J.2 based on the clipping factor $\alpha$ =0.31. The clipping factor was selected in order that $F_z$ = 4.17 kN would correspond to a 0.03 probability of a MAIS $\geq$ 3 injury (AAMA, 1998) as illustrated in Figure J.3. The resulting coefficients are listed in Table J.8 and the injury risk curves are illustrated in Figure J.4. The distribution of neck injuries for the 498 computer simulations also matches the distribution of injuries in the LA/Hannover database, as illustrated in Figure J.5. For reference purposes, the maximum neck force and moment distributions for the 498 computer simulations are illustrated in Figure L.1 in Annex L.

**Table J.8 — Injury severity risk coefficients for the new MATD neck**

| $k$ | $\mu_k$ | $\sigma_k = 0.2\mu_3$ | $\gamma_k$ | $\eta_k$ |
|---|---|---|---|---|
| 1 | 5,00 (4,33, 6,96) | 1,247 | 1,06 | 4,38 |
| 2 | 5,80 (4,46, 7,42) | 1,247 | 1,86 | 4,38 |
| 3 | 6,23 (4,70, 7,84) | 1,247 | 2,29 | 4,38 |
| 4 | 8,67 (6,62, -) | 1,247 | 4,73 | 4,38 |
| 5 | 8,67 (6,62, -) | 1,247 | 4,73 | 4,38 |
| 6 | 10,07 (7,59, -) | 1,247 | 6,13 | 4,38 |

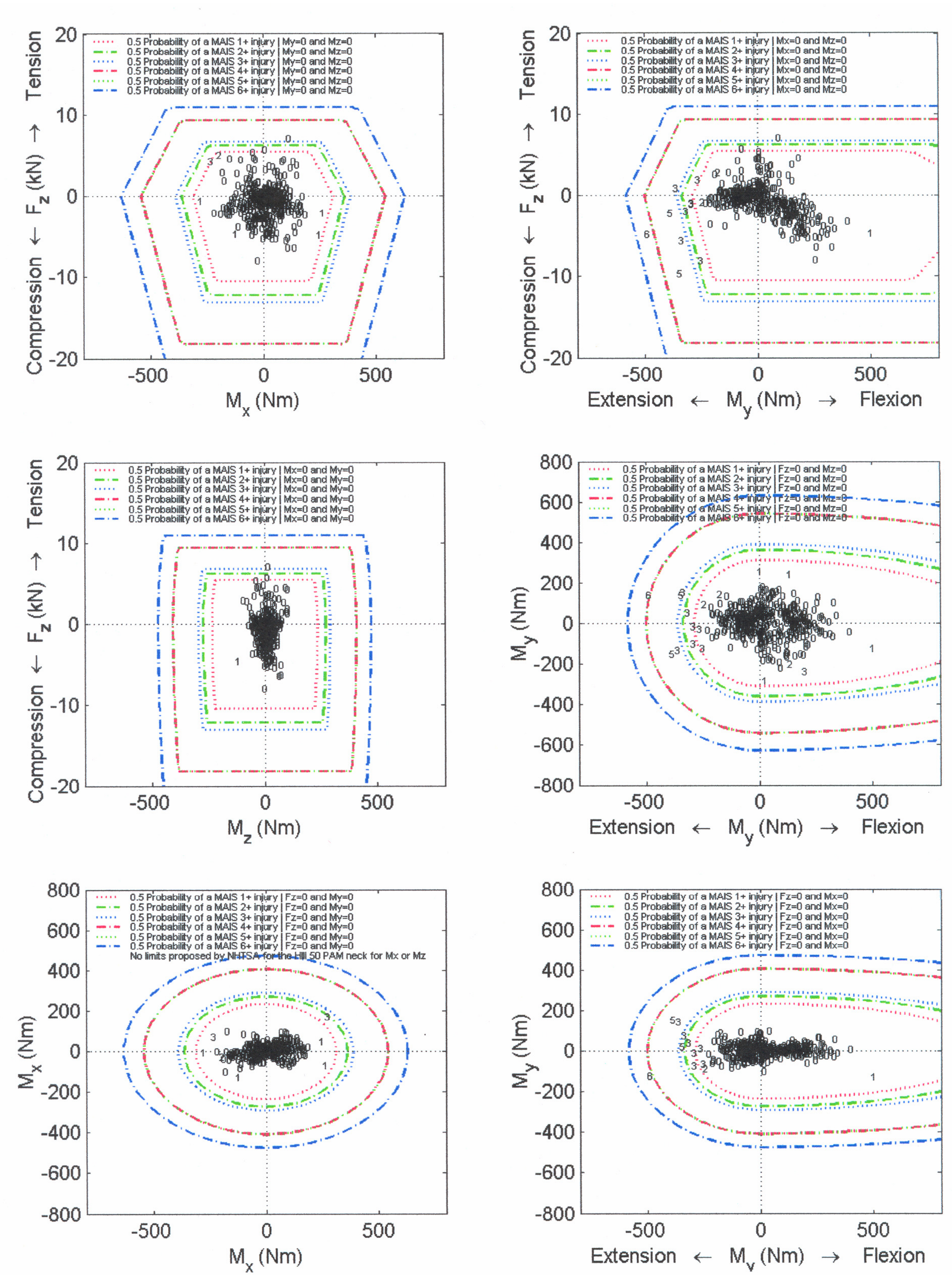


**Figure J.2 — Forces and moments at $t_{max}$ from computer simulations of 498 LA and Hannover cases and envelopes of constant $NII_{max}$, providing the basis for the $NII_{max}$ vs 50% injury probability**

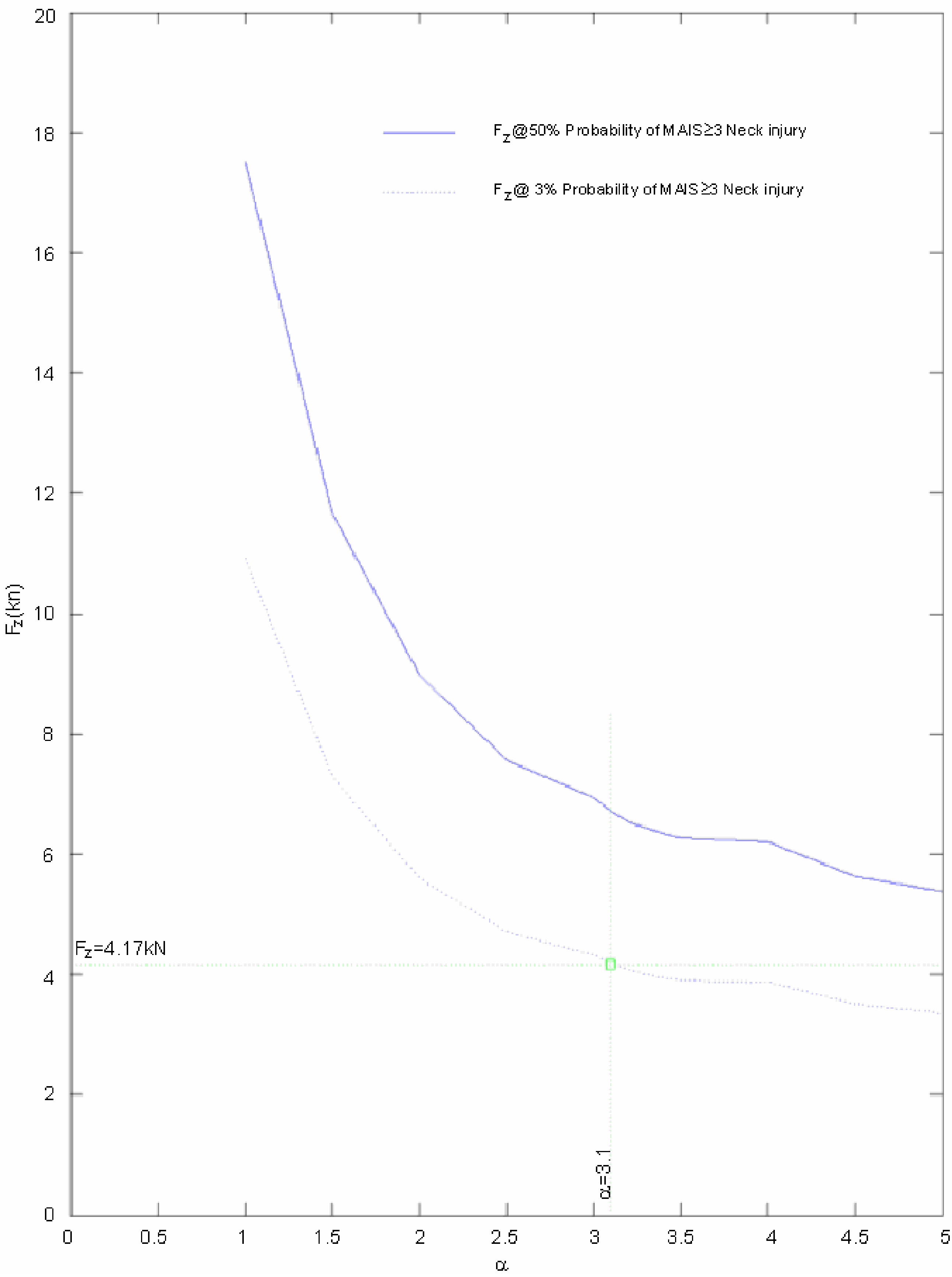


**Figure J.3 — Critical tension force vs the α coefficient, providing the basis for the α =3.1**

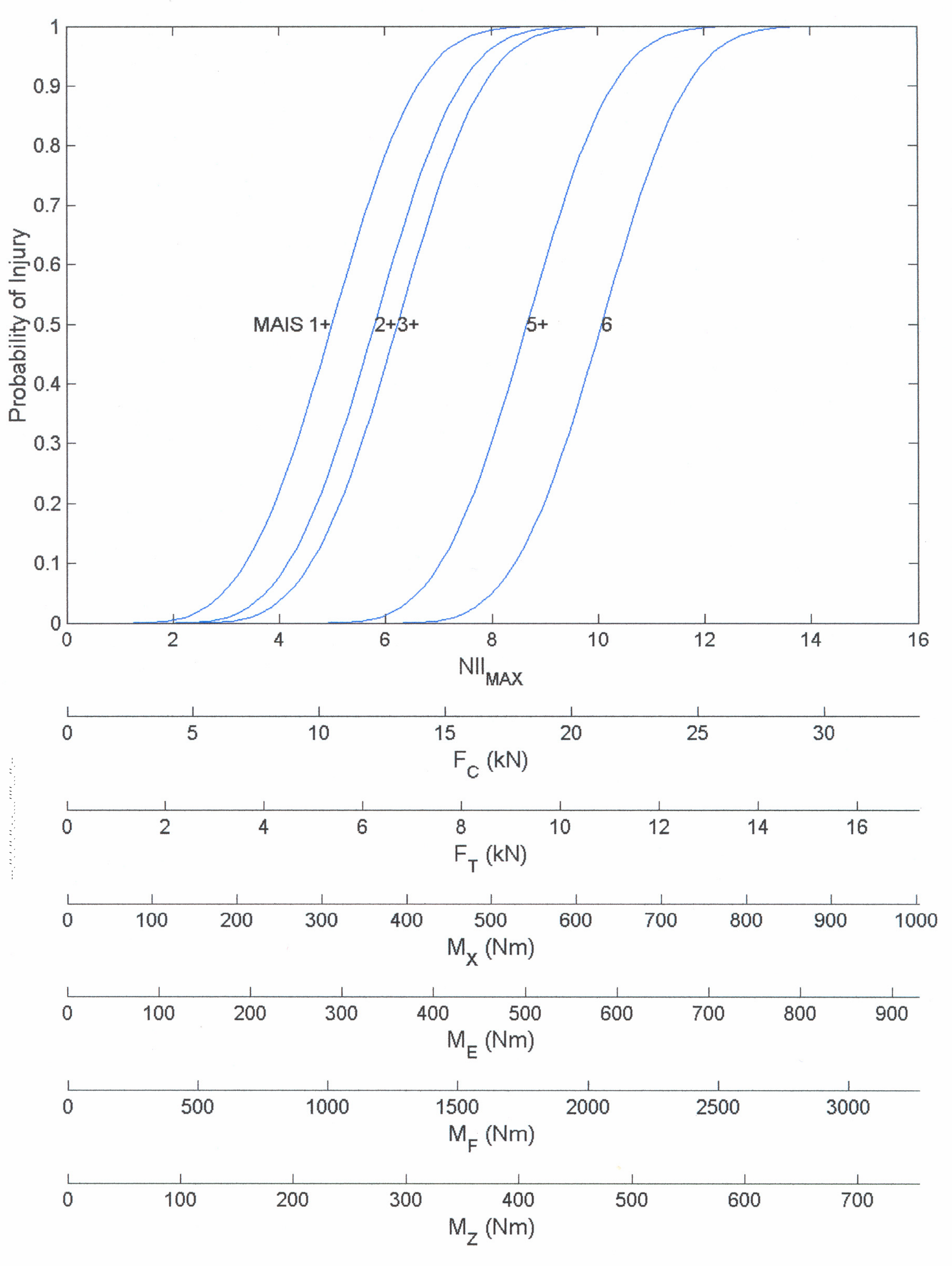


**Figure J.4 — Neck AO/C1/C2 injury risk curves for the new MATD neck**

NOTE The horizontal axis scales other than $NII_{max}$ assume that all other forces other than the denoted force are zero.

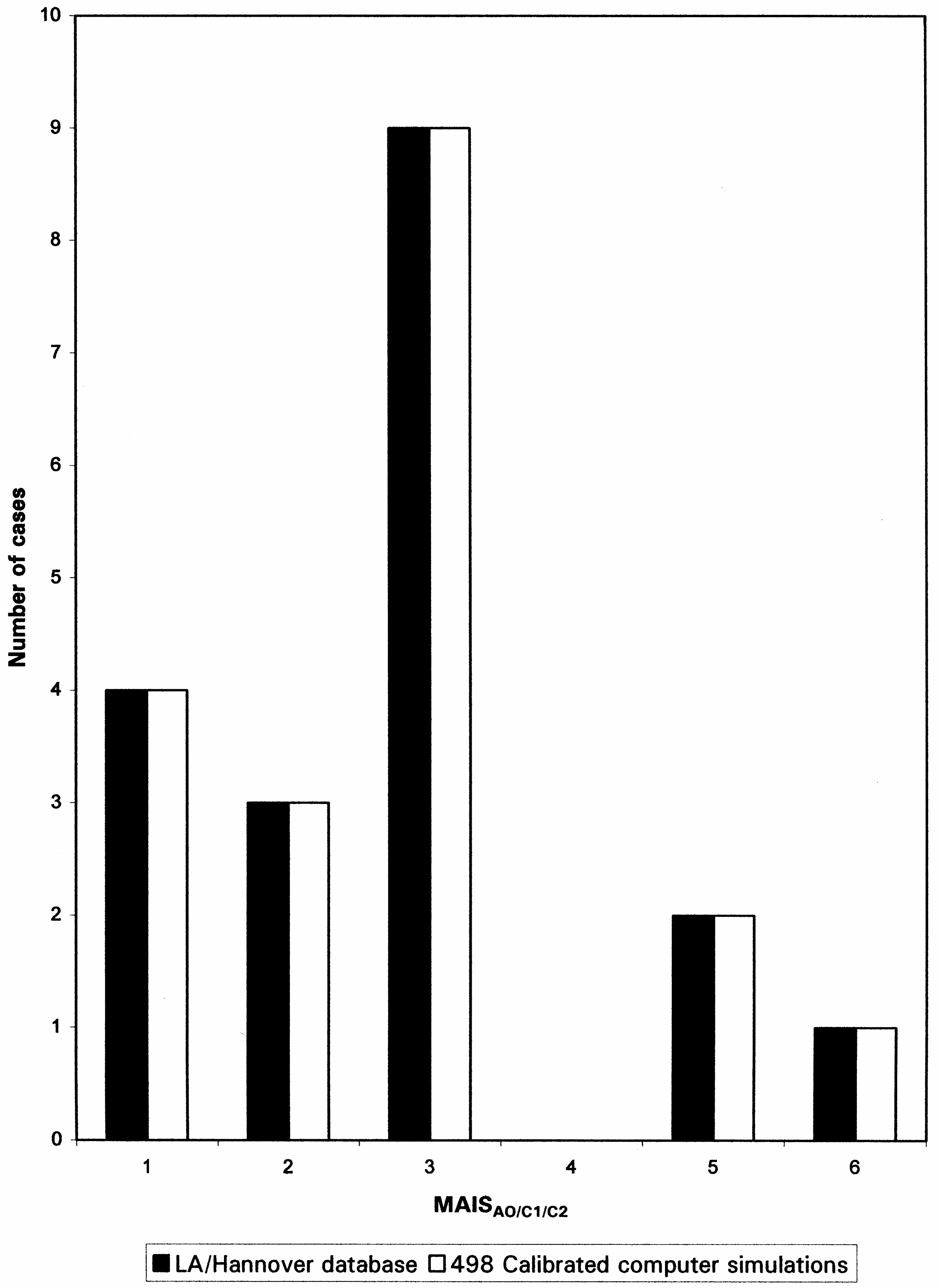


**Figure J.5 — Distribution of observed and predicted computer simulations**

## J.5 Comparison of neck injury criteria for a 50th percentile male

The developed injury criteria in clause J.4 are intended to be applied to the forces and moments measured with the revised 2001 MATD neck and cannot be applied to the forces and moments measured with other dummy necks.

The respective dummy necks are mechanically quite different, the $MAIS_{AO/C1/C2} \geq 3$ injury criteria for the new MATD neck are compared to criteria for the Hybrid III 50th percentile male neck according to Mertz and Prasad (2000), Alliance of Automobile Manufacturers NHTSA 98-4405-9 (1998), Alliance of Automobile Manufacturers NHTSA 99-6407-40 (1999), US DOT NHTSA 00-7013; Notice 1 (2001) in Table J.9. One important difference between the MATD and Hybrid III neck injury criteria is the number of axes for which the criteria are defined, as illustrated in Figure J.6. The Hybrid III neck injury criteria is based on one force and one moment (extension or compression force, and extension or bending moment), and does not take into consideration lateral bending or torsion moment. The MATD injury criteria are based on all four of these forces and moments. Neck $MAIS \geq 3$ injury risk curves for the Hybrid III 50th percentile male vs tension force and combined tension and extension moment, by Mertz and Prasad (2000), are illustrated in Figures J.7 and J.8, for comparison purposes.

In general, the shape of the injury criteria for the new MATD neck are in good agreement with the criteria for the Hybrid III 50th percentile adult male, although the AIS 3 + force and moment levels are generally larger than the Hybrid III levels. For example, whereas the tension only force level corresponding to a 3% probability of an AIS $\geq$ 3 injury for the MATD neck and the Hybrid III neck are in close agreement, the compression only force level is 8,2 kN for the MATD neck compared to 4,0 kN for the Hybrid III neck. The relative scaling between the injurious tension and compression force levels for the MATD neck was determined from the fatal USC cases based on the assumptions listed in subclause J.3.1, while the basis for the Hybrid III neck compression only force level appears to be less certain. The injurious force and moment levels for the four axis MATD neck criteria are larger than the two axis criteria for the Hybrid III neck. The force and moment levels for a four axis criteria would be expected to be slightly larger than for a one or two axis injury criteria because it does not need to compensate for the increased likelihood of injury that may be associated with lateral bending or torsion moments. Differences in the criteria can be attributed to:

— Differences between the new MATD neck and 50th percentile human adult male neck,

— The Hybrid III P50 criteria is based on data for pigs, which are assumed to be representative of 3 year old humans, which are then scaled to 50th percentile human adult male.

## Table J.9 — Comparison of neck injury criteria for a 50th percentile male

| Direction | Injury Severity | $\mu$ | $\sigma$ | $\sigma / \mu$ | Normalizing value | | Percentiles | | | Units | Applicable Neck | Criteria | Source | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | 3.0% | 5.0% | 50.0% | | | | | |
| **Compression** | AIS 3 + | 6,23 | 1,247 | 0,20 | $F_c^*/\alpha$ | 2,11 | 8,19 | 8,81 | 13,13 | kN | New MATD | a | ATB CS | |
| | | | | | $F_c^*$ | 6,53 | 25,40 | 27,32 | 40,71 | kN | | c | | |
| | Allowable | | | | - | 4,00 | 4,00 | - | - | kN | Hybrid III | a | AAMA, NHTSA 99-4405-79 (1998) | d |
| | | | | | $F_{zc}$ | 6,16 | 6,16 | | | kN | | b | USDoT, NHTSA 00-7013; Notice 1 | |
| **Tension** | AIS 3 + | 6,23 | 1,247 | 0,20 | $F_T^*/\alpha$ | 1,08 | 4,19 | 4,51 | 6,72 | kN | New MATD | a | ATB CS | |
| | | | | | $F_T^*$ | 3,34 | 12,99 | 13,97 | 20,82 | kN | | c | ATB CS | |
| | | 1,25 | 0.132 | 0,11 | $F_3$ | 3,29 | 3,30 | 3,40 | 4,11 | kN | Hybrid III | a | Mertz and Prasad, (2000) (Figure 8) | e |
| | | 1,48 | 0,235 | 0,16 | $F_2$ | 6,20 | 6,44 | 6,78 | 9,18 | kN | | b | Mertz and Prasad, (2000) (Figure 10) | e |
| | Allowable | | | | - | 4,170 | 4,17 | - | - | kN | | a | AAMA, NHTSA 99-4405-79 (1998) | d |
| | | | | | $F_{zc}$ | 6,806 | 6.81 | | | kN | | b | USDoT, NHTSA 00-7013; Notice 1 | |
| **Lat. Bending** | AIS 3 + | 6,23 | 1,247 | 0,20 | $M_x^*$ | 62,7 | 243,7 | 262,1 | 390.6 | Nm | New MATD | c | ATB CS | |
| **Extension** | AIS 3 + | 6,23 | 1,247 | 0,20 | $M_E^*$ | 58,0 | 225,6 | 242,6 | 361,6 | Nm | New MATD | c | ATB CS | |
| | | 1,53 | 0.324 | 0.21 | $M_5$ | 77,0 | 70,5 | 76,4 | 117,4 | Nm | Hybrid III | a | Mertz and Prasad, (2000) (Figure 9) | e |
| | | 1,48 | 0,235 | 0,16 | $M_2$ | 122,0 | 126,6 | 133,4 | 180,6 | Nm | | b | Mertz and Prasad, (2000) (Figure 10) | e |
| | Allowable | | | | $M_{yc}$ | 135,0 | 135,0 | | | Nm | | b | AAMA, NHTSA 99-4405-79 (1998) USDoT, NHTSA 00-7013; Notice 1 | d |
| **Flexion** | AIS 3 + | 6,23 | 1,247 | 0,20 | $M_F^*$ | 204,2 | 794,2 | 854,2 | 1273,0 | Nm | New MATD | c | ATB CS | |
| | Allowable | | | | $M_{yc}$ | 310,0 | 310,0 | | | Nm | Hybrid III | b | AAMA, NHTSA 99-4405-79 (1998) USDoT, NHTSA 00-7013; Notice 1 | d |
| **Torsion** | AIS 3 + | 6,23 | 1,247 | 0,20 | $M_z^*$ | 47,1 | 183,2 | 197,0 | 293,6 | Nm | New MATD | c | ATB CS | |

a Criteria applies to a single axis

b Criteria applies to four axes (Tension or Compression, Extension or Flexion, Bending, and Torsion)

c Criteria applies to two axes (Tension or Compression, and Extension or Flexion)

d Denotes coefficients corresponding to the maximum allowable values in US Federal Motor Vehicle Safety Standard No. 208 (2001); Occupant crash protection

e Based on a comparison of AIS 3 + neck injuries in 10 week old pigs, chosen to be representative of 3 year old children, and peak neck forces and moments measured by a HIII-3 year dummy in matching tests.

Neck forces and moments are scaled to 50th Percentile Male based on neck circumference.

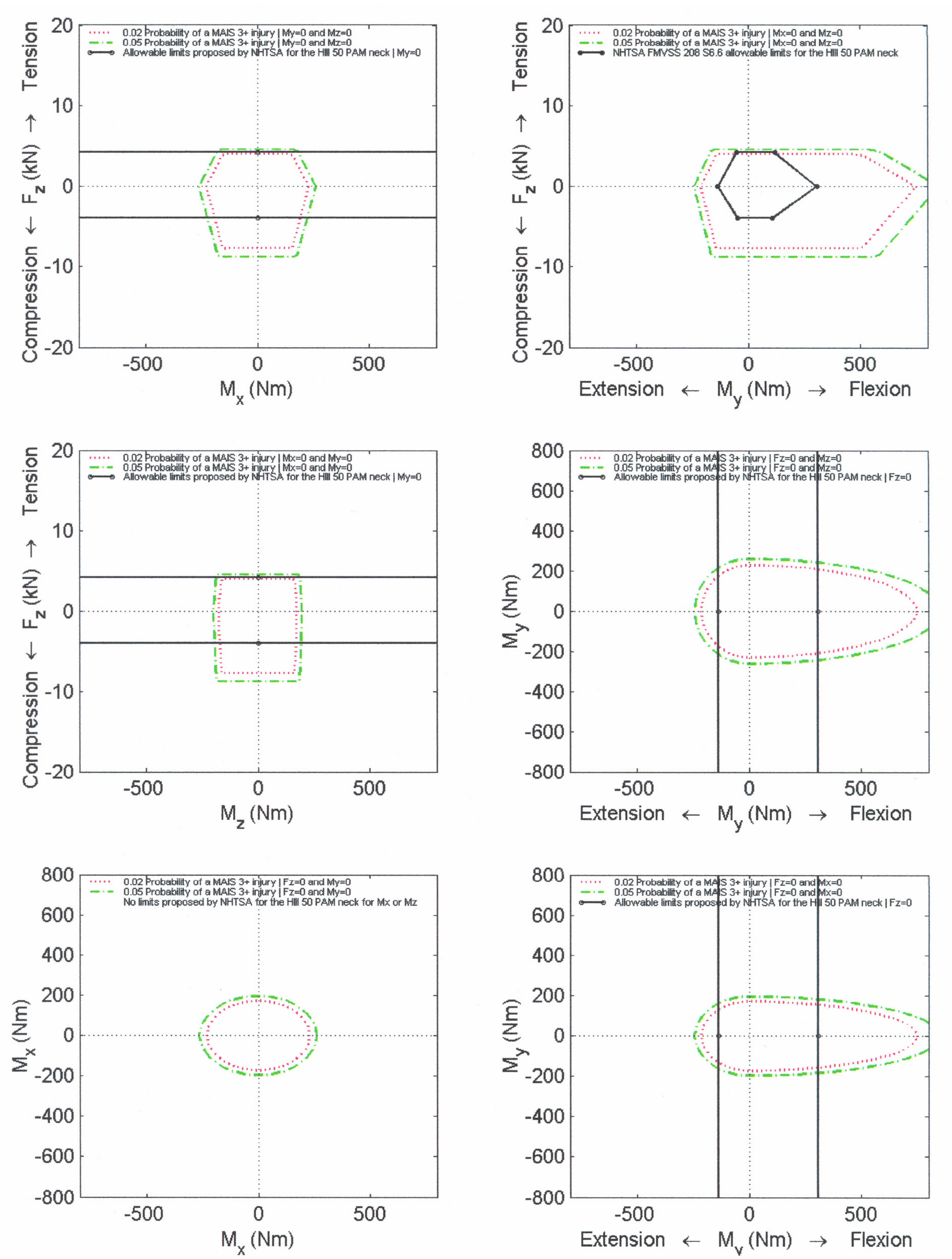


**Figure J.6 — Comparison of the general shape and axes of the injury criteria for the new MATD neck to the allowable limits proposed by NHTSA for the HIII 50 PAM neck (recognizing that the necks have very different stiffnesses)**

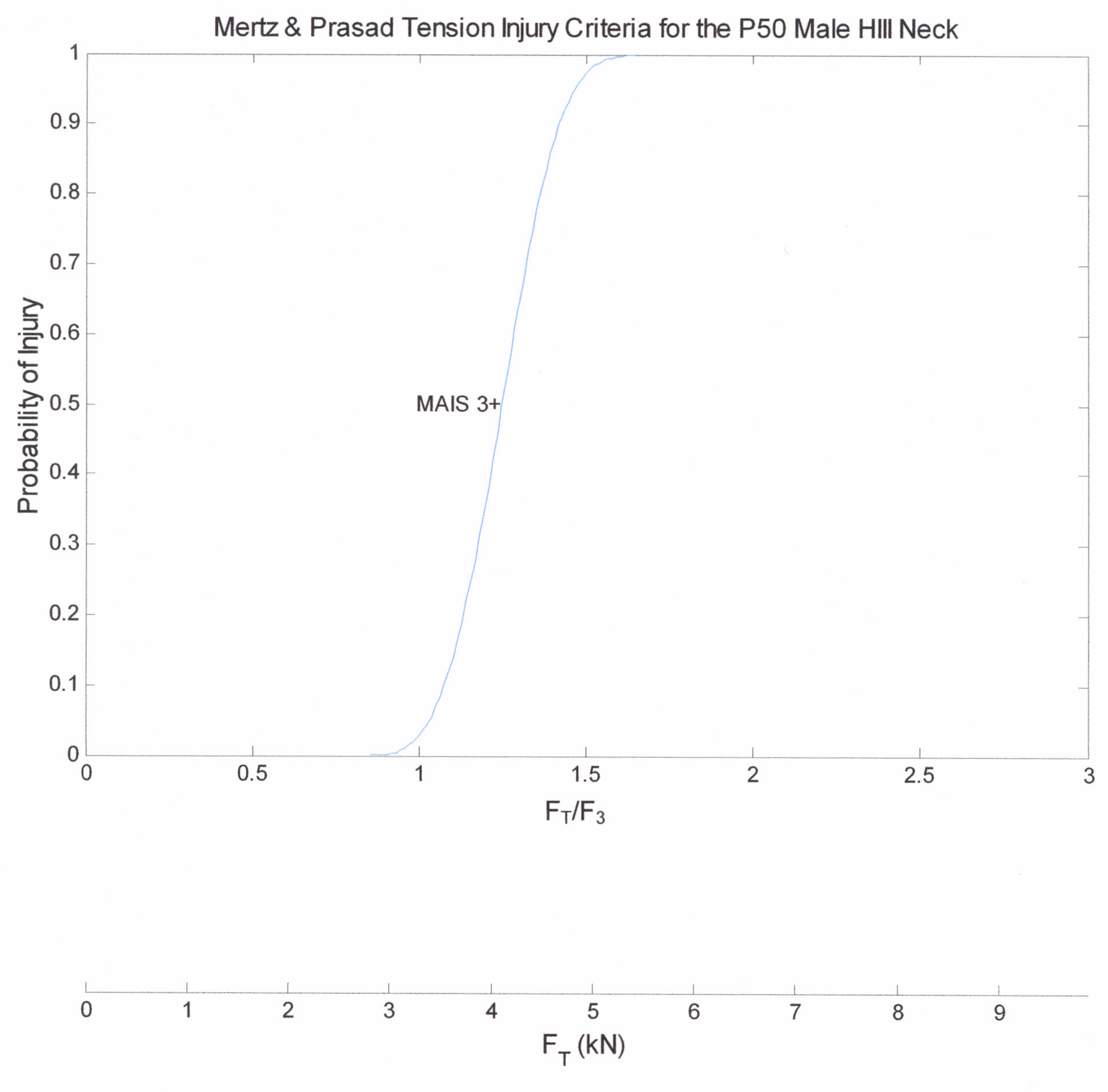


**Figure J.7 — Neck AIS 3 + injury risk vs tension for the Hybrid III P50 male neck (Mertz & Prasad 2000)**

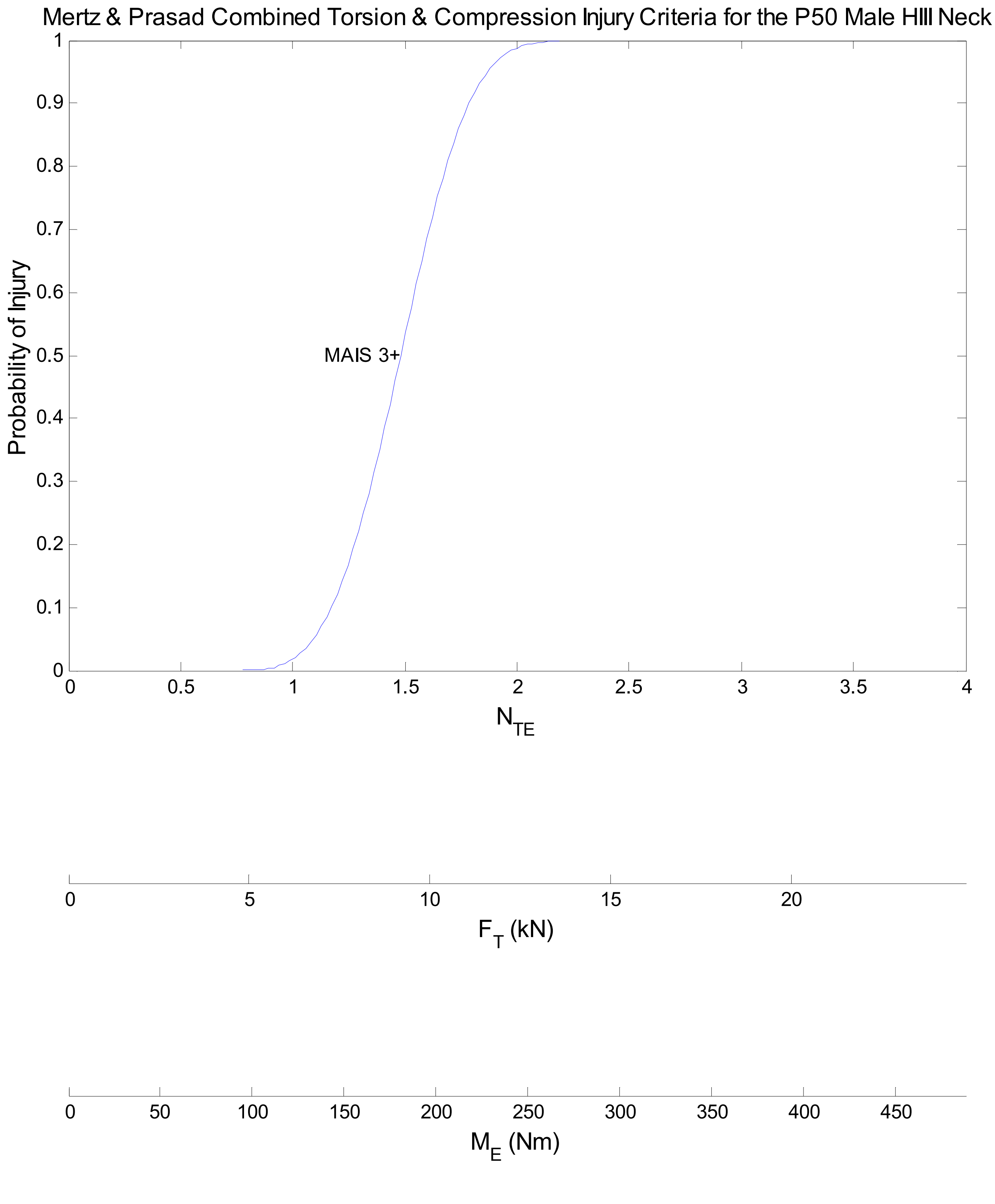


**Figure J.8 — Neck AIS 3 + injury risk vs combined tension and extension for the Hybrid III P50 male neck (Mertz & Prasad 2000)**

## J.6 Injury Cost Model Modifications

The injury cost model (ICM) can be expanded in a direct manner from the existing Part 5 analysis of four body regions (head, chest, abdomen, lower extremities) to five body regions, with the inclusion of the neck injury index ($NII_{max}$) and the resulting calculation of the probability of discrete neck AIS levels. The basic analysis procedures of the ICM will remain the same except that the probability of fatality will be based on the three highest AIS injuries from five body regions (previously four regions) and the normalized probable injury cost of survival may be increased if potential neck injuries are indicated.

Following the procedures used for the previous four body regions, the ancillary and medical costs for neck injuries can be based on the work of Miller as described by Newman, Tylko, and Miller (AAAM, 1992) except that it is proposed that the total hospital and ancillary cost will not be allowed to exceed the cost of fatality. The later constraint is needed to avoid the “critical injury cost anomaly”. This is needed because the cost of a critical neck injury (e.g., resulting in quadriplegia) is greater than the cost to society of a fatality. This amounts to applying an additional social constraint so that converting a critical injury into a fatality is not interpreted to be a possible design solution (which may be important in applying automated design optimization methods).

# Annex K
(informative)

# Estimated distribution of neck AO/C1/C2 injury severities in the LA/Hannover database

The distribution of neck injuries in the 498 LA/Hannover accident database cases with relative normal velocity ≤ 121 km/h was estimated by:

- imputing the distribution of neck injuries observed in the 67 USC fatal cases in the 13 fatal LA/Hannover cases; and
- redistributing the remaining 3 unknown injuries amongst the valid cases.

The data and results of this analysis are listed in Table K.1 as follows:

| | |
|---|---|
| Columns 1 and 10 | The maximum AO/C1/C2 AIS injury severity level ($MAIS_{AO/C1/C2}$). |
| Columns 2 and 4 | The numbers of non-fatal and fatal cases in the LA/Hannover database by $MAIS_{AO/C1/C2}$ Note that 3 non-fatal cases and all 13 fatal cases have unknown neck injuries. |
| Columns 3 and 5 | The percentages of cases in the LA/Hannover database corresponding to columns 2 and 4. The percentages in these columns are equal to the number of cases/498 x 100%. |
| Column 11 | The numbers of cases in the USC fatal accident database by $MAIS_{AO/C1/C2}$. |
| Column 12 | The percentages of cases in the USC fatal accident database by $MAIS_{AO/C1/C2}$. |
| Columns 6 and 13 | The estimated percentage of LA/Hannover cases which were fatal by $MAIS_{AO/C1/C2}$. The percentages in this column are equal to the values in column 12 x 2,61%. |
| Column 7 | The estimated percentage of all LA/Hannover cases by $MAIS_{AO/C1/C2}$. The percentages in this column are equal to the values in column 3 plus the values in column 6. |
| Column 8 | The estimated valid percentage of LA/Hannover cases by $MAIS_{AO/C1/C2}$, which reapportions the remaining 3 unknown cases amongst the valid cases. The percentages in this column are equal to the values in column 7 x 498 / (498-3). |
| Column 9 | The estimated number of LA/Hannover cases by $MAIS_{AO/C1/C2}$. The numbers in this column are equal to the values in column 8 x 498 / 100%. The estimated numbers of cases were rounded to integer values such that the total number of cases is 498. |

**Table K.1 — Distribution of neck AO/C1/C2 injury severities in the LA/Hannover and USC Fatal Accident Databases**

| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
|---|---|---|---|---|---|---|---|---|
| $MAIS_{AO/C1/C2}$ | LA/Hannover Database | | | | | | | |
| | Non Fatal | | Fatal | | | All | | |
| | Observed Number of Cases | Observed Percentage of all Cases | Observed Number of Cases | Observed Percentage of all Cases | Estimated Percentage of all Cases | Estimated Percentage of Cases | Estimated Valid Percentage of Cases | Estimated Number of Cases |
| 0 | 476 | 95,58% | | | 0,12% | 95,699% | 96,28% | 479 |
| 1 | 4 | 0,80% | | | 0,00% | 0,803% | 0,81% | 4 |
| 2 | 1 | 0,20% | | | 0,35% | 0,551% | 0,55% | 3 |
| 3 | 1 | 0,20% | | | 1,52% | 1,720% | 1,73% | 9 |
| 4 | 0 | 0,00% | | | 0,00% | 0,000% | 0,00% | 0 |
| 5 | 0 | 0,00% | | | 0,43% | 0,429% | 0,43% | 2 |
| 6 | 0 | 0,00% | | | 0,19% | 0,195% | 0,20% | 1 |
| unknown | 3 | 0,60% | 13 | 2,61% | 0,00% | 0,602% | - | 0 |
| Total | 485 | 97,39% | 13 | 2,61% | 2,61% | 100,000% | 100,00% | 498 |

| (10) | (11) | (12) | (13) |
|---|---|---|---|
| $MAIS_{AO/C1/C2}$ | USC Database | | Observed Percentage of USC Fatal Cases x 2,61% |
| | Fatal | | |
| | Observed Number of Cases | Observed Percentage of Fatal Cases | |
| 0 | 3 | 4,48% | 0,12% |
| 1 | 0 | 0,00% | 0,00% |
| 2 | 9 | 13,43% | 0,35% |
| 3 | 39 | 58,21% | 1,52% |
| 4 | 0 | 0,00% | 0,00% |
| 5 | 11 | 16,42% | 0,43% |
| 6 | 5 | 7,46% | 0,19% |
| unknown | 0 | 0,00% | 0,00% |
| Total | 67 | 100,00% | 2,61% |

# Annex L
(informative)

## Distribution of maximum neck forces and moments from computer simulations of 498 LA/Hannover cases and 67 fatal USC cases

For reference purposes, Figure L.1 illustrates the distributions of maximum neck forces and moments for the computer simulations used to identify the neck injury criteria for the new MATD neck (Annex N). Note that these maximum forces and moments were the maximum values observed in the entire impact sequence, including ground contacts, up to 5 s from the time of initial contact, for the purpose of correlating with injuries reported in the accident data.

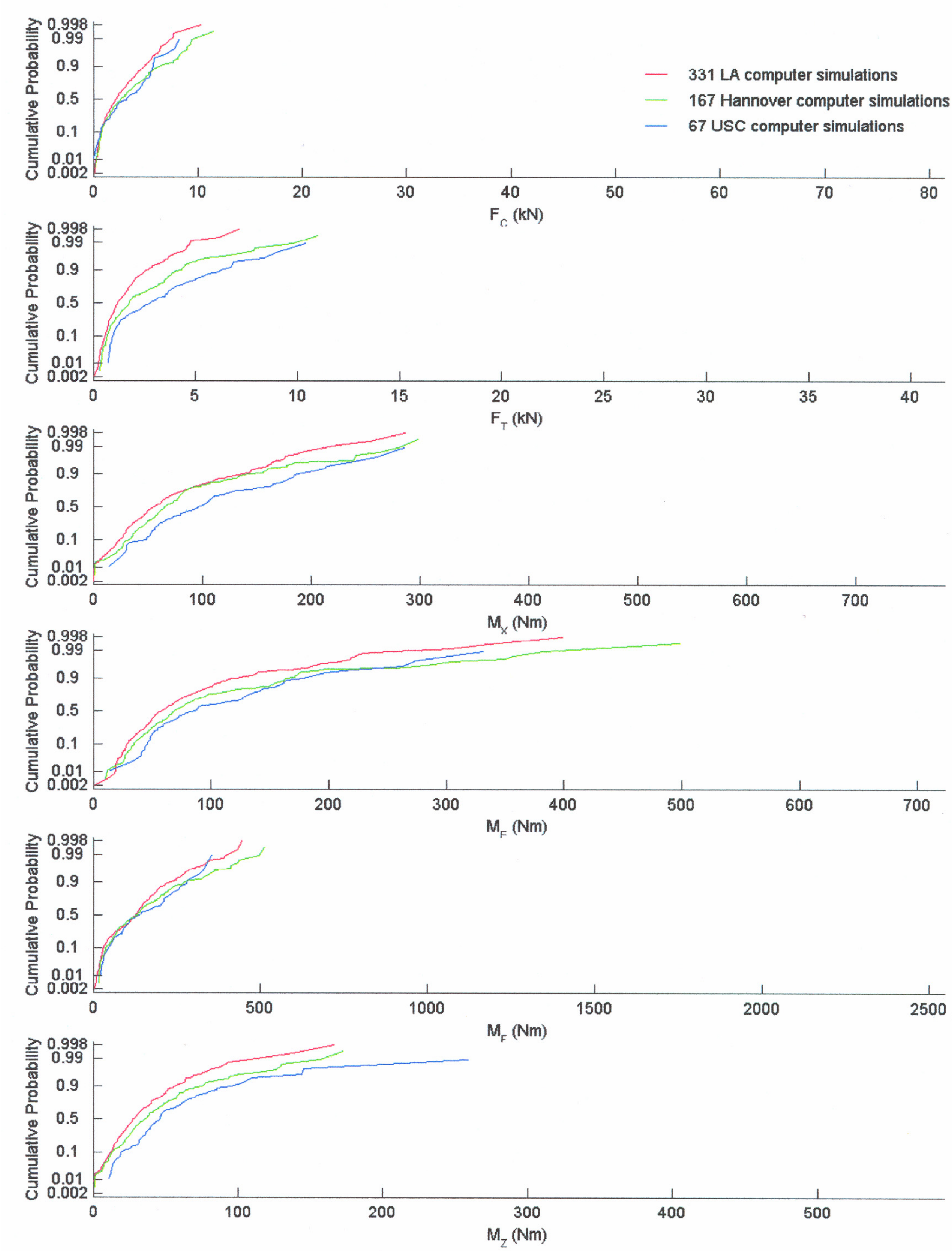


**Figure L.1 — Maximum neck force and moment distributions for the new MATD neck (498 LA/Hannover cases and 67 USC fatal cases)**

Injury criteria coefficient search algorithm used for neck injury criteria identification

# Annex M
(informative)

# Injury criteria coefficient search algorithm used for neck injury criteria identification

The critical injury criteria coefficients $F_I^*, M_I^*, Q_k^*$, and $S_k$ were selected to minimize the difference function $J$ that was defined by equations (12) and (13) in Annex J. This as accomplished using a global search described in clause M.1 followed by two local searches described in clause M.2.

## M.1 Global Search

The global search was accomplished for a given search resolution $n_{res}$ (e.g., $n_{res}$ = 25) as follows:

1) Determine the maximum values for $F_C$, $F_T$, $M_X$, $M_E$, $M_F$, and $M_Z$ over all of the 67 USC fatal cases, according to the equation:

$$\overline{F}_{I,i} = \max_t F_{I,i}(t), \quad \text{for } I = \{C,T\} \quad \text{and } i = 1 \text{ to } 67$$

$$\overline{M}_{I,i} = \max_t M_{I,i}(t), \quad \text{for } I = \{X,E,F,Z\} \quad \text{and } i = 1 \text{ to } 67$$

$$\overline{F}_{I,i} = \max_{i=1}^{67} \overline{F}_{I,i}, \quad \text{for } I = \{C,T\}$$

$$\overline{M}_I = \max_{i=1}^{67} \overline{M}_{I,i}, \quad \text{for } I = \{X,E,F,Z\}$$

Therefore $0 < F_I^* < \overline{F}_I^*$ and $0 < M_I^* < \overline{M}_I$ according to the fifth assumption in subclause J.3.1.3 of Annex J.

2) Eliminate any time samples $t$ for which $NII(t)$ = $NII_{\max}$ is unlikely, for any values of $F_I^*$ and $M_I^*$, in order to speed up the search. The following criteria were used to eliminate time samples from the search:

If there exists a time sample at time $t_k \neq t_l$ for the $i$th case such that $F_{I,i}(t_k) \leq F_{I,i}(t_l)$ and $M_{I,i}(t_k) \leq M_{I,i}(t_l)$ for all $I = \{C,T,X,E,F,Z\}$, then $NII_i(t_k) \leq NII_i(t_l) \leq NII_{\max,i}$ and the time sample at time $t_k$ can be eliminated from the search.

i) If there exists a time sample at time $t_k$ for the $i$th case such that $F_{I,i}(t_k) < \overline{F}_{I,i}/\sqrt{6}$ and $M_{I,i}(t_k) < \overline{M}_{I,i}/\sqrt{6}$ for all $I = \{C,T,X,E,F,Z\}$, then it was assumed that $NII_i(t_k) \leq NII_{\max,i}$ and the time sample at time $t_k$ can be eliminated from the search. This assumption is justified, in part, by the derivation in clause M.3. The final injury criteria can then be verified using the entire time history.

Calculate the global search step sizes for the force and moment coefficients, $F_C^*, F_T^*, M_X^*, M_E^*, M_F^*$, and $M_Z^*$, according to the equations:

$$\Delta F_I = \frac{\overline{F}_I}{n_{res} + 1}$$

$$\Delta M_I = \frac{\overline{M}_I}{n_{res} + 1}$$

3) For all $n_{res}^6$ combinations of $k_I$ = 1 to $n_{res}$ and $I = \{C,T,X,E,F,Z\}$ do the following:

   i) Calculate the candidate values for $F_I^*$ and $M_I^*$ according to the equations:

$$F_I^* = k_I^* \Delta F_I$$

$$M_I^* = k_I^* \Delta M_I$$

   ii) Calculate $NII_{max}$ for each of the 67 USC fatal cases according to equations (4) and (5) in Annex J.

   iii) Sort the 67 values for $NII_{max}$ such that $NII_{max,i} < NII_{max,I} + 1$, for $i$ = 1 to 66.

   iv) Determine values for $S_k$, such that $m_{k,0,0,0,0,0,0} = n_{k,0,0,0,0,0,0}$, according to the equation:

$$S_k \sqrt{NII_{max,n_{k,0,0,0,0,0,0}} NII_{max,n_{k+1,0,0,0,0,0,0}}}$$

   using the values for $n_{k,0,0,0,0,0,0}$ from Table J.2 in Annex J.

   v) Rescale $F_I^*, M_I^*, S_k$, and $NII_{max,i}$ such that $S_1 = 1$, according to the equations:

$$F_I^* \Leftarrow S_1 F_I^*, \quad \text{for } I = \{C,T\}$$

$$M_I^* \Leftarrow S_1 M_I^*, \quad \text{for } I = \{X,E,F,Z\}$$

$$NII_{max,i} \Leftarrow NII_{max,i} / S_1, \text{for } i = 1 \text{ to } 67$$

$$S_k \Leftarrow S_k / S_1, \quad \text{for } i = 2 \text{ to } 6$$

$$S_1 \Leftarrow 1$$

where $\Leftarrow$ denotes the replacement operator.

   vi) Calculate the difference function $J$ according to equations (12) and (13) in Annex J.

   vii) If $J$ is less than the $J_{min}$, then save the values for $F_I^*, M_I^*, Q_k^*$, and $S_k$ and set $J_{min} = J$.

Repeat steps 3 to 4 for other values of $n_{res}$ to establish convergence. The total number of candidate combinations of coefficients in each search is $n_{res}^6$. Save the values for $F_I^*, M_I^*, Q_k^*$, and $S_k$ that minimize both $J$ and $n_{res}$.

The resulting values for $J_{min}$ vs $n_{res}$ for the new MATD neck are illustrated in Figure M.1. The search size ($n_{res}^6$) vs $n_{res}$ is also illustrated.

## M.2 Local Searches

The values for $F_I^*, M_I^*, Q_k^*$, and $S_k$ from the global search can then be locally refined as follows:

1) Set the local search step sizes as follows:

$\Delta F_l = 0{,}01\,\text{kN}$
$\Delta M_l = 0{,}1\,\text{Nm}$

2) For all $(2n_{res}+1)$ 6 combinations of $k_I$ =- $n_{res}$ to $n_{res}$ and $I = \{C,T,X,E,F,Z\}$ do the following:

   i) Calculate the candidate values for $F_I^*$ and $M_I^*$ according to the equations:

$$F_l^* = F_{l,0}^* + k_l^* \Delta F_l$$
$$M_l^* = F_{l,0}^* + k_l^* \Delta M_l$$

   Where $F_{I,0}^*$ and $M_{I,0}^*$ are the values for $F_I^*$ and $M_I^*$ that minimized the difference function $J$ in the global search described in clause M.1.

   ii) Do steps 4.ii to 4.vii described in clause M.1.

Repeat step 2 for other values of $n_{res}$ to establish convergence. The total number of candidate combinations of coefficients in each search is $(1+2n_{res})^6$. Save the values for $F_I^*, M_I^*, Q_k^*$, and $S_k$ that minimize both $J$ and $n_{res}$.

Repeat the local search described above using the values for $F_I^*$ and $M_I^*$ and the following step sizes:

$\Delta F_l = 0{,}005\,\text{kN}$
$\Delta M_l = 0{,}05\,\text{Nm}$

The resulting values for $J_{min}$ vs $n_{res}$ for the new MATD neck are illustrated in Figure M.2. The search size ($n_{res}^6$) vs $n_{res}$ is also illustrated.

## M.3 A criterion to reduce the set of candidate time samples in a search for the generalized maximum value

### M.3.1 Criterion

Given time series $y_k$ and $x_{k,i}$, where $k$ is the time index and $i$ is the component index (e.g., $x_{k,i}$ is the component of $y_k$ due to tension, bending, torsion), such that:

$$y_k = \sum_{i=1}^{n} x_{k,i} \tag{1}$$

and

$$x_{k,i} \geq 0 \tag{2}$$

Let $K^-$ be defined as the set of all values for k that satisfy the equation:

$$x_{k,i} < \frac{1}{n}\left(\max_k x_{k,i}\right) \tag{3}$$

for all $i$. Then the set $K^-$ does not include the value for $k$ that maximizes $y_k$.

### M.3.2 Proof

For a given $k$, let $I_k$ be defined such that:

$$x_{k,I_k} = \max_i x_{k,i} \tag{4}$$

and thus:

$$x_{k,I_k} \geq x_{k,i} \tag{5}$$

for all $k$ and $i$. Then:

$$y_k = x_{k,I_k} + \sum_{\substack{i=1 \\ i \neq I_k}}^{n} x_{k,i} \geq x_{k,I_k} \tag{6}$$

since $x_{k,i}$ are all non-negative. Then combining equations (2), (5), and (6):

$$y_k \geq x_{k,I_k} \geq x_{k,i} \geq 0 \tag{7}$$

for all $k$ and $i$. Also, from equations (1) and (5) it follows that:

$$y_k = \sum_{i=1}^{n} x_{k,i} \geq \sum_{i=1}^{n} x_{k,I_k} = n x_{k,I_k} \tag{8}$$

Now, for a given resultant $i$, let $K_i$ be defined such that:

$$x_{K_i,i} = \max_k x_{k,i} \tag{9}$$

and thus:

$$x_{K_i,i} \geq x_{k,i} \tag{10}$$

for all $k$ and $i$. From equation (7) it follows that:

$$y_{K_i} \geq x_{K_i,i} \tag{11}$$

for all $i$.

Now, let $K_0$ be defined such that:

$$y_{K_0} = \max_k y_k \tag{12}$$

and thus:

$$y_{K_0} \geq y_k \tag{13}$$

for all $k$. From equations (11) and (13) it follows that:

$$y_{K_0} \geq y_{K_i,i} \tag{14}$$

for all $i$. From equation (8) it follows that:

$$x_{K_0,I_j} \geq \frac{1}{n} y_{K_0} \qquad (15)$$

Combining equations (14) and (15):

$$x_{K_0,I_{K_0}} \geq \frac{1}{n} x_{K_0,i} \qquad (16)$$

for all $i$, including the special case where $i = I_{K_0}$. Therefore:

$$x_{K_0,I_{K_0}} \geq \frac{1}{n} x_{K_{I_0},I_{K_0}} \qquad (17)$$

Now, if there exists one or more values for $k$, $k \in K^-$, such that:

$$x_{k,i} \geq \frac{1}{n} x_{K_i,i} \qquad (18)$$

for all $i$, then $K_0 \notin K^-$. This is because if $K_0 \in K^-$ then equations (17) and (18) would be in contradiction when $i = I_{K_0}$. Equation (18) is identical to equation (3). *Q.E.D.*

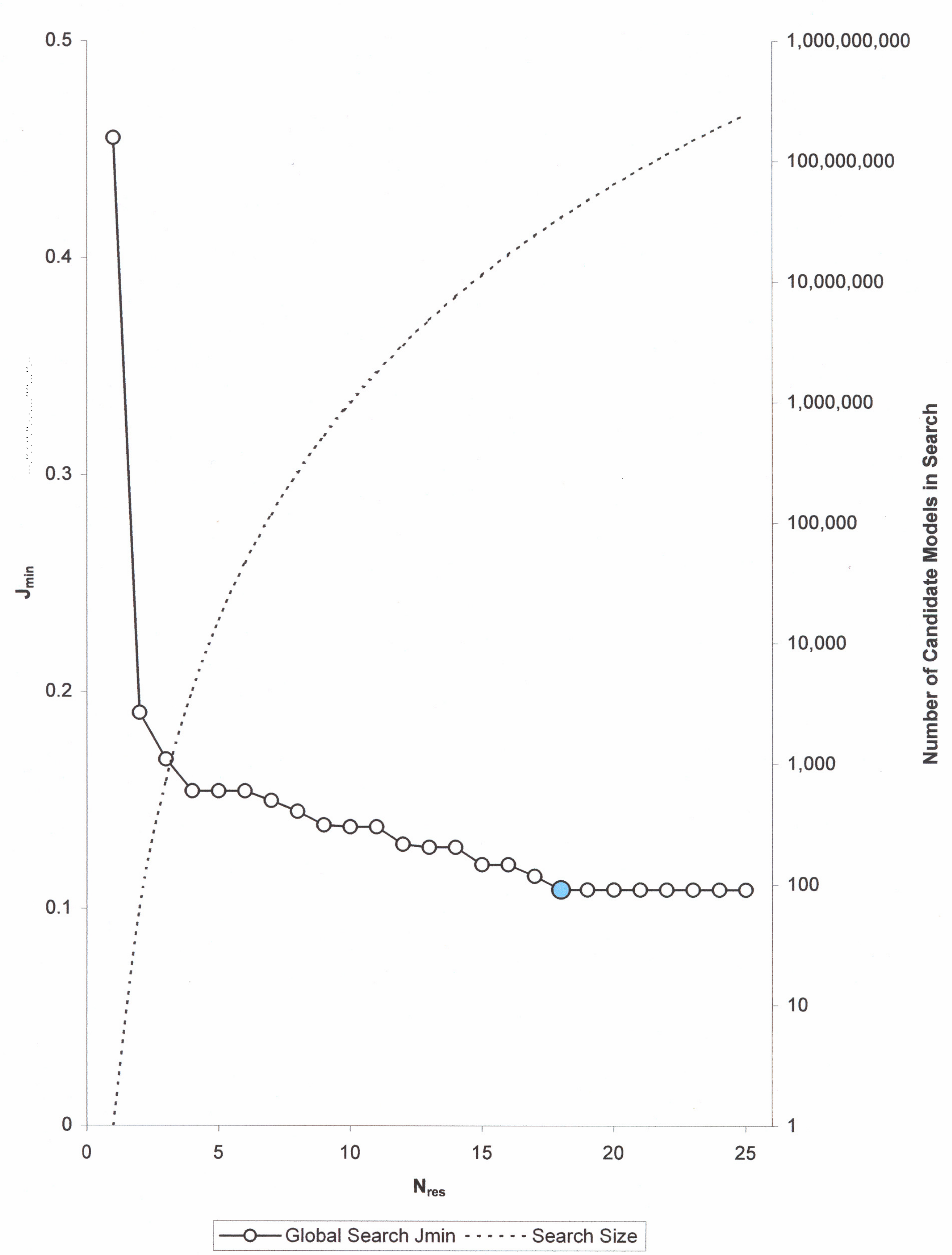


**Figure M.1 — Convergence of the global search algorithm**

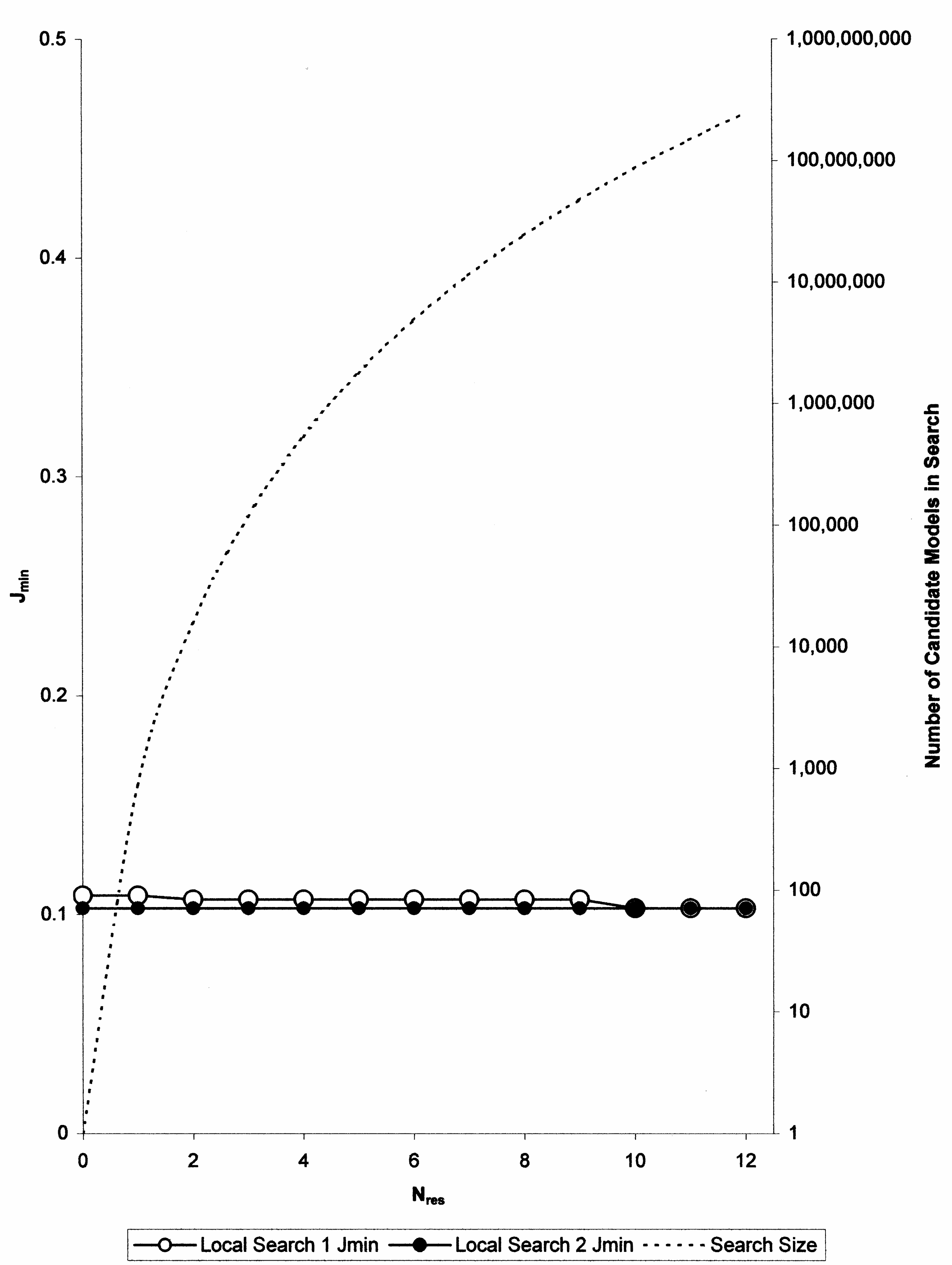


Figure M.2 — Convergence of the local search algorithm

# Annex N
(informative)

# Dummy neck computer simulation validation

## N.1 Introduction

A new MATD neck has been proposed to replace the MATD neck in ISO 13232-3:1996 (Withnall, 1999, 2000). This new neck has several advantages compared to the 1996 neck, for motorcycle test applications, including:

— good agreement with human response corridors applicable to motorcyclists (ISO/TC22/SC22/WG22/N227, approved by ISO/TC22/SC12/WG5),

— articulation more suitable for motorcyclist riding position.

A computer simulation of the new neck has been developed and calibrated according to the methods in ISO 13232-7, with the following exceptions:

— forward neck flexion, rearward neck extension, and lateral extension were calibrated using the sled tests specified in Withnall (1999, 2000) instead of the neck pendulum tests based on 49 CFR Part 572.

— comparison between full scale test and computer simulation was accomplished for one relatively severe impact configuration (413-0/30).

The resulting computer simulation was used to calculate neck forces and moments occurring in various impact configurations, to be correlated with neck injuries which were observed to occur in corresponding real world impact configurations. This formed the basis for development of neck injury probability functions.

## N.2 Laboratory component tests

Results from the computer simulation and laboratory component sled tests specified in Withnall (1999, 2000), and the torsion test specified in ISO 13232-3, are illustrated in Figures N.1 through N.8. Figures N.1, N.3, N.5, and N.7 are still images of the component tests and computer simulations, corresponding to the measured data that are overplotted in Figures N.2, N.4, N.6, and N.8.

Figures N.1 and N.2 illustrate the good agreement between the computer simulation and the laboratory test of the new neck in forward neck flexion. The position of the head and neck at t = 0.1 sec are illustrated in Figure N.1. The top of Figure N.1 is from video of the sled test; the bottom of Figure N.1 is from the computer simulation. The upper neck load cell y moment and the (x, z, and pitch) motion of the head cg responses are overplotted in Figure N.2.

Figures N.3 and N.4 illustrate the good agreement between the computer simulation and the laboratory test of the new neck in rearward neck extension. Figures N.3 and N.4 have the same format as Figures N.1 and N.2. Digitized head cg displacement data were not available for the laboratory test.

Figures N.5 and N.6 illustrate the good agreement between the computer simulation and the laboratory test of the new neck in the lateral neck flexion. The format of Figures N.5 and N.6 is similar to Figures N.1 and N.2. The lateral upper neck load cell x moment and the head lateral (y, z, and roll) motion are overplotted in Figure N.6.

Figures N.7 and N.8 illustrate the dynamic axial neck torsion test response according to clause 6.8 of ISO 13232-3. Video images of the torsion laboratory test were not available. Figure N.8 indicates good agreement between the computer simulation and the laboratory test for torsion moment vs rotation angle.

Figure N.9 illustrates the close agreement between the axis neck forces from the computer simulation and the laboratory test for a vertical impact to the top of the head.

Calibration results for the other MATD body regions, the motorcycle, and the opposing vehicle are illustrated in (Kebschull, 1998).

## N.3 Full scale test

Figures N.10 and N.11 illustrate the agreement between the computer simulation and full scale test of a Kawasaki GPZ with a prototype leg protective device for ISO impact configuration 413-0/30. The top of Figure N.10 is a still image of the full scale test at 0,1 sec after initial impact. The bottom of Figure N.10 is the corresponding computer simulation at the same time. Force and moment time histories of the upper neck, at the occipital condyle, are overplotted in Figure N.11. These results indicate generally good agreement between the computer simulation and full scale tests, especially for the peak tension and compression forces, and peak moments.

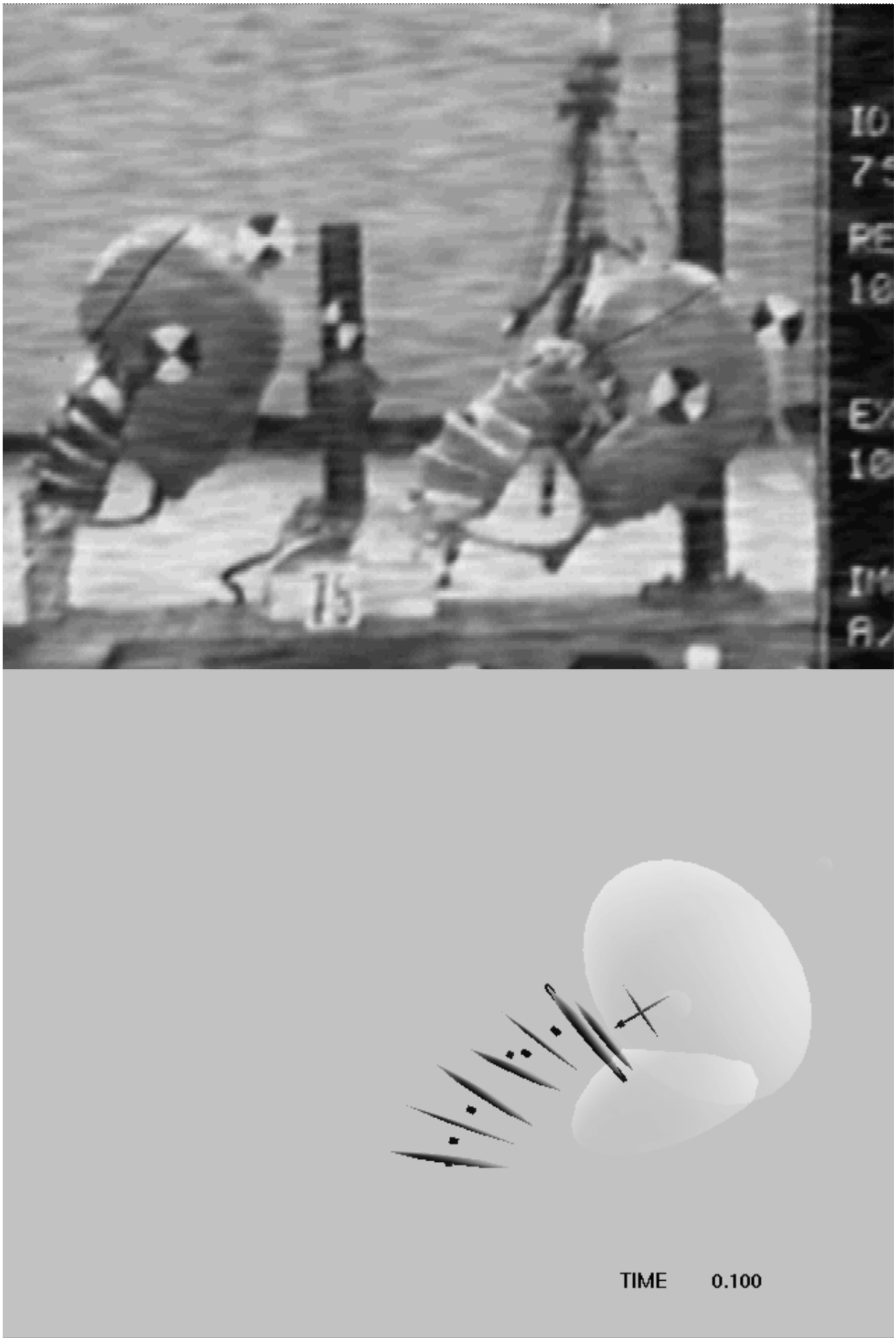


**Figure N.1 — Laboratory test and computer simulation of forward neck flexion at 0,1 s**

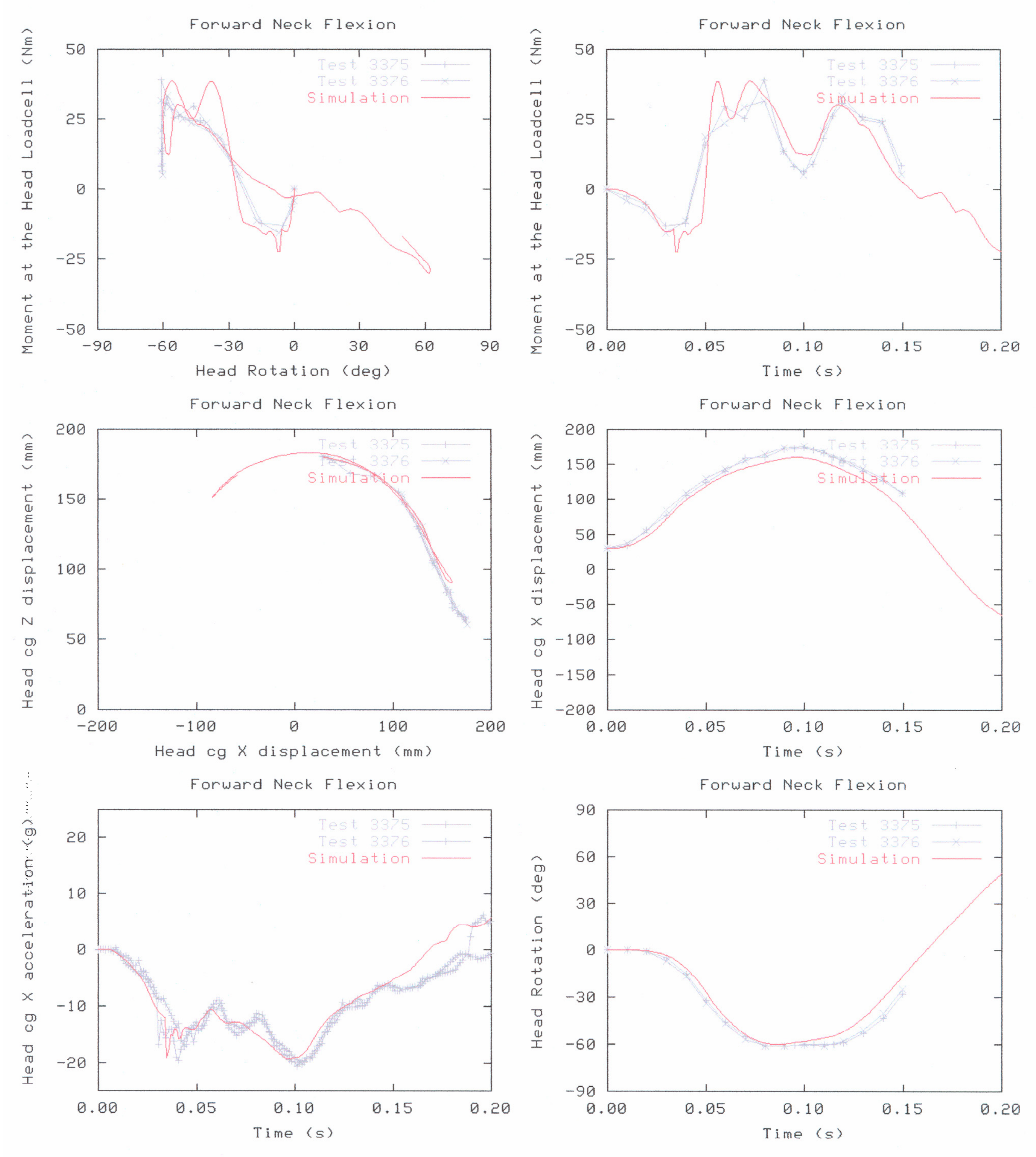


**Figure N.2 — Forward neck flexion response of laboratory test and computer simulation**

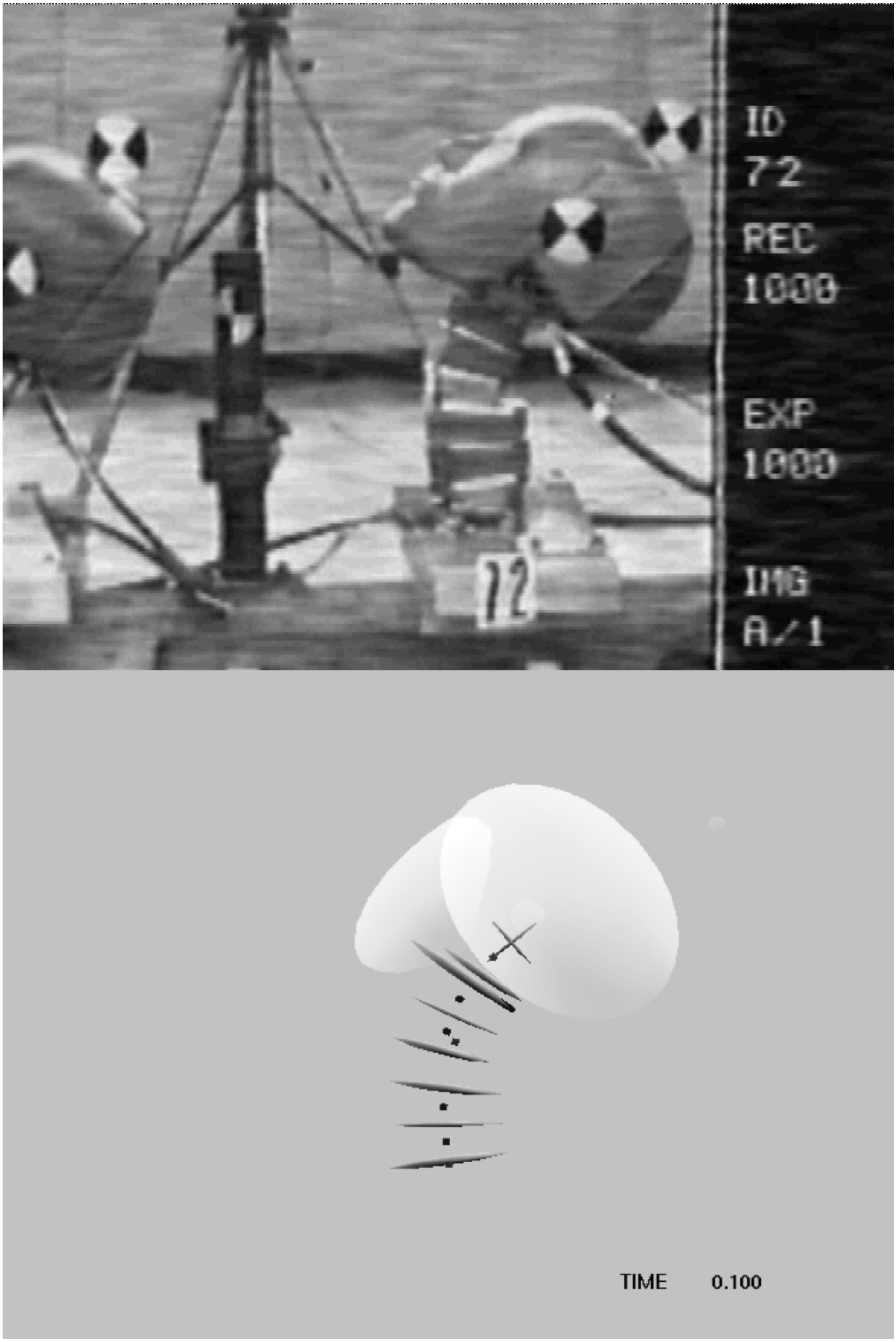


**Figure N.3 — Laboratory test and computer simulation of rearward neck extension at 0,1 s**

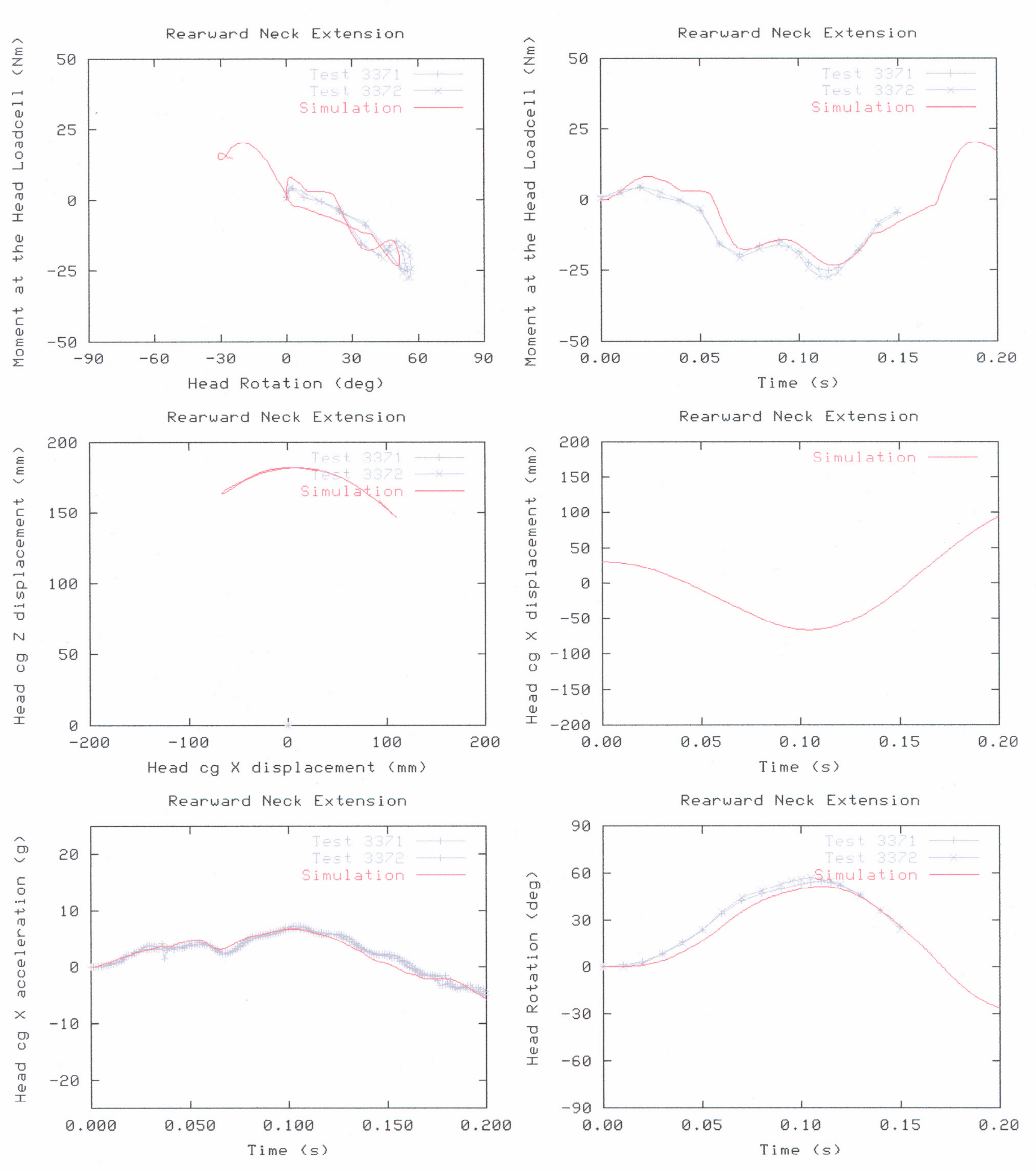


**Figure N.4 — Rearward neck extension response of laboratory test and computer simulation**

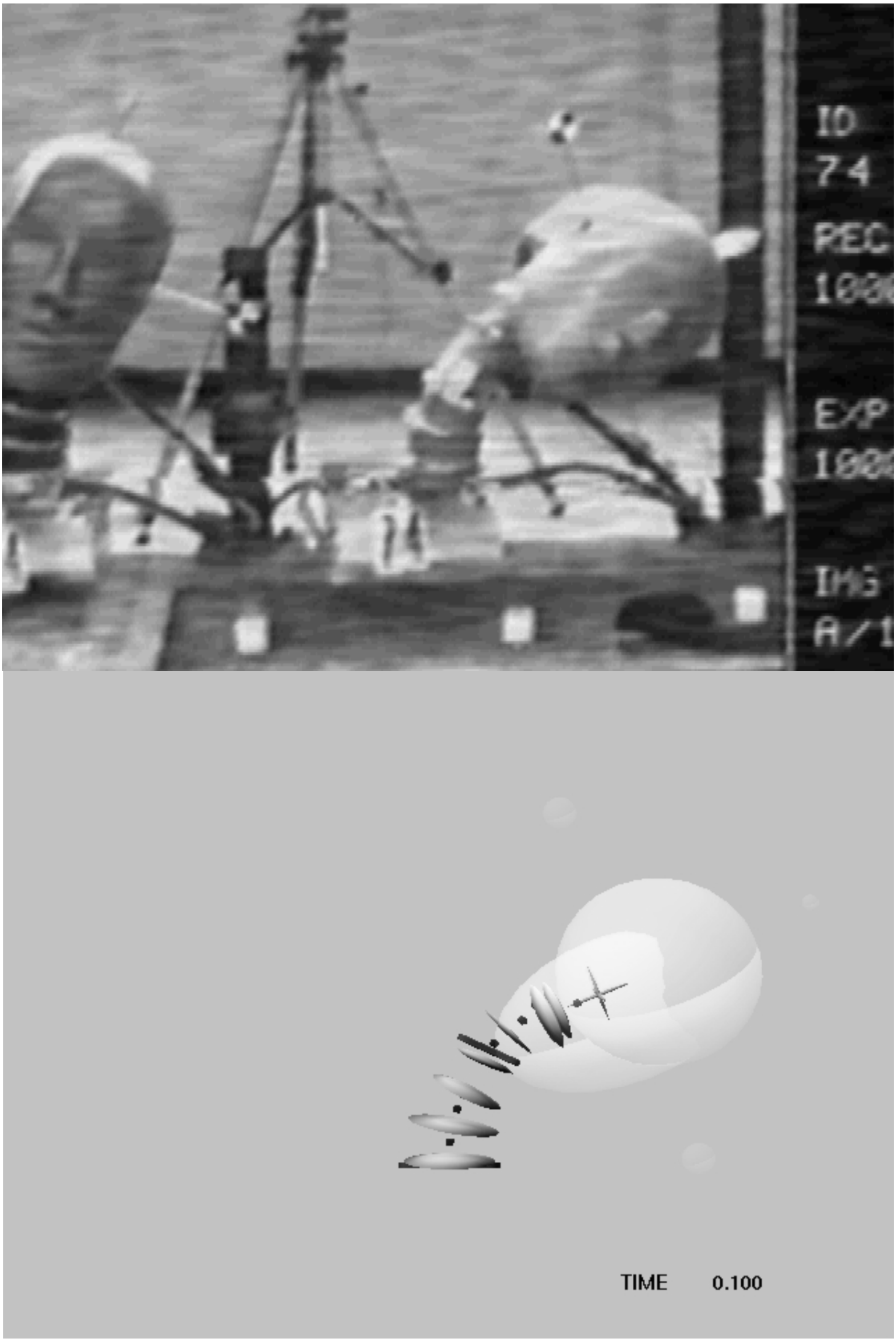


**Figure N.5 — Laboratory test and computer simulation of lateral neck flexion at 0,1 s**

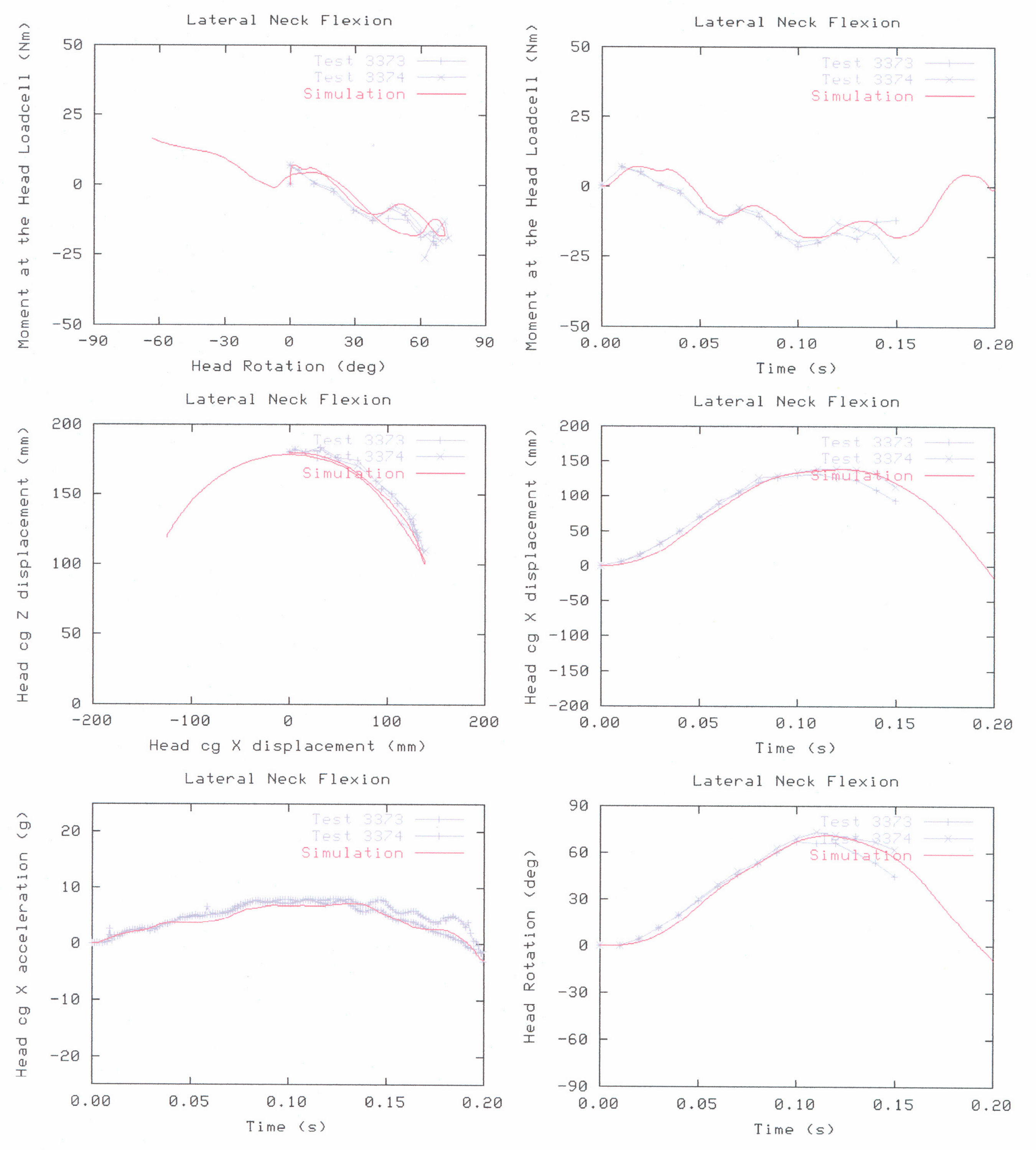


**Figure N.6 — Lateral neck flexion response of laboratory test and computer simulation**

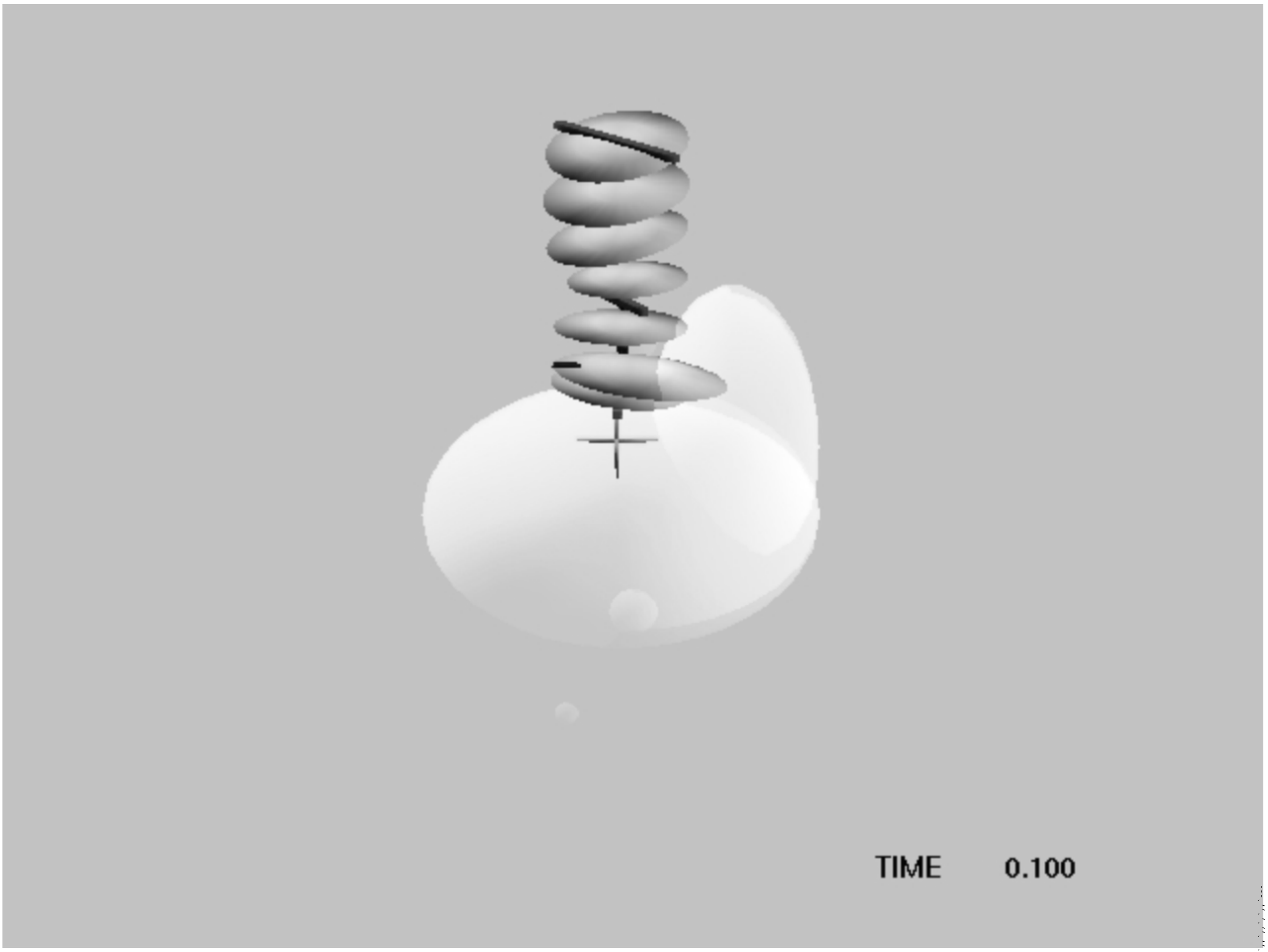


**Figure N.7 — Computer simulation of neck torsion test at 0,1 s**

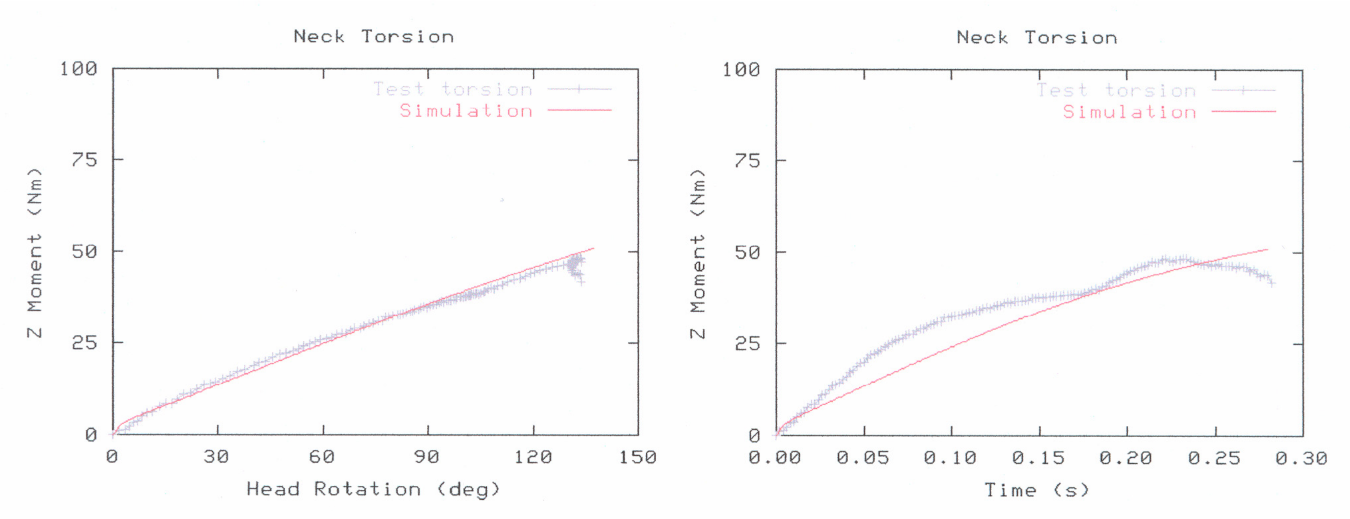


**Figure N.8 — Neck torsion response of laboratory test and computer simulation**

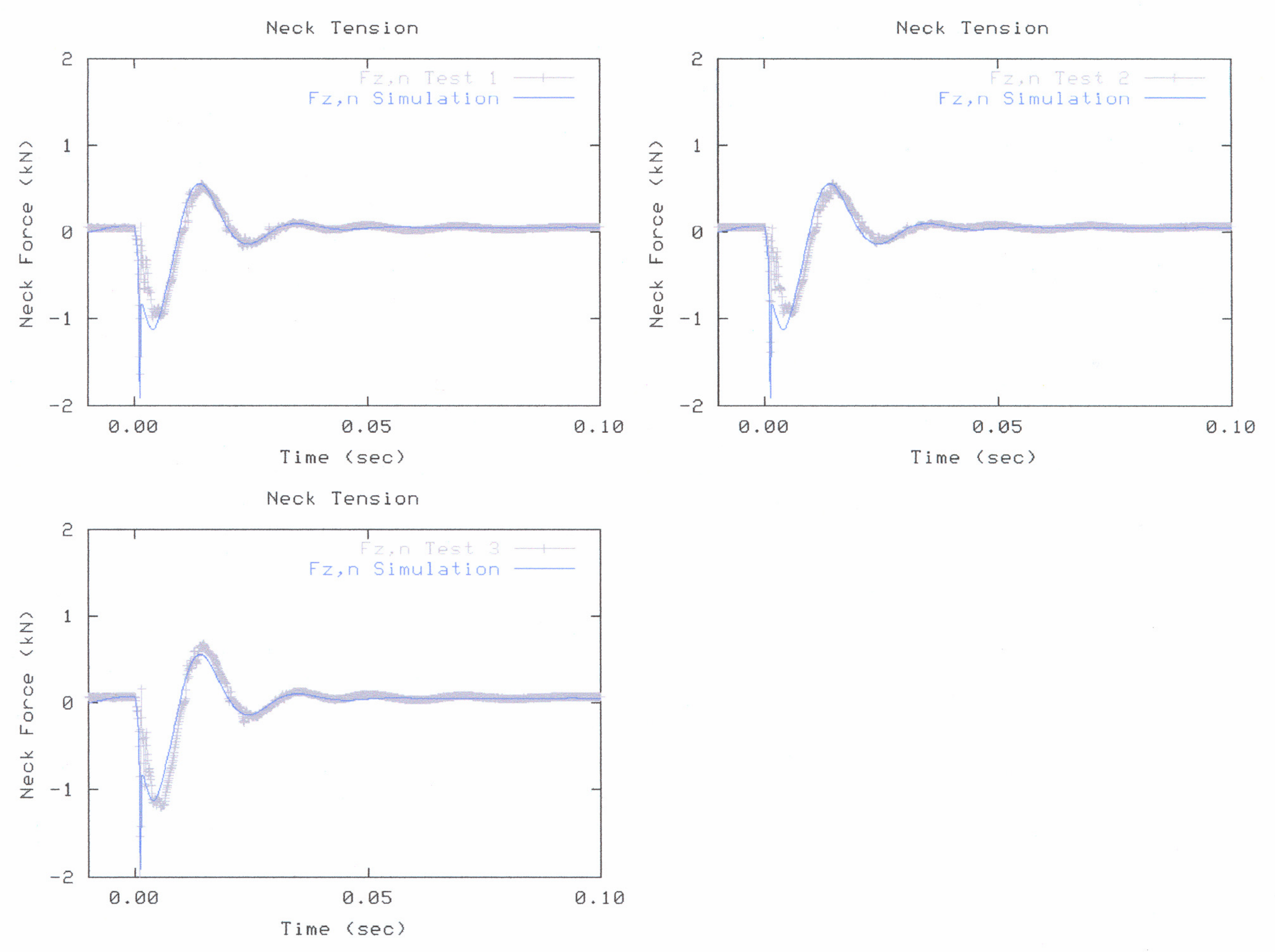


**Figure N.9 — Neck axial force response of laboratory impact test and computer simulation**


**Figure N.10 — Full scale test and computer simulation of impact configuration 413-0/30 0,1 s after initial contact**

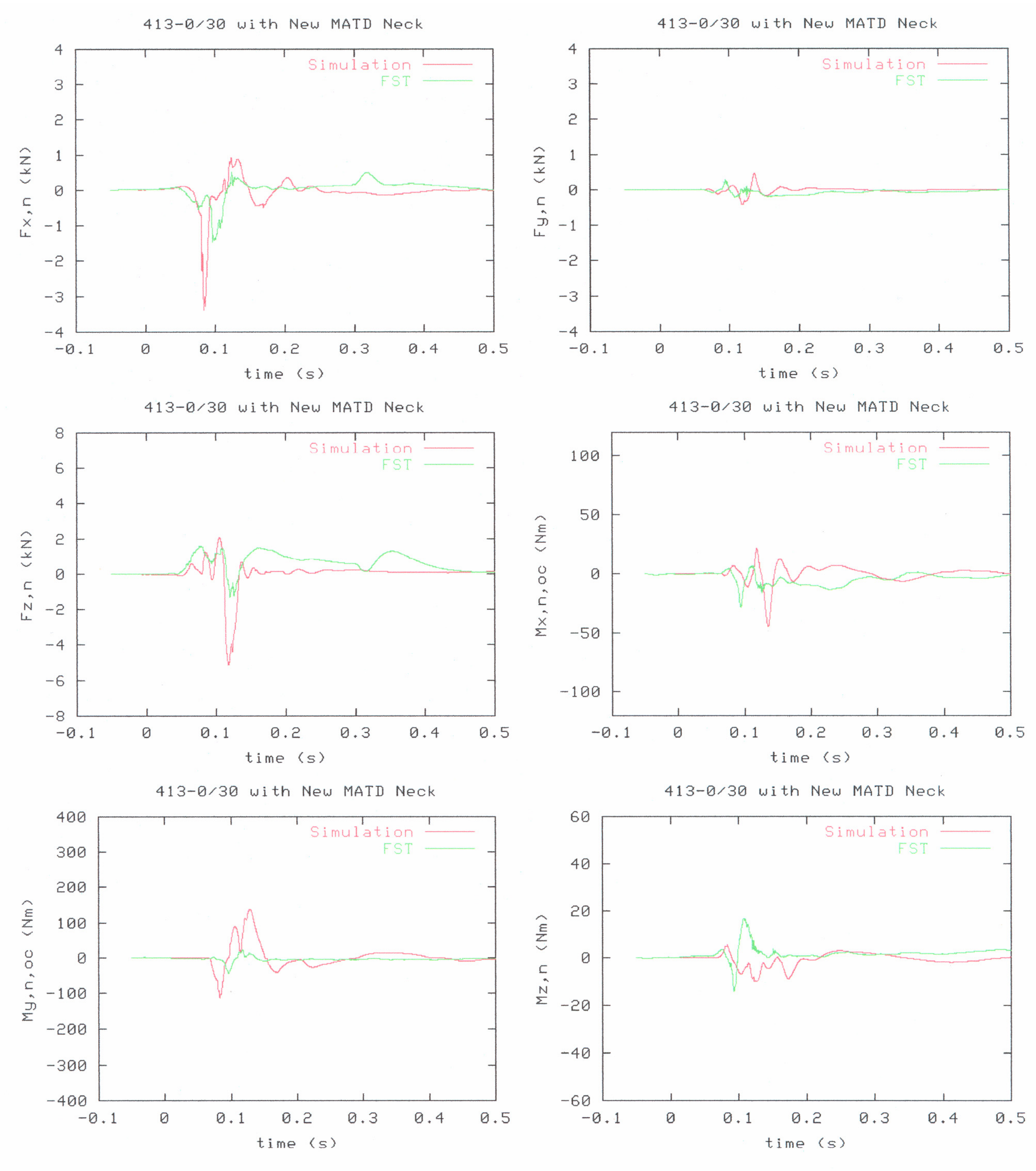


**Figure N.11 — Full scale test and computer simulation of 413-0/30 with new MATD neck**

# Annex O
(informative)

# Rationale for ISO 13232-5

The references cited in Annex O are listed in Annex B of ISO 13232-1.

## O.1 Specific portion of the Scope

A goal of ISO 13232 as a whole, and of this part in particular, is to provide for objective, rather than subjective, performance indices which are related to human injury potential. Consistency of interpretation is obviously desirable from test to test, and among different test facilities. "Probable injury cost" refers to the total societal cost of a given combination of injuries, based on bioeconomic data, and provides the best available means of quantifying the effects of multiple injuries which are characteristic of motorcycle accidents. "Combined effects" refers to the propensity toward multiple injuries in motorcycle accidents, and a means for addressing potential tradeoffs among or combinations of the various injuries. Verifiability refers to the ability of others to analyse the measured data from a test, and to confirm the final results (this would be difficult, for example, if the analysis was subjective). "Relative effects" refers to use of the paired comparison approach, as described in ISO 13232-6.

## O.2 Requirements

### O.2.1 Injury assessment variables (see 4.1.1)

#### O.2.1.1 Head

The head injury assessment is based upon the Generalized Acceleration Model for Brain Injury Tolerance (GAMBIT), first proposed by Newman (1985) and recently quantified by Kramer and Appel (1990); and also, for comparison purposes, the Head Injury Criterion (HIC).

To address the combined effects of rotational and linear motion, Newman introduced GAMBIT in 1984, based on the fundamental "failure theory" concept. The model was subsequently published in the Proceedings of the International IRCOBI Conference on the Biomechanics of Impacts in 1986. It employed all the data which was then available and which included measurements of both forms of motion. In 1990, Kramer and Appel modelled 226 actual automobile accidents for which head injury data was available. For the first time, they were able to produce validated statistical relations between head injury severity and GAMBIT. In the current standard, for consistency, GAMBIT is calculated as a time history, the maximum value of which is used as the injury assessment variable. Also, the Kramer and Appel normalizing values are used in the calculation, as these are the most recent and comprehensive results available.

The HIC was introduced in 1972 as part of a Proposed Rule Making by the National Highway Traffic Safety Administration (NHTSA) for the assessment of automobile frontal crash safety.

In the 1996 edition of ISO 13232, HIC was evaluated because it was considered to be a useful and interesting variable for injury assessment and for comparison purposes. It was used as a general indicator of "risk of life threatening brain injury" described below in H.3.5.3. However, in the original Standard HIC was not integrated into the injury cost model because there was no known published correlation between HIC and AIS, the latter being the basis of the injury cost model.

In Revision 1 of the Standard, HIC has been added to the head injury model, using the US/NHTSA-generated probability curves. The revised model considers the injury probabilities at each AIS level from both GAMBIT and from HIC, and selects the greater probability, in the same as the chest model considers both compression and VC injury probabilities. Typically, but not always, this corresponds more frequently to the GAMBIT injury probabilities.

#### O.2.1.2 Chest

Injury assessment variables for the chest include maximum velocity-compression, $VC_{max}$, and compression, $C_{max}$. The maximum values are associated with the greatest risk of injury. A number of other chest injury criteria have been proposed to address thoracic injuries, including the acceleration criterion and the thoracic trauma index (TTI). However, these criteria do not correlate as strongly to injury severity.

The acceleration criterion evolved from early studies of dynamic effects on injuries. Tolerance to deceleration was found to increase with decreased exposure. The criterion assumes the thorax acts as a rigid body subjected to whole body decelerations. The limitations associated with the application of this criterion include a lack of sensitivity to the impact location. Accelerations registered in the thorax cannot be isolated from load paths through the knees, legs, hips, head and shoulder. The effect of chest deformation on injury causation and the sensitivity to the impact test set up are not accounted for.

The TTI is an acceleration index derived from the application of blunt lateral impacts to cadaver chests. The index is a function of cadaver age, weight, maximum rib acceleration and lower thoracic spine acceleration. Since TTI is an acceleration based criteria, it is subject to the same limitations as those described for the acceleration criterion.

Studies conducted by Viano and Lau (1988) identify chest injuries as being characterized by two types of injury mechanisms: "viscous" injuries caused by rapid rates of deformation; and crushing type injuries caused by low rates of deformation. The injury criterion believed to be the most predictive of crushing injuries is the maximum compression. Maximum compression is the maximum resultant of the upper and lower sternum displacement, whichever is greater. When the velocity of deformation is greater than or equal to 3 m/s, the best predictor of injury is the maximum velocity-compression criterion or $VC_{max}$. $VC$ is calculated for both the upper and lower sternum and $VC_{max}$ is considered to be whichever one is greater. $VC$ is the product of instantaneous chest velocity and relative compression $V(t)C(t)$ measured at these two points on the chest. This formulation preserves the time history of the mechanical response.

#### O.2.1.3 Abdomen

The injury assessment variable for the abdomen is maximum penetration, pmax, as measured from the maximum deformation of the frangible element. It was developed by Rouhana, et al., (1990) and was based on frontal seat belt loading.

Studies conducted by Stalnaker (1985) and Viano (1989) found strong correlations between velocity-compression $VC_{max}$ and AIS, for abdominal injuries. However, since the time history for neither the velocity nor the penetration can be determined from the frangible element, $VC_{max}$ can not be included as an injury assessment variable, for the abdomen.

#### O.2.1.4 Neck

The skeletal portion of the neck is composed of a series of disc shaped bones alternating with compliant discs for cushioning, and supported by ligaments and muscle tissue. In the motorcycle crash environment the neck structure will be exposed to shear, flexion, extension, torsion, and axial tension and compression. Injury to the neck can result from a single load or from combined loading

### O.2.2 Injury potential variables (see 4.1.2)

The injury potential variables listed are those variables which (although not applicable to biomechanical injury evaluation) can be of use in evaluating the "potential" for head injury. The injury potential variables relate to the path of the helmet centroid until first helmet/OV contact and the velocity of the helmet centroid at first helmet/OV contact. Although there can be many individual variations due to differences in the OV or impact configuration, in general, a lower helmet path is considered to have higher injury potential because it brings the head into proximity with progressively stiffer OV structures. For example, a path leading to the roof edge is considered as having higher head injury potential than a path going over the roof; a path leading to the edge of the rear boot lid is worse than a path onto the boot lid, which is worse than a path going over the boot lid; and so on. Exceptions to this trend might appear to be the OV windows. The possibility of injury to OV occupants, or decapitation of the motorcycle rider could make window impact a more serious situation, overall, than roof impact, in some cases.

Greater head velocity at first helmet/OV contact is considered to represent a higher potential for head injury. There are four different components of this "impact" velocity which are calculated. The resultant velocity is pertinent from the standpoints of kinetic energy and momentum (the greater the head kinetic energy or momentum at impact, the higher the injury potential). The resultant velocity may be pertinent to impacts with convex or inclined OV surfaces, or when the surface geometry is unknown. Longitudinal velocity relates to the potential for injury when the impacted surface is mainly vertical, and as related to the initial, mainly longitudinal velocity of the motorcycle. The vertical velocity relates to injury potential when the impacted surface is mainly horizontal.

None of the injury potential variables have absolute criteria associated with them, and they are mainly used for comparative (paired comparison) purposes. Even in this case, it is not known whether or to what extent a 10% change in head trajectory or velocity, for example, relates to injury likelihood. It may be that such a change is inconsequential, or that it is extremely crucial, depending on what is hit, the angle of incidence, the impact configuration, and so on. It is fair to say that the injury potential variables lack a biomechanical basis, but nevertheless, may be useful in understanding a particular head injury phenomenon.

As further discussed in ISO 13232-8, the clearest conclusions can be drawn when the head injury assessment variables (GAMBIT and HIC) and the head injury potential variables are all showing the same trend for a given protective device.

### O.2.3 Injury severity probabilities (see 4.3)

Probabilities are used to describe the distribution of human tolerance over the entire spectrum of injury assessment variables. Because human tolerance levels are not fixed, there will always be some proportion of the accident population data scattered in each injury severity level, for the same injury assessment value. The most effective method for describing such a distribution, while defining a continuous function with a specific injury assessment variable, is with the use of probabilities.

### O.2.4 Injury indices (see 4.4)

The potential merits of protective systems for use in motorcycles are evaluated by comparing the injury consequences of crash tests and/or computer simulations conducted with standard and modified vehicles. Injury indices are used to describe and quantify the injury consequences. Correlation to specific injuries in humans is required to complete the description.

The AIS (Abbreviated Injury Scale) is the principle injury index on which the proposed methodology is based (AAAM, 1990). Developed in the 1960's and revised every five years since, the AIS is recognized worldwide as an acceptable method for ranking injuries. Most injury probability distributions and cost analyses are a function of AIS, thereby establishing the necessary link between crash injury consequences and specific injury severity in humans.

### O.2.5 Risk/benefit analysis (see 4.5)

One specific method for "risk/benefit analysis", which is a required component of an "overall evaluation" as specified in 4.2 of ISO 13232-2, and an optional way to define additional configurations for testing (also in ISO 13232-2), is prescribed so as to provide a common, objective and reproducible means for evaluating the effect on injuries of a proposed protective device.

## O.3 Procedures

### O.3.1 Injury variables (see 5.1)

#### O.3.1.1 GAMBIT (see 5.1.2)

The form of GAMBIT used here is based on the form quantified by Kramer and Appel (1990), with the exponent set to 2 rather than 2,5 (the former is simpler, and more in agreement with typical strength of materials fracture criteria). This involves calculation of GAMBIT on a continuous basis, and taking the maximum value (of what amounts to a failure index) over the relevant time interval. This approach was also supported in the car working group liaison discussion (ISO/TC22/SC22/WG22 N76).

#### O.3.1.2 HIC (see 5.1.3)

The form of HIC used here is based on SAE J885 (1986a), for consistency.

The use of head engagement and disengagement times and a 0,015 s maximum duration for the calculation of HIC is based on ISO/TC22/SC12/WG13 N355 (ISO Technical Report TR 12351).

#### O.3.1.3 Upper and lower sternum compression (see 5.1.4)

The upper and lower sternum compressions are calculated as a function of time, using the measurements from the left and right, upper and lower potentiometers. The calculations for $D_y$ and $D_x$ are based on trigonometry.

The normalizing factor of 187,5 was recommended by Neathery (1974) for the Hybrid III chest in compression.

#### O.3.1.4 Upper and lower sternum velocity-compression (see 5.1.6)

Equations for $V_{us}$, $V_{ls}$, $VC_{us}$, and $VC_{ls}$, including the normalizing factor of 1,3 and the dimensional factor of 229, and the $V$ limit of 3 m/s are per Viano and Lau (1988).

#### O.3.1.5 Neck injury indices (see 5.1.8)

Detailed descriptions and rationale for the calculation of the neck injury index ($NII$) are found in Annexes J, K, L, and M.

The procedures used in the calculation of $NII$ and neck injury severity probabilities were based on the best available information. Further refinement in the future should be considered. Analysis limitations and areas of possible further analysis include:

— The coefficient of variation for the AIS ≥ 3 injury risk curve is assumed to be 0.2 based on Mertz and Prasad (2000). The standard deviation of the injury risk for the other injury severity levels are assumed to be the same as the standard deviation for the AIS ≥ 3 injury risk. This assumption should be reconsidered in the future as new injury data becomes available and/or based on sensitivity analysis.

— Conduct accident reconstructions of full-scale ISO type tests and compare reconstructed neck "motion" results to measured responses.

— Attempt to obtain other injury databases to supplement the current set and improve statistical confidence.

— Lumbar spine studies addressing combined loading conditions were reviewed, but were found to have no usable quantitative data for the current model.

— AIS 1, 2, and 4 may be underrepresented in the current data set.

- Injuries are indicated by AIS values, however, AIS 1 are difficult to observe. The database used contains some types of AIS 1 injuries which are based upon reports by accident victims.
- Users should note that the normalizing factors used to calculate $NII$ are different than those published in FMVSS 208 because those in FMVSS are mapped to the response characteristics of the Hybrid III neck and those in the $NII$ equation are mapped to the response of the MATD neck.
- The identical slope for all AIS levels may imply that the injury mechanisms are the same, which they may not be.
- The injury probability distributions for AIS 1+, 2+, and 3+ are in close proximity to each other and AIS 4+ coincides with AIS 5+. This may cause large fluctuations for risk assessment since a small variation in neck force/moment measurement will cause a large variation in risk assessment. This is further compounded by the high exposure levels at low AIS levels possibly distorting the benefit analysis. This result should be verified as further data becomes available.
- The neck injury criteria employs a stress ratio method to evaluate the injury risk levels. This is based on combined loading theory for homogenous materials such as steel. The human is not a homogeneous structure and may have varying tolerance levels depending on the load paths.
- The physical and numerical MATD neck response has been validated mainly with inertial loading conditions (only one impact test was used for validation). Validation of the numerical model to impact conditions should be expanded by constructing impact experiments with the physical neck to provide such data. Ideally, human impact data would also be available for validation of the physical neck.
- It may be informative to look at airbag loading conditions if the neck is to be used in out-of-position tests in order to determine if the interactions are realistic. These loading conditions may also lead to new or different tolerance limits.

### O.3.2 Injury severity probabilities (see 5.3)

The probability associated with each AIS level for a given body region is determined by fitting Weibull functions to published injury severity probability curves. The Weibull cumulative frequency distribution is well suited to describe biomechanical data which is biased (Ran, et al., 1984). It is defined as follows:

$$W(z;K) = W(z;\alpha,\beta,\gamma,) = 1 - e^{-\left(\frac{z-y}{\alpha}\right)^{\beta}}$$

where

$W(z;K)$ is the Weibull cumulative frequency distribution with one variable and three parameters;

$z$ is the independent variable defined from $\gamma$ to 4. It represents the load variable or injury assessment value;

$\alpha$ is the scale parameter > 0;

$\beta$ is the shape parameter, $\beta$ > 1 indicates increasing hazard;

$\gamma$ is the location parameter.

#### O.3.2.1 Head (see 5.3.1)

Head injury probability curves as a function of GAMBIT and were derived from the work of Kramer and Appel (1990). These curves are the most comprehensive head injury response distributions currently available and are shown in Figure G.1. Kramer and Appel used accident data from the Medical College of Hannover for 1288 front seat occupants of 716 vehicles involved in frontal collisions.

Head injury probability curves as a function of HIC are based on ISO/TC22/SC22/WG22 N203 Rev 1.

#### O.3.2.2 Chest (see 5.3.2)

Chest injury probability curves have been established for high velocity impacts (≥ 3 m/s) and low velocity impacts (< 3 m/s). The most comprehensive distribution of high velocity impact injury severity probabilities is based on the work of Lowne and Janssen (1990). These include probability curves for AIS > 2, AIS > 3 and AIS > 4. Since there are no published data on the expected proportion of injuries for AIS 1, AIS 5 and AIS 6, the values were interpolated. The plot is shown in Figure G.3. Eventually, when more precise data become available, they could replace the interpolated data.

The probability curves relating to low velocity or crushing injuries to the chest are not as clearly defined. The only suitable injury distribution was published by Kroell, et al., (1974), and defined a step function from AIS 1 through AIS 6. Because the probability of injury is used to determine the relative ranking of crash response among similar crash tests, the step function was replaced with continuous monotonic functions for AIS 1 through AIS 6, shown in Figure G.2. Again, as more precise data become available the theoretical curves will be replaced.

To avoid underestimating the severity of injuries in the transition region, both injury criteria, $VC_{max}$ and $C_{max}$, for both upper and lower locations are considered during calculations of injury distributions. The probability of injury at each AIS level from the two locations for each of the two injury criteria are compared and the maximum (i.e., worst case) is selected. Then the probability of injury at each AIS level calculated from $VC_{max}$ and $C_{max}$ are compared and the maximum is selected. The resulting distribution may be a combination of $VC_{max}$ and $C_{max}$, upper and lower sternum injury probabilities.

#### O.3.2.3 Abdomen (see 5.3.3)

Abdominal injury probability distributions have been compiled by Rouhana, et al., (1990) for AIS ≥ 3 and AIS ≥ 4. The data have been extrapolated to include AIS 1 and AIS 2 injuries. The plot is shown in Figure G.4. The maximum penetration of the frangible element is restricted to magnitudes which are insufficient to cause AIS 5 and AIS 6 injuries. Impact location, whether frontal or lateral, was found to have no effect on abdominal response (Stalnaker, 1985). Therefore, the probability distributions are used for both frontal and lateral abdominal impacts. The injury severity probability distributions are based on studies carried out by Cavanaugh, et al., (1986) in which cadaver specimens were loaded with a cylindrical bar. Though no bars as such are to be found in the current crash test procedures, loading of the motorcyclist dummy abdomen by the motorcycle handlebars or the car roof rail can be expected.

At the researcher's option, the abdominal penetration can also be omitted from the injury calculation, provided the calculations are done with and without the penetration value. This is because of some uncertainty regarding the dynamic response of the foam material, and the question of whether or not there is a relaxation phenomenon at work. This should be clarified through further research. In the interim, therefore, injury calculations may be done with and without the abdominal variable.

### O.3.3 Probability of discrete AIS injury severity level (see 5.4)

#### O.3.3.1 Head, neck, thorax, abdomen (see 5.4.1)

The injury severity distributions identify the probability of the least expected AIS if a human subject were exposed to an injury assessment value equivalent to that observed in the motorcyclist dummy or simulation model. In order to isolate the probabilities associated with a specific AIS level, the probabilities involving AIS injuries which are more severe than the AIS level of interest, must be subtracted.

#### O.3.3.2 Lower extremities (see 5.4.2)

For the lower extremities, injury assessment is non-probabilistic in nature. The reasons for this are described below.

In general, for other body regions, injury assessment functions of indices are based upon injury severity distributions derived from statistical analyses of biomechanical data. Currently, published indices, i.e., for the head, chest, and the abdomen, are all based upon observable kinematic responses, i.e., acceleration, velocity, and displacement. A discrete value of $G_{max}$, for example, which depends upon measured linear and rotational accelerations, corresponds to probable distribution of closed head injury severity.

So, in general, injury assessment functions of indices require two types of databases:

— an injury statistical database, relating specific human body region injury severities and types to specific accident circumstances;

— an injury index database based upon simulating the "specific accident circumstances" noted above, and measuring the injury indices in those simulations.

In the case of the lower extremities, neither the injury statistical database nor the injury index database currently exists. In fact, a numerical injury index which is generally applicable to the wide range of possible lower extremity impacts has yet to be defined.

For the lower extremities, injury severities are limited to low severity soft tissue injury which cannot currently be monitored by any available anthropometric test device, or AIS 2 or AIS 3 severity injuries which take the form of fractures.

In probabilistic terms, the leg bones will be observed to fracture or to not fracture, that is, 0% or 100% chance of occurrence. In addition, the probabilistic distributions of the dummy leg bone static and dynamic strengths have been measured, as quantified in the rationale to ISO 13232-3. Also, the probabilistic distribution of human cadaver leg bone static strength has been measured (Yamada, 1970). In principle, these distributions can be related.

Fracture of the frangible bone element of the upper leg is indicative of a femoral fracture. The severity of such an injury is classified as an AIS 3, regardless of the fracture type i.e., comminuted, open, simple.

Injury to the knee is dependent on the condition of the shear pins and the pivot bolt. Failure of either or both shear pins corresponds to loads resulting in a ligament rupture and constitutes a partial knee dislocation. Failure of both shear pins is considered to be equivalent to a complete knee dislocation. The AIS categorizes these injuries as AIS 2 and AIS 3, respectively.

Damage to the frangible bone element of the lower leg is indicative of a tibial fracture. Injury severity is dependent on the extent or type of fracture observed in the tibia. Damage to the frangible bone element without displacement (considered to be indicated by a narrow fracture zone) is considered to be equivalent to a simple closed fracture of the tibia of AIS 2 severity. Damage with displacement of the frangible bone element (considered to be indicated by a wide fracture zone) is equivalent to a compound or complex fracture and hence represents an AIS 3 severity injury.

There are no published injury probability distributions for the lower extremities. Since it is the observation or simulation of damage to the frangible leg element that dictates the AIS injury severity level, no calculations are required to isolate the AIS level. Injuries of AIS 2 and AIS 3 are predicted to occur or not to occur.

#### O.3.3.3 Permanent partial incapacity (see 5.4.2.3)

Injuries of the same AIS may involve significantly different disability outcomes, and costs which can not be recognized if lower extremity injuries are differentiated by AIS alone. The permanent partial incapacity index is used for lower extremity injuries to address the problem of diminished sensitivity to the AIS. The PPI approach, developed by Farisse, et al., (1983), assumes that injuries involving the joint are more serious than injuries of the shaft and that multiple leg injuries are more serious than single injuries. Leg injuries are assigned a PPI value representative of the expected percentage of disability to result from the injuries. This simple solution increases sensitivity to injury type as well as to the number of injuries. Because the PPI represents a percentage of disability it can be directly applied to disability costs.

### O.3.4 Injury costs (see 5.5)

There have been many cost studies conducted in both North America and Europe. The data used for this application was published by Miller, et al., (1990) and is the only known database which defines cost, both medical and ancillary, by AIS and body region. The format is such that the costs can be applied directly to the injury severity probabilities. Future substitution, with more population specific cost data, will make the analysis more representative of the international population base.

#### O.3.4.1 Medical costs (see 5.5.1)

Medical costs include medical care and initial and subsequent hospitalization associated with the injuries.

Injury severity probabilities are multiplied by the associated medical cost for each AIS level and summed to produce the medical probability costs of the entire injury distribution for each body region. Since no probability distribution is available for the lower extremities, observation or simulation of leg injuries automatically implies a 100% probability of occurrence. The medical costs for such injuries are then directly extracted from the cost data, without any need for further manipulation. The highest medical cost of all injured body regions is selected because it is assumed that medical costs are controlled by the most costly injury.

Medical probability costs are calculated independently of ancillary probability costs to allow for more specific cost definition. It may be of interest, for example, to know what proportion of the total cost arises from the medical component.

#### O.3.4.2 Ancillary costs (see 5.5.2)

Ancillary costs include household productivity, lost wages, workplace costs, and legal costs but exclude "pain and suffering," which is subject to considerable variation.

The calculations of injury probability ancillary costs for the head, thorax, and abdomen are performed using the same methods as described for the medical costs. Ancillary costs for the lower extremity injuries are derived from the PPI. Since PPI is a function of disability, ancillary costs are more significantly affected by PPI, then are medical costs.

Because cost data are based on AIS, a correlation between AIS and PPI must be established if costs are to be evaluated as a function of PPI. The closest cost equivalent to a complete loss of function in the lower extremities is assumed to be equivalent to the ancillary cost of an AIS 4 spinal injury causing motor/sensory loss in both legs. A partial disability, reflected by a PPI value of 20%, is estimated to cost 20% of the AIS 4 spinal injury.

The highest ancillary cost of all body regions is selected because as with medical costs, the ancillary costs are assumed to be driven by the most costly injury.

#### O.3.4.3 Fatality cost (see 5.5.3)

The cost of fatality, obtained from Miller, et al., (1990) is defined independently of body region. The current methodology treats fatality costs separately to provide greater insight into the injury scenario.

### O.3.5 Probability of fatality (see 5.6)

All AIS 6 injuries, regardless of body region are assumed fatal. Although the proportion of survivors may be growing with improved medical care, the cost data, which was collected in 1982-85 by Miller, defines costs for AIS 1 through AIS 5 and for fatalities, AIS 6 level injuries, and/or from combinations of less severe injuries (AIS < 6) in addition to the probability of death from injuries of AIS < 6. The probabilities of all these possibilities, therefore, must be accounted for.

#### O.3.5.1 Due to AIS 6 injuries (see 5.6.1)

Fatal injuries constitute an AIS 6 and are detectable in the head, neck, and thorax. It is assumed that death occurs as the result of an AIS 6 to the head *or* thorax. Therefore, the probability of two or more AIS 6 injuries occurring simultaneously must be removed.

#### O.3.5.2 Due to non-AIS 6 injuries (see 5.6.2)

Several methods for calculating the probability of death have been proposed, the most renown being the Probability of Death Score, PODS (Somers, 1981).

The odds of death or PODS, is the ratio of the probability of death to the probability of survival. The problem with this method is that it implies that the probability of survival for the given population must be known. In the case of motorcycle crash test simulations and modelling, this data may not be known. PODS and other models base the fatality estimates on the two most serious injuries. This provides the greatest improvement in goodness of fit, but in no way precludes the use of multiple injuries.

The method of choice for estimating the probability of death from AIS < 6 injuries is defined by Ulman and Stalnaker (1986). The rates proposed by Ulman and Stalnaker are based on data obtained from the National Crash Severity System (NCSS) database, and are derived from separate regression equations for each AIS level. Fatality estimates are based on the three most severely injured body regions. Ulman and Stalnaker define a probability of death for each combination of three AIS injuries from 1-0-0 to 5-5-5. This approach integrates well with the crash test and simulation data. The injury severity probabilities are used directly to calculate the probability of occurrence of each triple AIS combination. No other description of the population is required.

The use of three body regions allows for the differentiation of single and multiple injury outcomes. Since cost data do not distinguish between single and multiple injuries and since the proportion of costs attributable to multiple injuries is not known, the fatality rate is the best measure.

#### O.3.5.3 Risk of life threatening brain injury (see 5.6.4)

The risk of life threatening brain injury is reported as an injury index, based on HIC, as correlated by Mertz (1984) for $HIC_{15}$.

### O.3.6 Probable AIS (see 5.7)

#### O.3.6.1 By body region (see 5.7.1)

For understanding of results and test documentation purposes, it is useful to list the "expected" injury severity for each body region. To do this, a weighted average, PAIS, is calculated and the equation is self explanatory.

#### O.3.6.2 Maximum PAIS (see 5.7.2)

This index provides a very course metric of overall somatic injury severity, and it is calculated mainly for historical comparison purposes (as in e.g., Rogers, 1991a).

#### O.3.6.3 Total PAIS (see 5.7.3)

This index provides a very course metric of overall somatic injury severity, and it is calculated mainly for historical comparison purposes (as in e.g., Rogers, 1991a).

### O.3.7 Normalized injury costs (see 5.8)

The cost of injuries is derived by Miller, et al., (1990) and is based on data from the U.S. National Highway Traffic Safety Administration National Accident Sampling System (NASS), the NCSS, and the Detailed Claims Information of the National Council in Compensation Insurance and FARS. A medical and ancillary cost based on AIS is defined for head, neck, chest, abdomen, and lower extremities.

Costs are calculated separately for survivors and fatalities to provide a better definition of the injury consequences.

Except for the neck, all other body regions tend to have an increasing functional relationship between the injury index and injury cost (i.e., if the injury index increases the injury cost increases). However, for the neck, the combined medical and ancillary costs of some injuries could potentially exceed the cost of a fatality, resulting in an injury cost versus injury index relationship which is a decreasing function (e.g., for an AIS 5 critical injury level it could be possible to decrease injury costs by increasing the injury index).

To prevent such a paradox the maximum value of the cost of survival is limited to (1-$P_{fatal}$) and by this means the normalized injury cost never exceeds 1.0. This has the effect of preventing an increase followed by a decrease of the injury cost function. This constraint is needed because the cost of a critical neck injury is greater than the cost to society of a fatality. This amounts to applying an additional social constraint so that converting a critical injury into a fatality is not interpreted to be a possible design solution (which may be important in applying automated optimization methods).

### O.3.8 Risk/benefit analysis (see 5.9.4)

The risk/benefit analysis is done across the accident population, in this case as represented by the 200 impact configurations described in ISO 13232-2. ISO 13232-2 also recommends that the analysis be done by means of computer simulation (as opposed to full-scale testing) for practical reasons, and in this case, the simulation must meet the requirements (e.g., modelling, parameters, output, calibration, and correlation) of ISO 13232-7.

The variables and indices in Table 9 are calculated because these represent key components of the injury evaluation process, ranging from physical variables (e.g., head maximum resultant acceleration) to total normalized injury cost, for each impact test. In Table 9, the "change due to protective device" is calculated, because that is the variable of greatest interest in the paired comparison, for each assessment variable/injury index.

The "distributions of injury assessment variables and injury indices" are determined using straightforward, standard statistical methods; and taking into account the frequency of occurrence of each impact configuration, to produce an appropriate quantification of the accident population.

In the "risk/benefit calculations" the percentage of cases with negative, zero, and positive changes are designated as "beneficial", "no effect", and "harmful", respectively, in order to simplify and clarify the interpretation of this calculation, which is done for each assessment variable/injury index.

#### O.3.8.1 Average risk/benefit percentage (see 5.9.4.2)

This is a simple basic and common risk-benefit calculation used to determine whether a device has a net benefit across the conditions of intended use. This calculation is based on the average risk and benefit across all accidents. Of course the total net benefit could be determined by multiplying this by the total number of accidents evaluated.

#### O.3.8.2 Average net benefit (see 5.9.4.3)

Compared to the previous proposal of 1997 (N 236), these risk and benefit equations proposed by Iijima, et al., 1998, involve dividing by the total number of accidents (i.e., to give the average risk and benefit per accident), rather than dividing by the summed baseline vehicle injury indices. The latter in many cases can be zero, which leads to various mathematically undefined conditions, which N 236 handled in only a very awkward way. The proposed method is improved and mathematically well-conditioned.

#### O.3.8.3 Average benefit per beneficial case and average risk per harmful case (see 5.9.4.4)

These indices are needed in order to quantify whether there is an appropriate balance between individual benefits and risks. For example, these indices quantify the relative magnitude of a typical injury benefit (e.g., elimination of fatal injuries in some accidents) or a typical injury risk (normalized injury costs increased by 0,1 in some other accidents), as in the previously mentioned example. A negative example would be a device which slightly decreased chest injuries in a large number of cases at the expense of fatal chest injuries in a few cases. These indices can be used to clarify these tradeoffs.

## O.4 Annex D (informative) Example computer code of the injury cost model

This annex was provided in order to enable uniform implementation of the injury index calculations.

## O.5 Annex E (informative) Comparison of results to reference risk and benefit values

These reference values are be included to assist in interpreting the risk-benefit results and not as mandatory requirements, for which they would be too arbitrary. The first and third of these reference values are self-explanatory and self-evident. The second reference value is based on the cited published references for cars, which however might or might not be suitable for motorcycles. The fourth reference value is based on the basic concept of the rights of an individual, i.e., that the risk to any one individual should not be greater than the individual benefit to others.

## O.6 Annex F (informative) Example probable injury cost data

This annex is provided for reference, to facilitate understanding of the numerical interactions and overall behavior of the injury index calculations. It is also provided as a numerical check case for any implementations of the injury index calculations.

## O.7 Annex G (informative) Probability distribution curves

These curves were included as an informative annex to improve visualization of the equations given in Tables 1, 2, 3, and 4.

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