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

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

*Motorcycles — Méthodes d'essai et d'analyse de l'évaluation par la
recherche des dispositifs, montés sur les motorcycles, 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 (IE);
- 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 $V_{us} \geq 3$ m/s;
- lower sternum maximum velocity-compression ($VC_{ls,max}$) for $V_{ls} \geq 3$ 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 ($V_{r,hfc}$);
- helmet longitudinal velocity at first helmet/OV contact ($V_{x,hfc}$);
- helmet lateral velocity at first helmet/OV contact ($V_{y,hfc}$);
- helmet vertical velocity at first helmet/OV contact ($V_{z,hfc}$).

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 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.

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:

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

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:

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

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:

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

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 below¹⁾:

1) SAE J885, July 1986.

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

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 $t_1 \geq t_e$ and $t_2 \leq t_d$.

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:

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

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

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

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;

Δl_{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;

Δl_{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 $C_{ls,max}$, respectively.

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

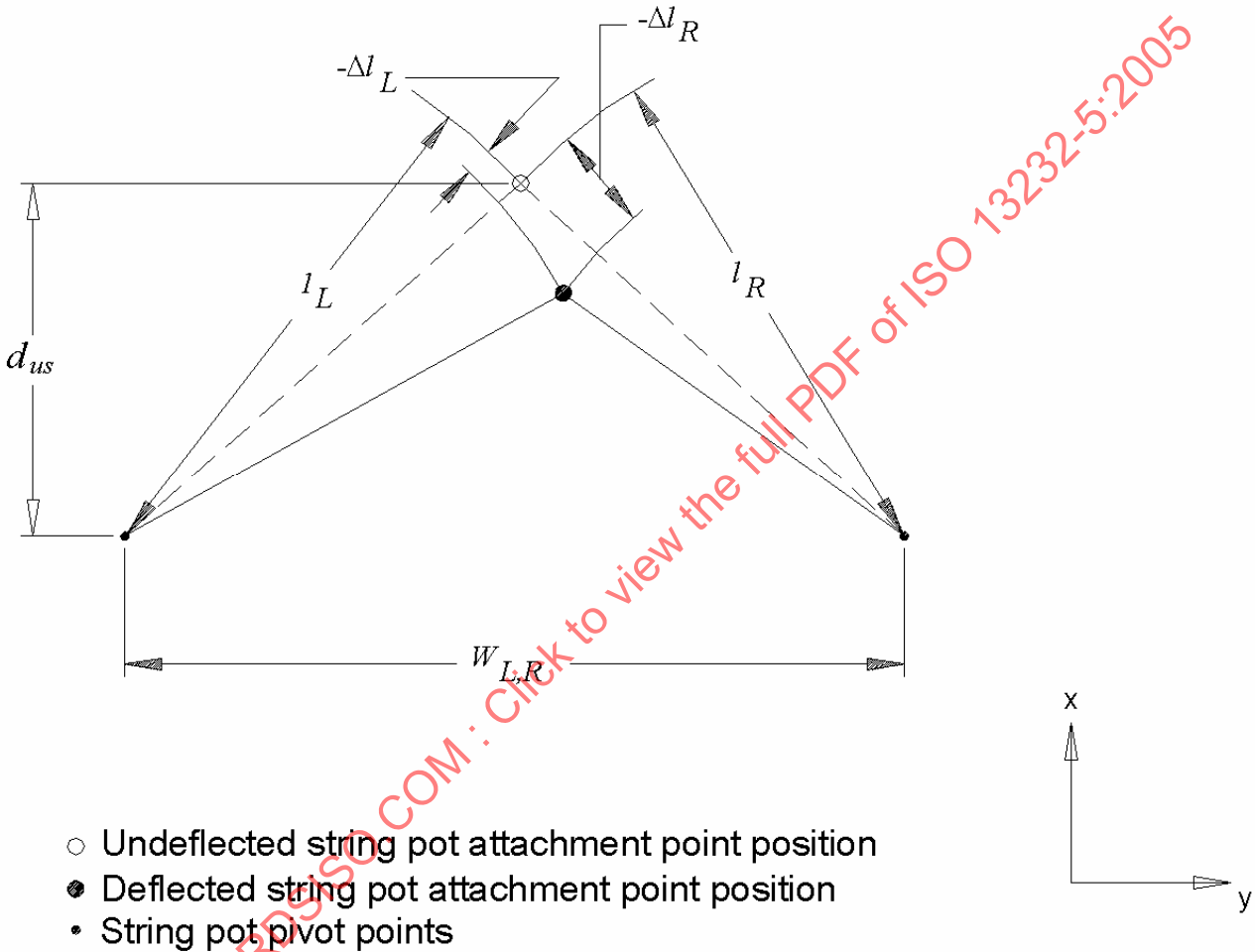


Figure 1 — Chest potentiometer geometry shown for the upper sternum

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.

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

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:

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

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
$AIS \geq 1$	0	$ISP_{H,1} = 1 - \exp\left[-(G_{max} / 0,755)^{3,5}\right]$
$AIS \geq 2$	0,125	$ISP_{H,2} = 1 - \exp\left[-((G_{max} - 0,125) / 0,70)^{3,5}\right]$
$AIS \geq 3$	0,375	$ISP_{H,3} = 1 - \exp\left[-((G_{max} - 0,375) / 0,64)^{3,5}\right]$
$AIS \geq 4$	0,438	$ISP_{H,4} = 1 - \exp\left[-((G_{max} - 0,438) / 0,62)^{3,5}\right]$
$AIS \geq 5$	0,650	$ISP_{H,5} = 1 - \exp\left[-((G_{max} - 0,650) / 0,54)^{2,2}\right]$
$AIS = 6$	0,680	$ISP_{H,6} = 1 - \exp\left[-((G_{max} - 0,680) / 0,60)^{1,8}\right]$
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
$AIS \geq 1$	0	$ISP_{HIC,H,1} = 1 - \exp\left[-(HIC / 560)^{2,98}\right]$
$AIS \geq 2$	0	$ISP_{HIC,H,2} = ISP_{HIC,H,3} + (ISP_{HIC,H,1} - ISP_{HIC,H,3}) \times (55 / 123)$
$AIS \geq 3$	0	$ISP_{HIC,H,3} = 1 - \exp\left[-((HIC - 500) / 1990)^{4,5}\right]$
$AIS \geq 4$	450	$ISP_{HIC,H,4} = ISP_{HIC,H,6} + (ISP_{HIC,H,3} - ISP_{HIC,H,6}) \times (24 / 41)$
$AIS \geq 5$	450	$ISP_{HIC,H,5} = ISP_{HIC,H,6} + (ISP_{HIC,H,3} - ISP_{HIC,H,6}) \times (14 / 41)$
$AIS \geq 6$	450	$ISP_{HIC,H,6} = 1 - \exp\left[-((HIC - 450) / 3275)^{1,36}\right]$

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
$AIS \geq 1$	1,77	$ISP_{C,us,1} = 1 - \exp\left[-\left((C_{us,max} - 1,77)/24\right)^{6,00}\right]$
$AIS \geq 2$	7,47	$ISP_{C,us,2} = 1 - \exp\left[-\left((C_{us,max} - 7,47)/24\right)^{6,00}\right]$
$AIS \geq 3$	13,22	$ISP_{C,us,3} = 1 - \exp\left[-\left((C_{us,max} - 13,22)/24\right)^{6,00}\right]$
$AIS \geq 4$	18,97	$ISP_{C,us,4} = 1 - \exp\left[-\left((C_{us,max} - 18,97)/24\right)^{6,00}\right]$
$AIS \geq 5$	24,72	$ISP_{C,us,5} = 1 - \exp\left[-\left((C_{us,max} - 24,72)/24\right)^{6,00}\right]$
$AIS = 6$	32,52	$ISP_{C,us,6} = 1 - \exp\left[-\left((C_{us,max} - 32,52)/24\right)^{6,00}\right]$
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 $VC_{us,max}$ required	Injury assessment function ^a
$AIS \geq 1$	0	$ISP_{VC,us,1} = 1 - \exp\left[-(VC_{us,max}/0,30)^{0,99}\right]$
$AIS \geq 2$	0	$ISP_{VC,us,2} = 1 - \exp\left[-(VC_{us,max}/0,68)^{1,46}\right]$
$AIS \geq 3$	0	$ISP_{VC,us,3} = 1 - \exp\left[-(VC_{us,max}/1,40)^{2,85}\right]$
$AIS \geq 4$	0,4	$ISP_{VC,us,4} = 1 - \exp\left[-\left((VC_{us,max} - 0,4)/1,291\right)^{3,10}\right]$
$AIS \geq 5$	1,00	$ISP_{VC,us,5} = 1 - \exp\left[-\left((VC_{us,max} - 1,00)/0,995\right)^{3,10}\right]$
$AIS = 6$	1,50	$ISP_{VC,us,6} = 1 - \exp\left[-\left((VC_{us,max} - 1,50)/0,78\right)^{3,10}\right]$
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
$AIS \geq 1$	$ISP_{A,1} = 1,57 \times 10^{-2} \times p_{A,max}$
$AIS \geq 2$	$ISP_{A,2} = 1,23 \times 10^{-2} \times p_{A,max}$
$AIS \geq 3$	$ISP_{A,3} = 1,55 \times 10^{-4} \times (p_{A,max})^{2,00}$
$AIS = 4$	$ISP_{A,4} = 9,36 \times 10^{-13} \times (p_{A,max})^{6,50}$
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
$AIS \geq 1$	1,06	$ISP_{n,1} = 1 - e^{-\left(\frac{NII_{max} - 1,06}{4,38}\right)^{3,5}}$
$AIS \geq 2$	1,86	$ISP_{n,2} = 1 - e^{-\left(\frac{NII_{max} - 1,86}{4,38}\right)^{3,5}}$
$AIS \geq 3$	2,29	$ISP_{n,3} = 1 - e^{-\left(\frac{NII_{max} - 2,29}{4,38}\right)^{3,5}}$
$AIS \geq 4$	4,73	$ISP_{n,4} = 1 - e^{-\left(\frac{NII_{max} - 4,73}{4,38}\right)^{3,5}}$
$AIS \geq 5$	4,73	$ISP_{n,5} = 1 - e^{-\left(\frac{NII_{max} - 4,73}{4,38}\right)^{3,5}}$

Severity level	Minimum NII_{max} required	Injury assessment function
AIS = 6	6,13	$ISP_{n,6} = 1 - e^{-\left(\frac{NII_{max} - 6,13}{4,38}\right)^{3,5}}$
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, $P_{IE,j}$ 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 $P_{IE,j}$ equal to 1 for that AIS injury severity level, j , and set $P_{IE,j}$ 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, $P_{IE,j}$ 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 $P_{IE,j}$ determination

Damaged component	Damage type	AIS	$P_{IE,j}$
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 $P_{IE,j}$ 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:

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

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 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.

5.5.1 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:

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

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_{ij} is the probability of sustaining an injury of AIS injury severity level j to the body region i ;

AC_{ij} 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:

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

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:

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

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	$P_{H,0}$	$P_{n,0}$	$P_{Th,0}$	$P_{A,0}$	$P_{IE,0}$	-
1	$P_{H,1}$	$P_{n,1}$	$P_{Th,1}$	$P_{A,1}$	0	-
2	$P_{H,2}$	$P_{n,2}$	$P_{Th,2}$	$P_{A,2}$	$P_{IE,2}$	$N_{IE,2}$
3	$P_{H,3}$	$P_{n,3}$	$P_{Th,3}$	$P_{A,3}$	$P_{IE,3}$	$N_{IE,3}$
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	$PAIS_H$	$PAIS_n$	$PAIS_{Th}$	$PAIS_A$	$PAIS_{IE}$	-

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:

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

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;

$P_{IE,3}$ 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:

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

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_{ij} 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 IE ;

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;

jIE 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.

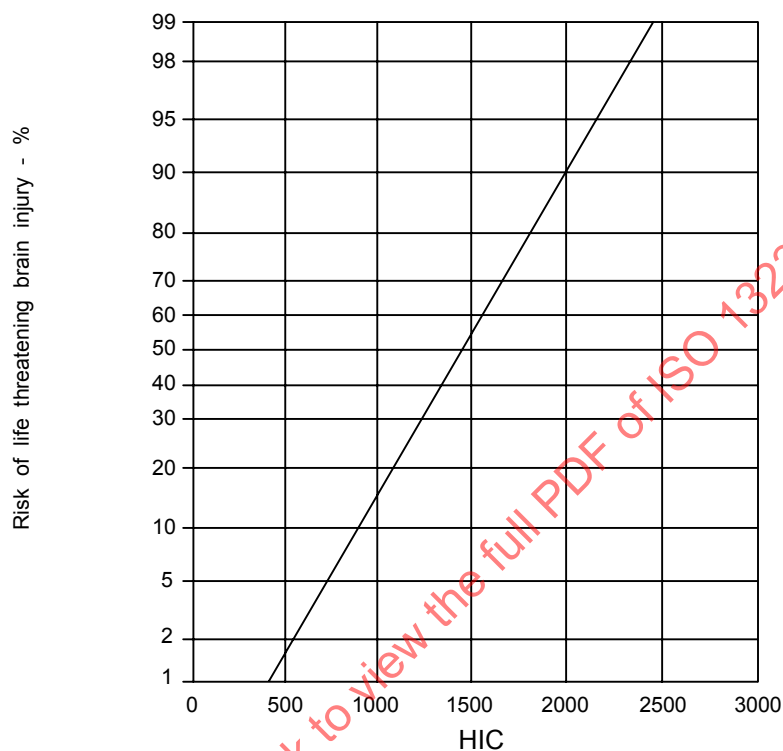


Figure 2 — Risk of life threatening brain injury for HIC for $t_2 - t_1 \leq 0,015$ s

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:

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

where

$N_{IE,3}$ 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:

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

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:

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

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;

$N_{IE,j}$ 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:

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

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 <i>g</i>	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:

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

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

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

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;

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

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	Permanent partial incapacity index.
NII	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
<i>L</i>	left	<i>uL, uR,</i>	upper left, upper right,
<i>max</i>	maximum value	<i>lL, lR</i>	lower left, lower right
<i>min</i>	minimum value	<i>x, y, z</i>	<i>x, y, z</i> direction
<i>norm</i>	normalized	<i>xy, yz, xz, xyz</i>	resultant of two or three axes

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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
c  integer stdout
c  parameter (stdout=6)
c
c  program variables
c
c  integer nldatin, nrdatin, ndatout
c  parameter (nldatin=5, nrdatin=6, ndatout=10)
c  integer ldatin(nldatin), lerr
c  integer lcmax, lvcmax
c  real Rldatin(nrdatin), Table(9,6), Datout(ndatout)
c  real Cmax, Cmaxls, Cmaxus, VCmax, VCmaxls, VCmaxus
c  character*50 sidatin(nldatin), srldatin(nrdatin), sdatout(ndatout)
c  character*13 slc(2)
c  character*20 aformat
c  character tnumstr*12, hline*60, overwrite*1, wnum*1
c  character wdsc*10, tnum*12, tfile*50
c  integer cnt, fdout
c
c  program data
c
c  data tnumstr/'File Name'/
c
c  data sidatin/'Number of AIS 3 Femur Fractures',
c  &      'Number of AIS 2 Tibia Fractures',
c  &      'Number of AIS 3 Tibia Fractures',
c  &      'Number of AIS 2 Knee Dislocation Injuries',
c  &      'Number of AIS 3 Knee Dislocation Injuries'
c  data srldatin/'maximum Abdomen Penetration',
c  &      'maximum GAMBIT',
c  &      'Cmax',
c  &      'VCmax',
c  &      'HIC',
c  &      'NII (2001 MATD Neck)'/
c  data sdatout/'MAIS',
c  &      'Total AIS',
c  &      'Normalized Injury Cost',
c  &      'Normalized Cost of Survival',
c  &      'Normalized Cost of Dying',
c  &      'Probability of Fatality',
c  &      'Probability of Fatality due to non AIS 6 injuries',
c  &      'Probability of Fatality due AIS 6 injuries',
c  &      'Permanent Partial Incapacity',
c  &      'Risk of life threatening brain injury (%)'/
c  data slc/'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
c  do cnt = 1,60
c    hline(cnt:cnt) = char(45)
c  end do
c  write(stdout,101) hline
c  write(stdout,101)
c  * '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
        ldatin(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
    lmax = 1
else
    Cmax = Cmaxls
    lmax = 2
end if
Rdatin(3) = Cmax

```

```

c
c determine the larger VCmax value and location

```

```

c
if(VCmaxus.gt.VCmaxls) then
    VCmax = VCmaxus
    lvcmax = 1
else
    VCmax = VCmaxls
    lvcmax = 2
end if
Rdatin(4) = VCmax

```

```

c
c call the Injury Cost Model

```

```

c
call icm(latin,Rdatin,Table,Datout,lerr)

```

```

if(lerr.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(lmax)
write(stdout,104) 'Location of VCmax',sloc(lvcmax)
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
c   write(stdout,*)
c   call wrbcm(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

```

```

        end if
    end do
    write(fdout,104) 'Location of Cmax ',sloc(lcmax)
    write(fdout,104) 'Location of VCmax',sloc(lvcmax)
    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 wrbcm(fdout,Table)

    close(fdout)

else

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

    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,lerr)
integer Idatin(5), lerr
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:

```

element	symbol	units	description
1	AP	mm	maximum abdomen penetration
2	Gmax	-	maximum GAMBIT
3	Cmax	%	maximum normalized chest compression
4	VCmax	m/s	maximum chest viscous criteria when V>3 m/s
5	HIC	-	Head Injury Criteria
6	NII	-	Neck Injury Index

Table o table 1 values

Datout o real data output array, elements as follows:
element symbol units description

1	MAIS		maximum AIS
2	TAIS		total AIS
3	NIC	-	Normalized Injury Cost
4	NCOS	-	Normalized Cost of Survival
5	NCOD	-	Normalized Cost of Dying
6	POF	-	Probability of Fatality
7	POF5	-	POF due to non AIS 6 injuries
8	POF6	-	POF due to AIS 6 injuries
9	PPI	-	Permanent Partial Incapacity
10	Prisk	%	Risk of life threatening brain injury

Ierr o error code

- 0 - normal return
- 1- 5 - index of out of range Idatin
- 11-14 - index of out of range Rdatin

version history

- original version by RMV, DRI, March 1993
- first revision by RMV, DRI, April 1993
 - AIS 3 knee dislocation injuries added
 - Input range checking added
- second revision by RMV, DRI, March 1994
 - changed model and subroutine name from Injury Cost Model II (icm2) to Injury Cost Model (icm)
 - changed hospital cost (HC) to medical cost (MDC)
 - changed parameter names from AISmax to AIS6, AISsrv to AIS5
- third revision by RMV, DRI, August 1994
 - added PPI to Datout output array
 - added risk of life threatening brain injury calculation based on HIC, HIC input was added to Rdatin and Prisk output added to Datout arrays
- fourth revision by RMV, DRI, December 1994
 - Corrected PPI for 1 leg injury
- include HIC ISP for to head AIS, revision by DPC, DRI, March 1998
- include Neck Injury Criteria, revision by KDW,RMV,SM, DRI, May 2001
- sixth revision by KDW, DRI, February 2002
 - added new neck ISPn equation coefficients
- seventh revision by RMV, DRI, June 2004

```

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

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 Ancillary Cost data in U.S. Dollars

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

```
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

data COF/596580./

c Risk of life threatening brain injury vs HIC data

```
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 *** Extract input data from input arrays ***
```

```

C      ***
C      *****
C
C      FF3 = Idatin(1)
C      TF2 = Idatin(2)
C      TF3 = Idatin(3)
C      KDI2 = Idatin(4)
C      KDI3 = Idatin(5)
C
C      AP = Rdatin(1)
C      Gmax = Rdatin(2)
C      Cmax = Rdatin(3)
C      VCmax = Rdatin(4)
C      HIC = Rdatin(5)
C      NII = Rdatin(6)
C
C      check inputs for allowable ranges
C
C      do 2 i=1,5
C          if( (Idatin(i).lt.0) .or. (Idatin(i).gt.2) ) then
C              lerr = i
C              return
C          end if
C      2 continue
C      do 5 i=1,6
C          if( (Rdatin(i).lt.0.0) ) then
C              lerr = 10+i
C              return
C          end if
C      5 continue
C
C      *****
C      ***
C      *** Calculate injury severity probabilities (ISP) for head, ***
C      *** neck, chest, and abdomen ***
C      ***
C      *****
C
C      begin loop through injury severity levels
C
C      do 10 kais1=1,AIS6
C
C          calculate the head injury severity probability (ISP) based on
C          Gmax
C
C          if(Gmax.ge.Gamma1(kais1)) then
C              HGISP(kais1) =
C      & 1.0-exp(-(((Gmax-Gamma1(kais1))/Eta1(kais1))**Beta1(kais1)))
C          else
C              HGISP(kais1) = 0.0
C          end if
C
C          calculate the chest ISP based on VCmax
C
C          if(VCmax.ge.Gamma2(kais1)) then
C              CVCISP =
C      & 1.0-exp(-(((VCmax-Gamma2(kais1))/Eta2(kais1))**Beta2(kais1)))
C          else
C              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
C   PPI = 0.38
C   LACT = LAC38

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

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

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

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

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

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

C   end if

C   else
C
C     no leg injuries
C
C     PPI = 0.0
C     LACT = 0.0

```

```

end if
C
C *****
C ***
C *** Calculate medical and ancillary costs ***
C ***
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)
    IAP AIS = 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) = IAP AIS
Table(krow,5) = ILPAIS
Table(krow,6) = 0.0

```

```

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

```

```

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

else if(HIC.gt.curve(1,jhic)) then
c
c   Risk is greater than 99%, return 100%
c
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
c Datout(1) = MAIS
c Datout(2) = TAIS
c Datout(3) = NIC
c Datout(4) = NCOS
c Datout(5) = NCOD
c Datout(6) = POF
c Datout(7) = POF5
c Datout(8) = POF6
c Datout(9) = PPI
c Datout(10) = Prisk
c
c done, normal return
c
c lerr = 0
c return

end

```

```

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

```

```

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

```

```

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

```

description

This subroutine writes the Injury Cost Model results for the inputs in arrays *ldatin* and *Rdatin* and outputs in arrays *Table* and *Datout*.

calling sequence

argument i/o description

lout i output unit number

ldatin i integer data input array, elements as follows:

element	symbol	description
1	FF3	number of AIS 3 femur fractures
2	TF2	number of AIS 2 tibia fractures
3	TF3	number of AIS 3 tibia fractures
4	KDI2	number of AIS 2 knee dislocated injuries
5	KDI3	number of AIS 3 knee dislocated injuries

Rdatin i real data input array, elements as follows:

element	symbol	units	description
1	AP	mm	maximum abdomen penetration
2	Gmax	-	maximum GAMBIT
3	Cmax	%	maximum normalize chest compression
4	VCmax	m/s	maximum chest viscous criteria when $V > 3$ m/s
5	HIC	-	Head Injury Criteria
6	NII	-	Neck Injury Index

Table o table 1 values

Datout o real data output array, elements as follows:

element	symbol	units	description
1	MAIS		maximum AIS
2	TAIS		total AIS
3	NIC	-	Normalized Injury Cost
4	NCOS	-	Normalized Cost of Survival
5	NCOD	-	Normalized Cost of Dying
6	POF	-	Probability of Fatality
7	POF5	-	POF due to non AIS 6 injuries
8	POF6	-	POF due to AIS 6 injuries

version history

- original version by RMV, DRI, March 1993
- first revision by RMV, DRI, April 1993
 - AIS 3 knee dislocation injuries added
- second revision by RMV, DRI, March 1994
 - changed model and subroutine name from Injury Cost Model II (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
c   integer kcol, krow
c   character*69 blank, dline
c
c   data
c
c   data blank/' '/
c   data dline( 1:40)/'-----'/
c   data dline(41:69)/'-----'/
c
c*****
c
c   write out Table
c
c   write(lout,101) dline,dline
c   write(lout,101) blank,
c   & '          BODY REGION          '
c   write(lout,101) ' AIS ',dline
c   write(lout,102) blank,' HEAD ',' NECK ',' CHEST ',
c   & ' ABDOMEN ',' LEG '
c   write(lout,103) blank,('Probability',kcol=1,5),'# Injuries'
c   write(lout,103) (dline,kcol=1,7)
c   do 10 krow=1,7
c     write(lout,104) krow-1,(Table(krow,kcol),kcol=1,5),
c     & nint(Table(krow,6))
c 10 continue
c   write(lout,103) (dline,kcol=1,7)
c   krow=8
c   write(lout,105) ' PAIS ',(Table(krow,kcol),kcol=1,5)
c   write(lout,103) (dline,kcol=1,7)
c   krow=9
c   write(lout,106) ' PAIS ',(nint(Table(krow,kcol)),kcol=1,5)
c   write(lout,103) (dline,kcol=1,7)
c
c   return
c
c*****
c
c   format statements
c
c 101 format(1x,'|',a6,'|',a70,'|')
c 102 format(1x,'|',a6,4('|',a11),'|',a22,'|')
c 103 format(1x,'|',a6,5('|',a11),'|',a10,'|')
c 104 format(1x,'|',3x,i1,2x,5('|',3x,f5.3,3x),'|',4x,i1,5x,'|')
c 105 format(1x,'|',a6,5('|',3x,f5.3,3x),'|',10x,'|')
c 106 format(1x,'|',a6,5('|',5x,i1,5x),'|',10x,'|')
c
c   end
c...+...1...+...2...+...3...+...4...+...5...+...6...+...7...+...8

```

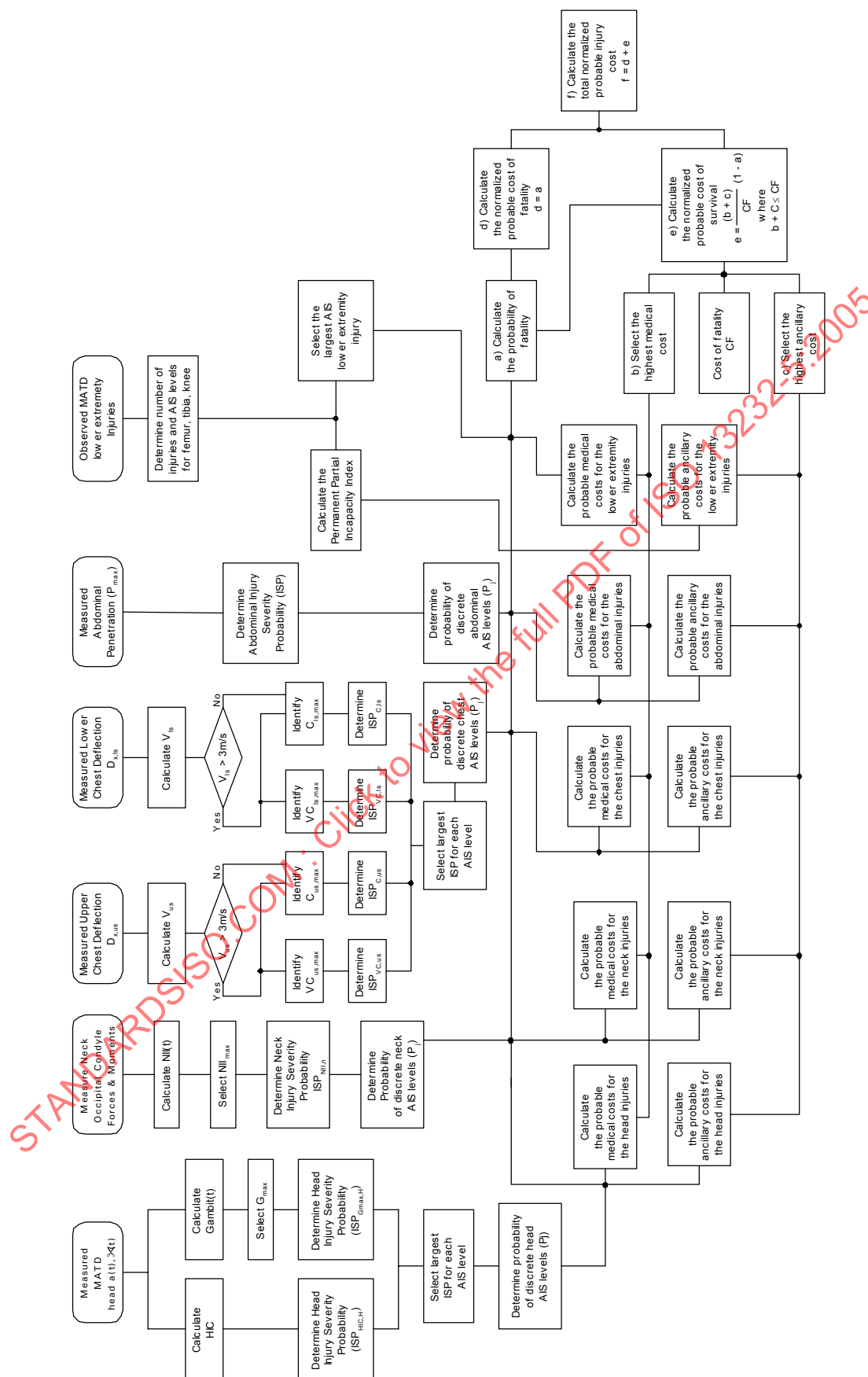


Figure D.1 — Flow diagram of the injury cost model

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 percent²⁾,
- 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

<i>GMAX</i>	maximum GAMBIT
<i>VC</i>	maximum VC, in metres per second
<i>CMAX</i>	maximum normalized chest compression, in percent
<i>PA</i>	abdominal penetration, in millimetres
<i>FEM</i>	AIS 2 femur fracture = 1, no fracture = 0
<i>KNE</i>	AIS 2 knee dislocation = 1, no dislocation = 0
<i>TIB</i>	tibia fracture = 1, no fracture = 0
<i>NUM</i>	total number of leg injuries
<i>HP</i>	head probable AIS
<i>ThP</i>	thorax probable AIS
<i>AP</i>	abdomen probable AIS
<i>F</i>	femur AIS
<i>K</i>	knee AIS
<i>T</i>	tibia AIS
<i>MAIS</i>	maximum AIS
<i>TAIS</i>	total AIS
<i>POF</i>	probability of fatality, in percent
<i>ICn</i>	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	60	1	1	0	2	1	6	0	3	2	0	6	12	92	94
0.6	2.5	0	60	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

<i>GMAX</i>	<i>VC</i>	<i>CMAX</i>	<i>PA</i>	<i>FEM</i>	<i>KNE</i>	<i>TIB</i>	<i>NUM</i>	<i>HP</i>	<i>ThP</i>	<i>AP</i>	<i>F</i>	<i>K</i>	<i>T</i>	<i>MAIS</i>	<i>TAIS</i>	<i>POF</i>	<i>IC_n</i>
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.

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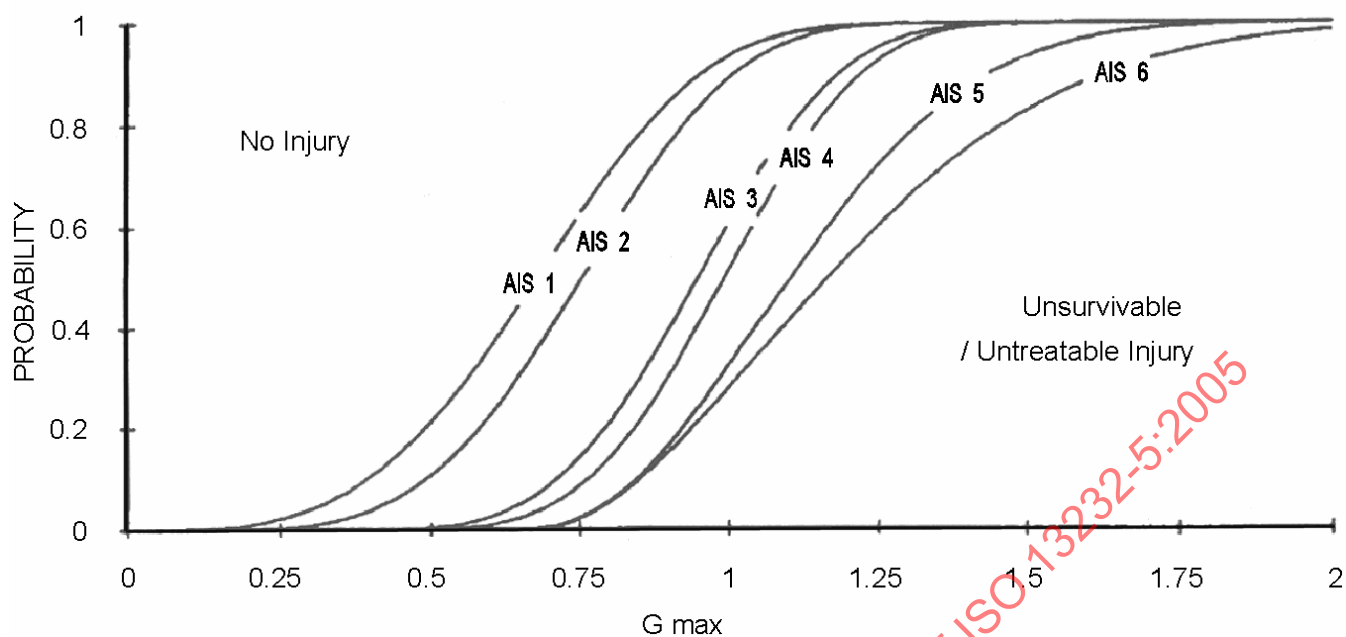


Figure G.1 — Probability distribution of head injuries as a function of G_{max} (Kramer & Appel, 1990)

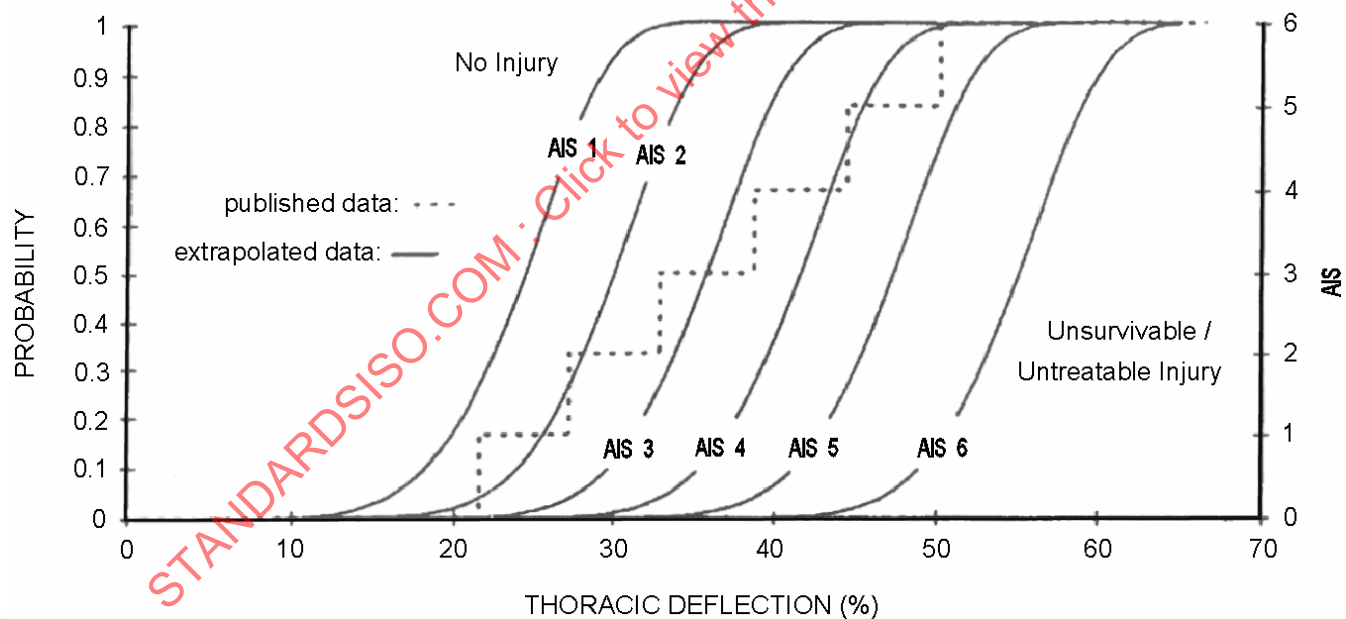


Figure G.2 — Probability distribution of thoracic injury as a function of maximum resultant upper (or lower) sternum compression (Kroell, et al., 1974)

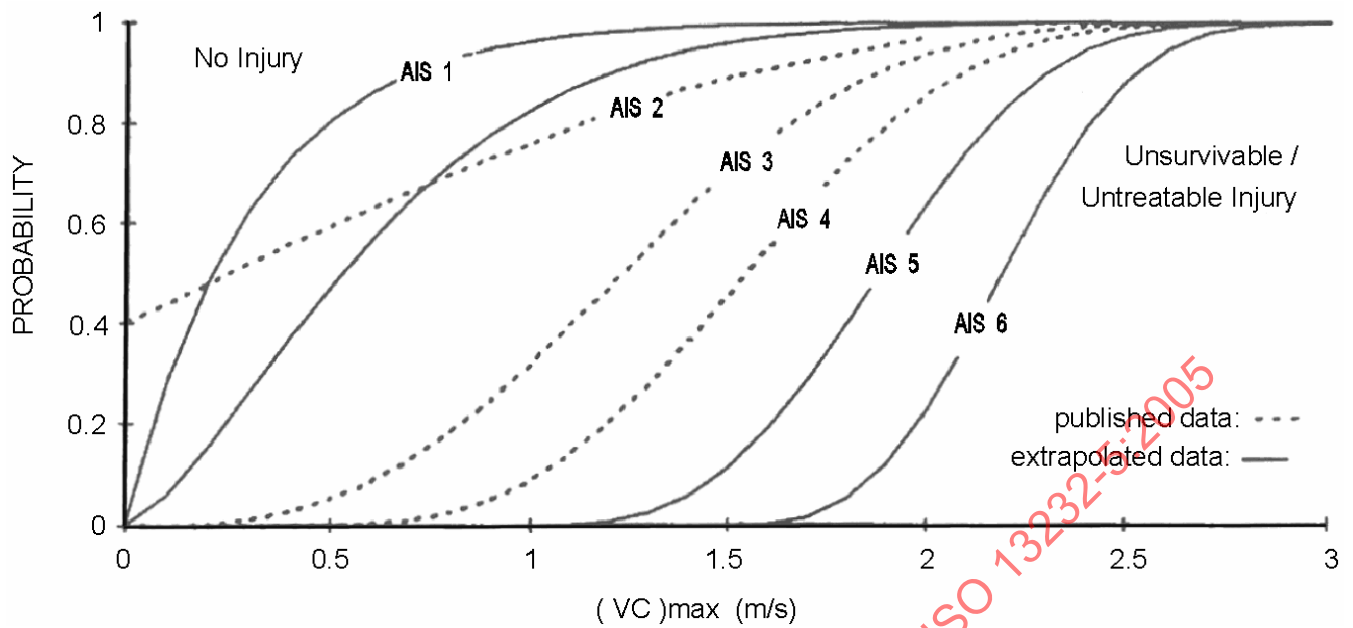


Figure G.3 — Probability distribution of thoracic injuries as a function of maximum resultant upper (or lower) sternum velocity-compression (Lowne & Janssen, 1990)

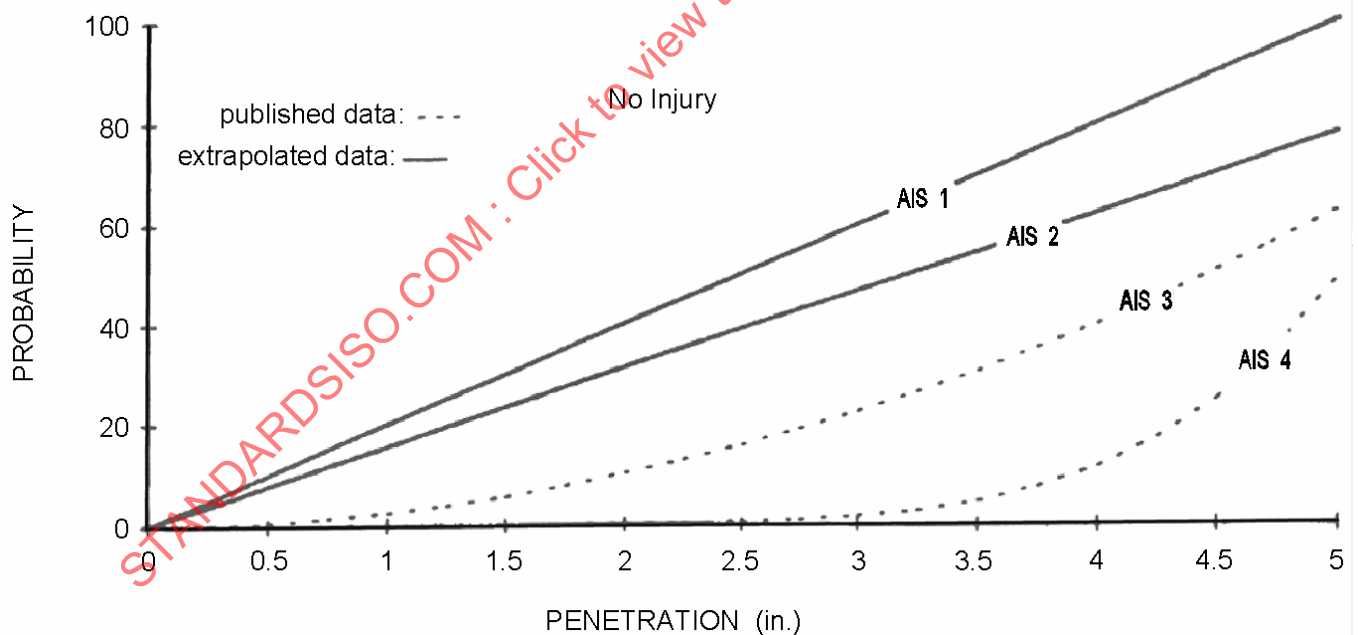


Figure G.4 — Probability distribution of human abdominal injuries as a function of maximum human abdominal penetration (Rouhana, et al., 1990)

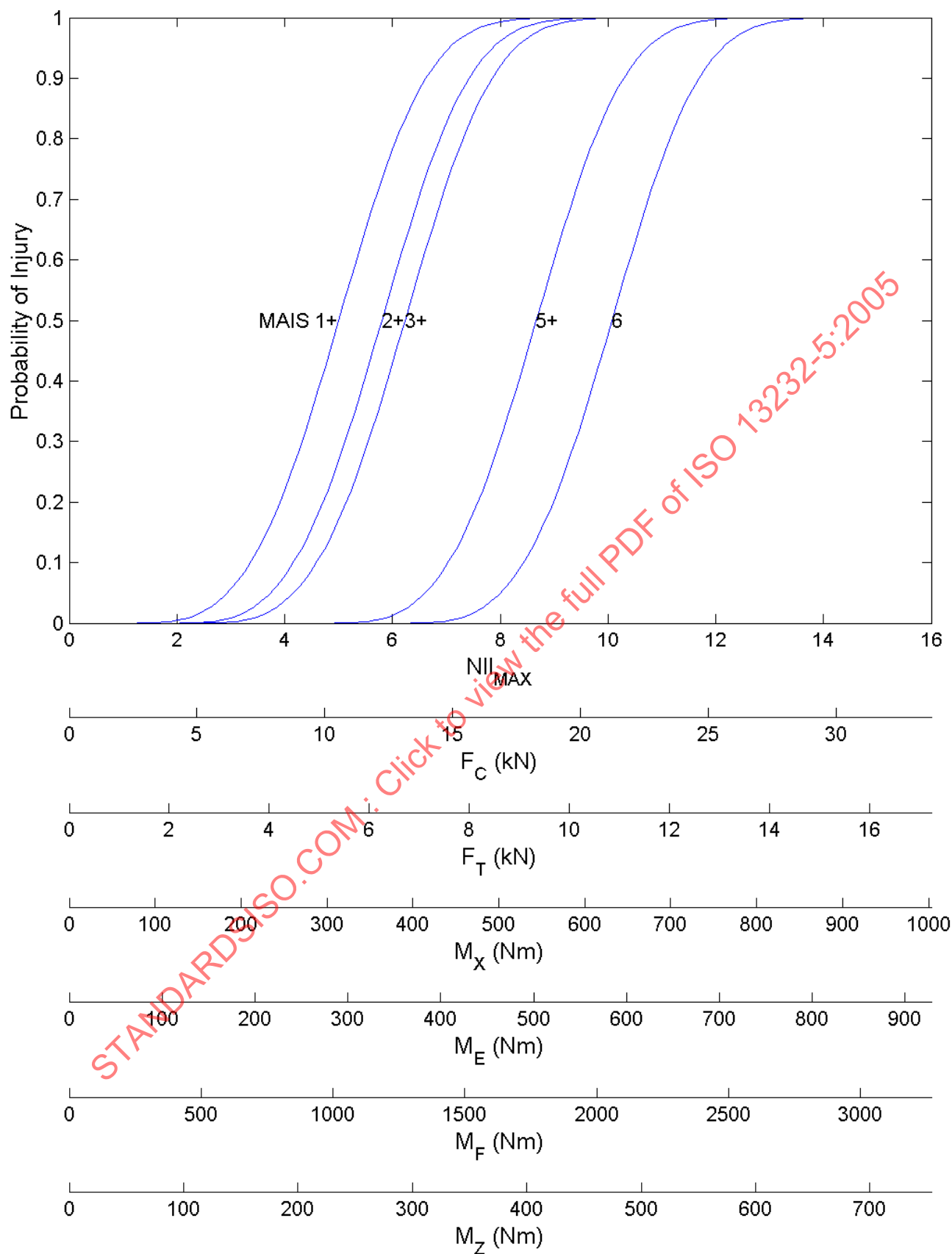


Figure G.5 — Probability distribution of neck injury as a function of NII_{max}

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.

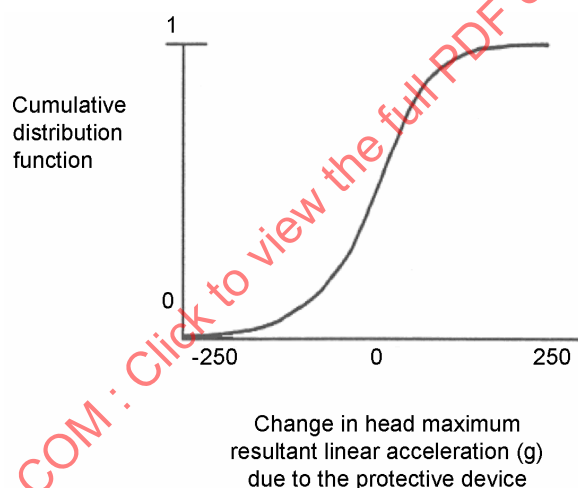


Figure H.1 — Example of a continuous cumulative distribution function graph for change in an injury assessment variable

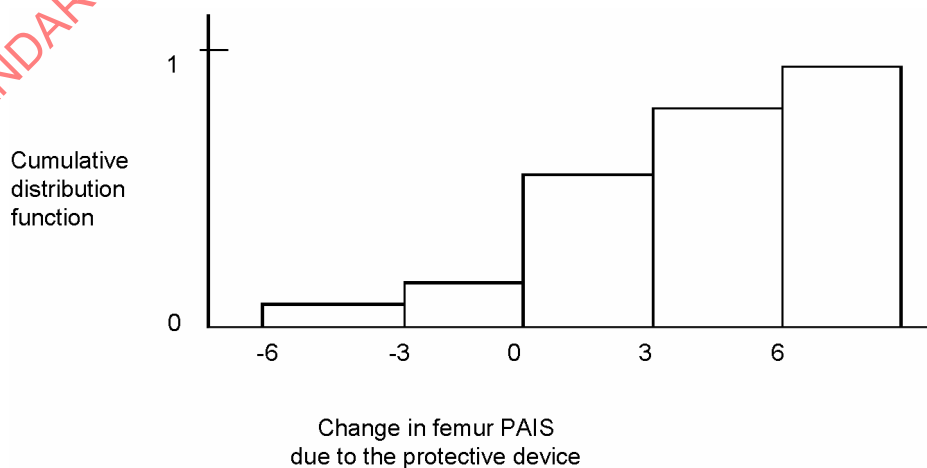


Figure H.2 — Example of a discrete cumulative distribution function graph for change in an injury index

Annex I (informative)

Example computer code for calculations of head contacts

```

C *****
C PROGRAM CONTACT
C -----
C Programme CONTACT
C But: DÈterminer le temps de contact de la tÈte pour ensuite
C       calculer le HIC sur cette pÈriode. ȳ noter qu'il peut y
C       voir plusieurs temps de contact et qu'ainsi plusieurs HIC
C       peut Ètre 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 boÈtes
C -----

REAL*4 Y(4096),YY(4096),ZSAUT
INTEGER*2 ICH,IUN,GROUPE(4),CHAN(4,6),UNIT(4,6)! 4 Groupes ȳ 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 III m',
:'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      Debut du programme
C      *****

CALL ERRSET(63,.,TRUE.,.FALSE.,.TRUE.,.FALSE.,)
CALL CHECK(NCAN,IGO)      ! VÉRifier 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      VÉRifier 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 tÈte 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

```

```

C      IGRP=GROUPE(IL)                ! Le type de groupe
C      CALL FORCE_EXT(IL,IGRP,Y,TITRE,CHAN,UNIT)! Cal. force
C
C      _____
C      /_____Maximum
C      /_____Minimum
C      /_____Echelle (+)
C      /_____Echelle (-)
C      /_____Temps du max
C      /_____Temps du min
C
C      CALL DSCALE(Y,YMAX,YMIN,IMAX,IMIN,KMX,KMN,IDIV,IUNIT)
C      IMIN=0                          ! Forcer les Échelles 0 @ max
C
C      -----
C      Calcul des temps d'engagement et de desengagement t(e) et t(d)
C      -----
C
C      DO KJ=1,500                      ! Boucler sur le nombre temps
C      ITE(KJ)=0                        ! Initialiser tous les TE
C      ITD(KJ)=0                        ! Initialiser tous les TD
C      ENDDO                            ! Fin de boucle TE TD
C
C      CALL TEMPS_ENGAGE(Y,ITE,ITD)      ! Calculer tous les Te et Td
C
C      -----
C      ...valuer tous les HIC pour tous les TE et TD trouvÈs
C      -----
C      IUNIT=IUN(36+IL)                 ! No de l'unitÈ logique de RES
C      KKK=ICH(36+IL)                   ! No ducanal de la RESULTANTE
C
C      ZMAX=0.0
C      DO 110 KI=1,500                  ! Boucler sur possibilitÈ de 500
C      IF(ITE(KI).EQ.0.OR.ITD(KI).EQ.0) GOTO 110 Fini, plus de TE et TD
C      INT=ITD(KI)-ITE(KI)              ! Intervalle maximum pour HIC
C      CALL LOCATE(9,22,'CONTACT Étudie l'intervalle suivant')
C      TYPE 312,ITE(KI),ITD(KI)
C      IF(INT.LE.10) GOTO 110
C      CALL HICSUB(KKK,TABT1,TABT2,TABHIC,IL,IBOUK,IUNIT,INT,
C      :ITE(KI))
C      IF(SUPHIC.GT.ZMAX) THEN            ! Tester si on a un HIC max
C      MAXTAB1=TABT1(IL,1)
C      MAXTAB2=TABT2(IL,1)
C      MAXHIC=TABHIC(IL,1)
C      ZMAX=SUPHIC                        ! Retenir le HIC max
C      ITT1=HICT1                         ! Le temps T1
C      ITT2=HICT2                         ! et le temps T2
C      ITTE=ITE(KI)                       ! Enregistrer le Te corresp.
C      ITTD=ITD(KI)                       ! Et le Td correspondant.
C      ENDIF                              ! Fin de test sur HIC max
C      CALL CLS(8,1)                      ! Effacer a partir de (4,1)
C      CONTINUE                           ! Fin de boucle sur Te,Td poss.
C      TABT1(IL,1)=MAXTAB1                ! Tabuler le T1 max
C      TABT2(IL,1)=MAXTAB2                ! Tabuler le T2 max
C      TABHIC(IL,1)=MAXHIC                ! Tabuler le HIC max
C
C      -----
C      Tracer le rÈsultats
C      -----
C
C      IPAGE=IPAGE+1                     ! IncrÈm. le no de pied de page
C      CALL IMP_CONTACT(Y,IMIN,IMAX,IDIV,IPAGE,
C      :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 derniÈre 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      \ / \ /
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      
$$F = \frac{\sqrt{[(Ma(x)-Fx)^2 + (Ma(y)-Fy)^2 + (Ma(z)-Fz)^2]}}{V}$$

C

```

```

C  M : la masse de la tete = 4500 grammes (Fourni par R.M)
C  a(x), a(y) et a(z): les accélérations de la tête dans les 3 axes
C  Fx,Fy et Fz      : les forces du cou (pour les signes voir SAE J211)
C  F                : la force résultante
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 IIIIm',
:'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)          ! UnitÉ 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)          ! UnitÉ 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)          ! UnitÉ 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)          ! UnitÉ 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) ! UnitÉ 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)          ! UnitÉ 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)          ! UnitÉ 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)      ! UnitÉ 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 rÉsultante est maintenant Égale ‡
C -----

```

```

DO I=1,4096      ! Boucler sur le nombre de pts
  F(I)=SQRT(F(I))      ! Calculer F rÉsultante
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      /-----/
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/4,3,4,3,4,3,4,3,4,3,4,3,4,3,4/

```

```

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 appropriée
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      sert 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 LNEXTCL          ! 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'entête
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=BUY1
DELTAX=(BUY2-BUY1)/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 caractères
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'Écran
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),.08,8HVehicle,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 à ...VALUER TOUS LES Te et les Td possibles
C (jusqu'à 5 recherche)
C
C Version: 1.0      8-Mai-92Alain 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 à 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 dÉpart de recherche
1  CONTINUE            ! Fin des recherches

```

```

2  RETURN
   END

```

```

C=====
C  Sous-routine utilisÉe 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  DÉbut 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 Égal ± 500 N
        RETURN              ! Retourner le no de l'Échantillon
1  CONTINUE                ! Fin de la boucle de recherche
      IT500=0               ! Valeur de dÉfaut si rien trouvÉ

      RETURN
      END

```

```

C=====
C  Sous-routine utilisÉe 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  DÉbut 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 Égal que 200
        RETURN              ! Retourner le no de l'Échantillon
1  CONTINUE                ! Fin de la boucle de recherche

```

```

RETURN
END

```

```

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

```

```

C-----
C  Variables locales
C-----
C  REAL*4 Y(4096)
C  REAL FACTEUR_MASSE,FC
C  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 1 nouveau
        ITSUP=I             ! Plus petit ou Égal 1 200 N
        RETURN              ! Retourner le no de l'Échantillon
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. Labocchetta :
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)      ! Première 1/2 du titre
          LBL(2,KLBL)=PLBL(2,K)      ! Seconde 1/2 du titre
1140  KLBL=KLBL+1      ! Incrémenter 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)      ! Première 1/2 du titre
          LBL(2,KLBL)=PLBL(2,K+10)      ! Seconde 1/2 du titre
1150  KLBL=KLBL+1      ! Incrémenter 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)      ! Première 1/2 du titre
          LBL(2,KLBL)=PLBL(2,K+20)      ! Seconde 1/2 du titre
1160  KLBL=KLBL+1      ! Incrémenter 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***      ! Définir M
      ENCODE(3,130,M(24:26)) KKK      ! Insérer KKK dans M
      CALL EFFET(2)      ! Haute intensité
      CALL LOCATE(13,25,M(1:29))      ! ...crire M
      CALL EFFET(3)      ! Vidéo normal
      CALL DELAIS(1.0)      ! Attendre 2 secondes

C-----
C----Lire les données 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
  T11=HICT1*DTIME                       ! T1 exprimÉ en sec
  T12=HICT2*DTIME                       ! T2 exprimÉ en sec
  TABT1(IS,1)=T11                      ! Sauvegarder les donnÉes
  TABT2(IS,1)=T12                      ! Sous forme de tableau
  TABHIC(IS,1)=SUPHIC                  ! Pour impression futur

C-----
C  Faire une grille
C-----
400 CALL LOCATE(16,1,' ')               ! Pour Écrire sur la ligne 13
    IF(INT.LE.10) GOTO 303              ! Afficher le message d'erreur
    WRITE(5,200,ERR=303)SUPHIC,T11,T12,
    :      AMPLT1,AMPLT2,AMPMAX,AMPBAR   ! Afficher ± l'Écran
    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)                   ! CaractÉres graphiques
M='lqqqqqqqqqqqwwqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqq'
CALL LOCATE(16,10,M)                  ! Ligne blanche haut de la boite
CALL LOCATE(17,10,'x')                ! SÉparateurs 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='tqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqq'
CALL LOCATE(18,10,M)                  ! Ligne blanche milieu boite
CALL LOCATE(19,10,'x')                ! SÉparateurs 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='mqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqj'
CALL LOCATE(20,10,M)                  ! Ligne blanche bas de boite
CALL DELAIS(2.0)                      ! Afficher pendant 2 sec
CALL SETCAR(0,2)                      ! CaractÉres 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 donnÉ ± la diffÉrence avec une la restriction de chercher
C      entre les no d'Échantillon 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 msec
      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 default (1 msec)
2031      INT=INT+1      ! IncrÉmenter 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  $\neq$  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 mÊme 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 rappeler 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 concernEs.
 C Version permettant d'avoir des unitEs logiques diffErentes
 C Version: 1.1 25-AUG-87
 C Version: 2.0 24-nov-89 Marc Villeneuve, Stagiaire
 C PremiÈre 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 On cherche les titres suivants:

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 /2,2,2,2,2,2,2,2,3,3,3,3,3,3,3,3,

4,4,4,4,4,4,4,4,5,5,5,5,5,5,5,5,2,3,4,5/

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'Écran et afficher le titre du programme
C -----

CALL CLEAR ! Effacer complètement l'Écran
CALL TITCAR('CONTACT (V1.1:Automatique)') ! Mettre un titre

C -----
C VÉRifier si un fichier CONTACT.X existe et si oui l'effacer.
C IdÉE de commande.com de Yves Gaudreau (Août 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;*' ! Insc. nomess ds Commande.com
WRITE (UNIT=97,FMT=100) NOMESS

```

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 XXXXXXXX.CNT
COMMDE(1:17) = 'DEL CONTACT.DAT;*'
WRITE (UNIT=97,FMT=100) COMMDE      ! Effacer les CONTACT.DAT
100 FORMAT('$ ',A250)                ! 2 + 250 = 252 caractères
CLOSE(UNIT=97,DISPOSE='KEEP')       ! Fermer pour exécuter
COM80(1:9) = '@COMMANDE'            ! Composition du FUNMCR
CALL FUNMCR(COM80)                  ! Exécution 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)                  ! Exécuter 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-demandé! Stopper pas CONTACT

```

```

NBFICH=BOITE                        ! Nombre de fichier à lire
DOSS1(1:9) = BOX1                   ! Premier dossier Boite #1
DOSS2(1:9) = BOX2                   ! Deuxième dossier Boite #2
DOSS3(1:9) = BOX3                   ! Troisième dossier Boite #3
DOSS4(1:9) = BOX4                   ! Troisième 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 à traiter
IUNIT=24                            ! Unité logique de départ + 1
511 IW=1                             ! Au début 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 trouvés
    GOTO 5511                        ! Vérifier si déjà trouvé
ENDIF                                ! Fin du test
IUNIT=IUNIT-1                       ! Unité logique de départ
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) ! Définir la zone mémoire

```

```

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 à 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 à partir de 10
  CALL BOX(7,4,70,3)     ! Dessiner une boîte
  MESS(1:30)='Fichier: xxxxxxxxxxxxxx ouvert'
  MESS(31:63)= ' , contenant yyy canaux de données'
  MESS(10:23)=DOSSIE(IBOUK) ! Insérer le nom du canal
  ENCODE(3,6,MESS(43:45)) NCHS ! et le numéro 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 intensité
  CALL LOCATE(7,17,MESS(10:23)) ! Réécrire le nom du canal
  CALL LOCATE(7,50,MESS(43:45)) ! Réécrire le numéro
  CALL EFFET(3)           ! Vidéo normal
  IF (ITEM.EQ.0) ITEM=NBFICH ! Pour TEMOIN (1 seule fois)
  CALL TEMOIN(1,ITEM,15,IBOUK,ZSAUT) ! Afficher un témoin indiquant à
                                   ! 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 trouvé
  GOTO 53      ! Oui on a trouvé
51 CONTINUE      ! Fin de la boucle de recherche
MESS(1:40)=' '      ! Vider MESS
MESS(41:80)=' '      !
MESS(29:76)='CONTACT-XXXXXXXXXXXXXXXXX introuvable; fichier Y' '
MESS(37:52)=CHERCH ! Insérer CHERCH dans MESS
ENCODE(1,4,MESS(75:75)) IFOIS
C CALL FUNMCR(MESS)      ! Envoyer msg à 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 à chercher
IF(ICH(IW).EQ.0) GOTO 519 ! Encoder et chercher
GOTO 520      ! Le suivant
53 ICH(IW)=I      ! On connaît le canal
IUN(IW)=IUNIT      ! Enregistrer le LUN
TYPE_MANNEQUIN(IW)=ICON(POSI_MANNEQUIN(IW))
MESS(1:43)='-----> '
MESS(44:80)='XXXXXXXXXXXXXXXXX. Canal# YY. Fic# YY'"

```

```

MESS(44:59)=TROUVE          ! RÈÉcrire le message
ENCODE(2,5,MESS(69:70)) I    ! avec les mèmes donnÈes
ENCODE(2,5,MESS(78:79)) IFOIS !
WRITE(66,707) MESS
C  CALL FUNMCR(MESS)          ! et l'envoyer à 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'entête
C  -----
777  IGO=1
778  CALL PLOTS(0.0,0.0,0)    ! Initialisation de LASERPLOT
      ierr = usfil('CONTACT.X') ! Nom du fichier à produire
      CALL LNXCL              ! 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 ERRST(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 être 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/h³⁾, 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 Kabschull, 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 ≤ 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 ≤ 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	$\leq 2\%$ ^a		92,5% ^b
	Fatal neck injuries	Unknown, but $\leq 3\%$		7,5%
	Fatal (all causes)	3%		100%
Comment		No neck dissections, 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 $MAIS_{AO/C1/C2} \geq k$ neck injury is related to an objective injury index NII_{max} as follows:

$$P(MAIS_{AO/C1/C2} \geq k | NII_{max} = x) = 1 - e^{-\left(\left(\frac{x - \gamma_k}{\eta_k}\right)^{3.5}\right)} \quad (1)$$

where γ_k and η_k are injury risk distribution coefficients to be determined. It is further assumed that this distribution approximates a normal distribution with mean μ_k and standard deviation σ_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 force⁴⁾, $F_C = -\min(F_Z, 0)$;

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 moment⁴⁾, $M_E = -\min(M_Y, 0)$;

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 $I = \{C, T, X, E, F, Z\}$;

α is a coefficient 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 2⁵⁾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 force⁸⁾.

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

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

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

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

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:

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

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

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

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 α coefficient that describes the injury potential for axial forces relative to the injury potential 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 injuries 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 μ_k for riders in fatal accidents may be different from μ_k for injured riders);
- the standard deviation of the injury risk, σ_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 ≥ 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 ≥ 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 μ_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 γ_k and η_k were then calculated from μ_k and σ_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:

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

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:

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

$$I = 0 \quad \text{otherwise.}$$

The total number of computer simulation cases is:

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

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 ,

$$J = \sum_{k=1}^6 J_k \quad (12)$$

where

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

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 $m_{k,0,0,0,0,0,0} = n_{k,0,0,0,0,0,0}$ 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 m_k such that $\chi^2 \leq 3.84$ (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 $MAIS_{AO/C1/C2} \geq k$ injuries and computer simulation cases with $NII_{max} \geq \mu_k$ can be expressed according Table J.4, where μ_k and m_k are to be determined. If NII_{max} is sorted such that $NII_{max,i} \leq NII_{max,i+1}$, for $i = 1$ to 497, then the values for μ_k can be calculated from m_k according to the equation:

$$\mu_k = \sqrt{NII_{max,m_k} NII_{max,m_k+1}} \quad (14)$$

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

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

The best estimate of μ_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 μ_k can be considered the range of values for μ_k such that the portion of cases with $NII_{max} \geq \mu_k$ is not statistically significantly different than the portion of cases with $MAIS_{AO/C1/C2} \geq k$. This

condition is satisfied for $m_k^- \leq m_k \leq m_k^+$ such that $\chi^2 \leq 3,84$, where χ^2 is calculated according to the following equation from Box, et al., (1978).

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

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 μ_4 , μ_5 , and μ_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 $NII_{max} \geq S_k$ 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 ($NII_T(t_{max}) \geq Q_k^* S_k$), compression ($NII_C(t_{max}) \geq Q_k^* S_k$), and/or lateral bending ($NII_X(t_{max}) \geq Q_k^* S_k$) 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.

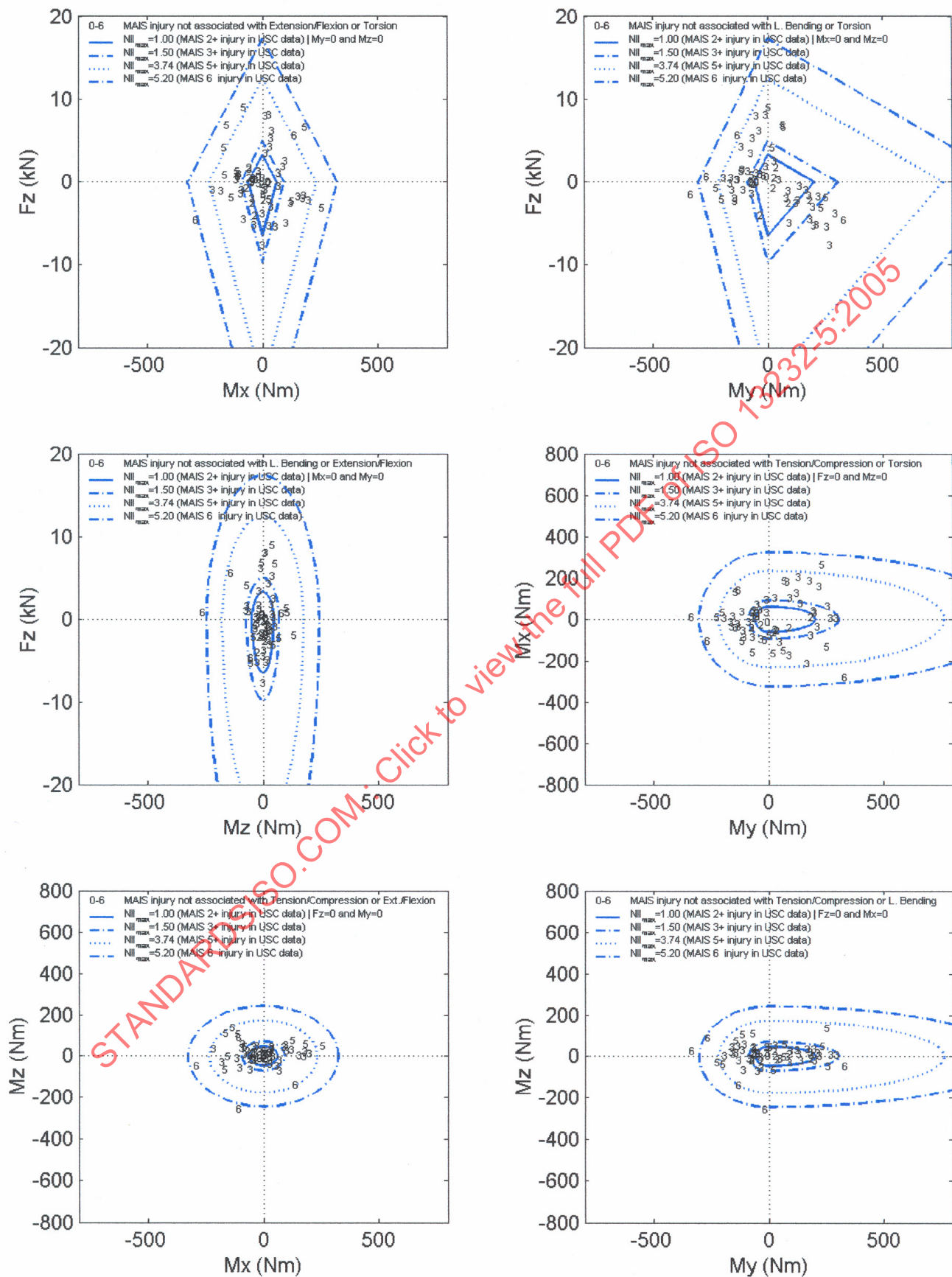


Figure J.1 — Forces and moments at t_{max} from computer simulations of 67 USC fatal cases and the best step-wise fit envelopes of constant NII_{max} , providing the basis for the envelope shape

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 $\text{MAIS} \geq 3$ 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	μ_k	$\sigma_k = 0.2\mu_3$	γ_k	η_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

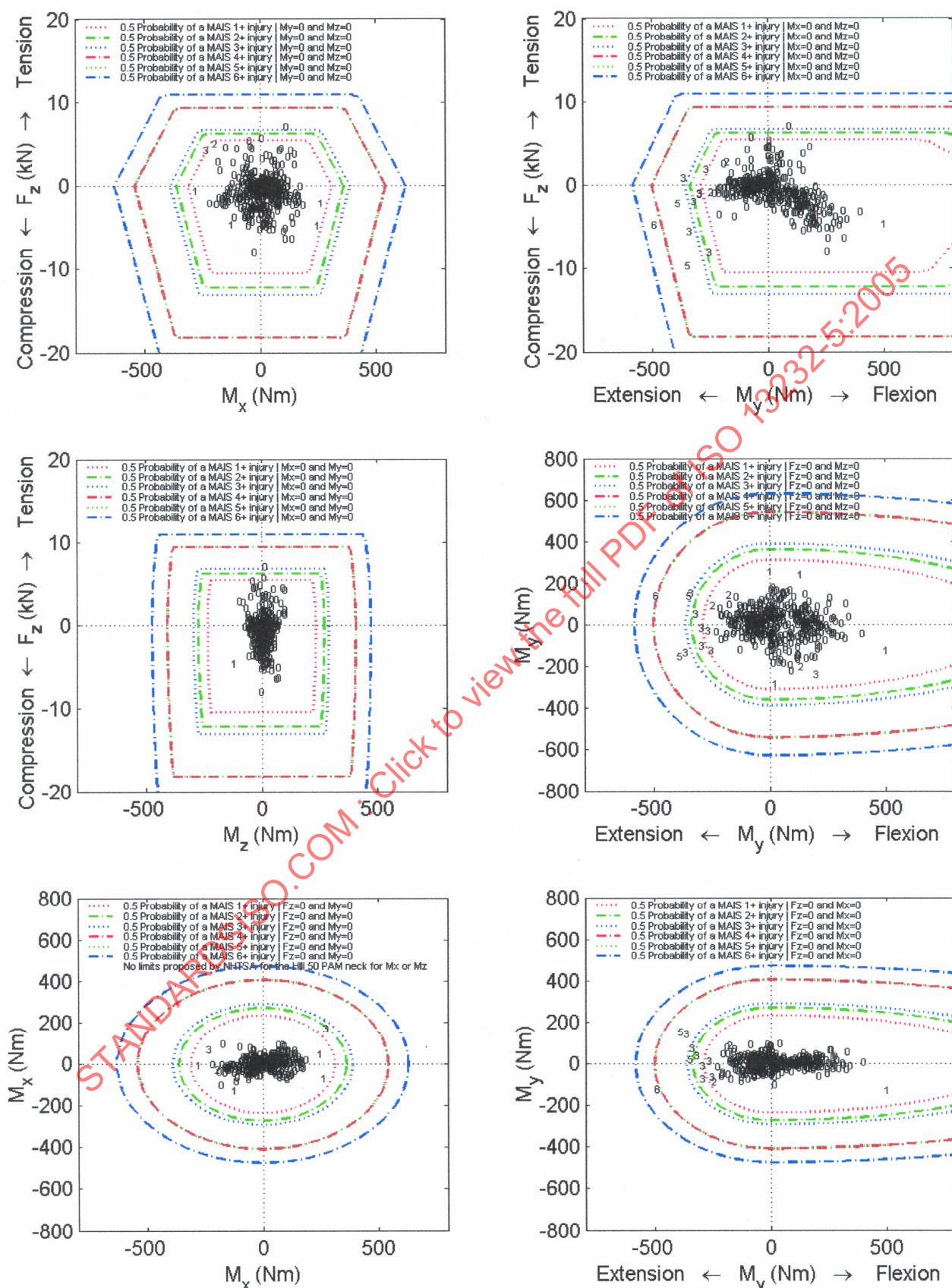


Figure J.2 — Forces and moments at t_{max} from computer simulations of 498 LA and Hannover cases and envelopes of constant NII_{max} , providing the basis for the NII_{max} vs 50% injury probability

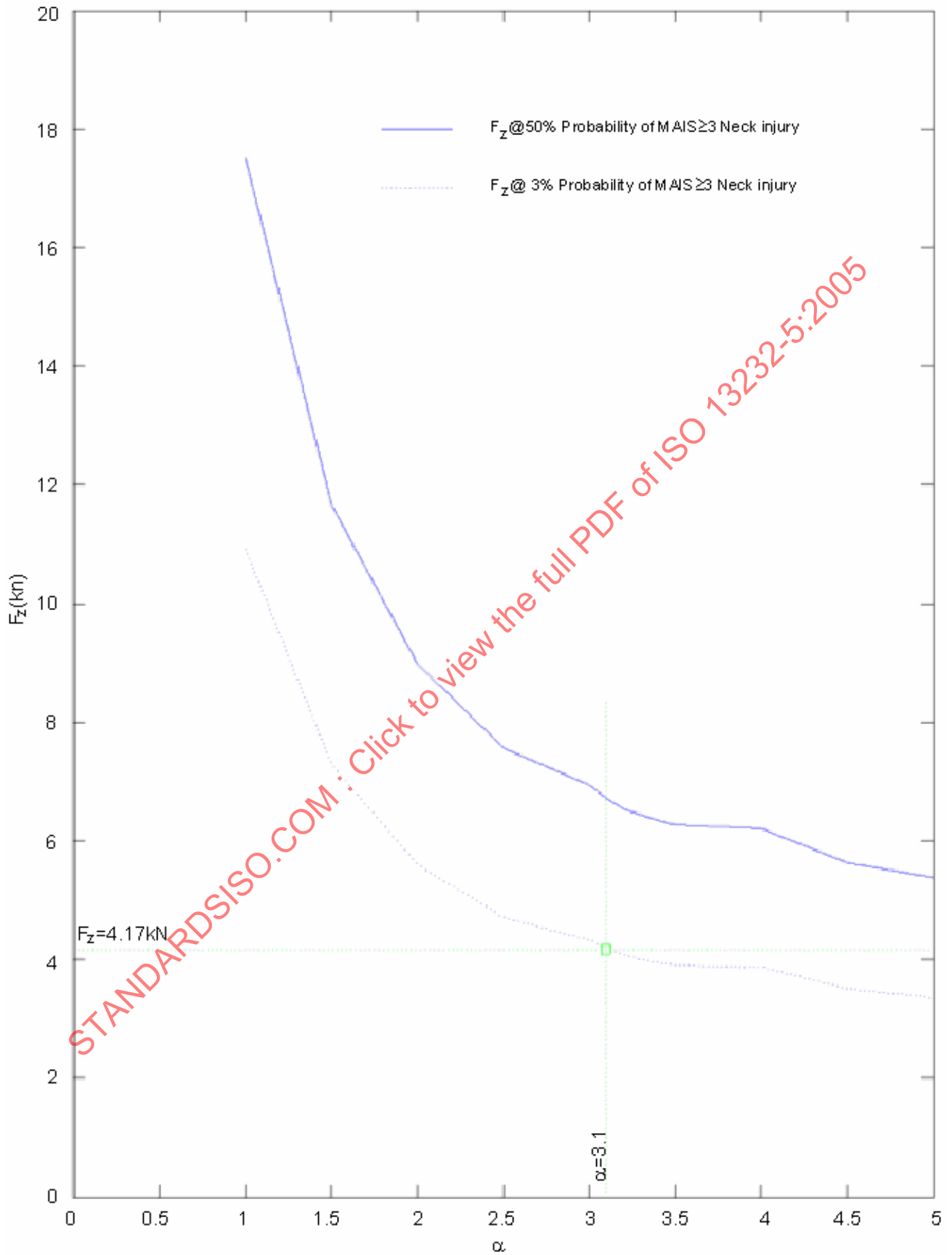


Figure J.3 — Critical tension force vs the α coefficient, providing the basis for the $\alpha = 3.1$

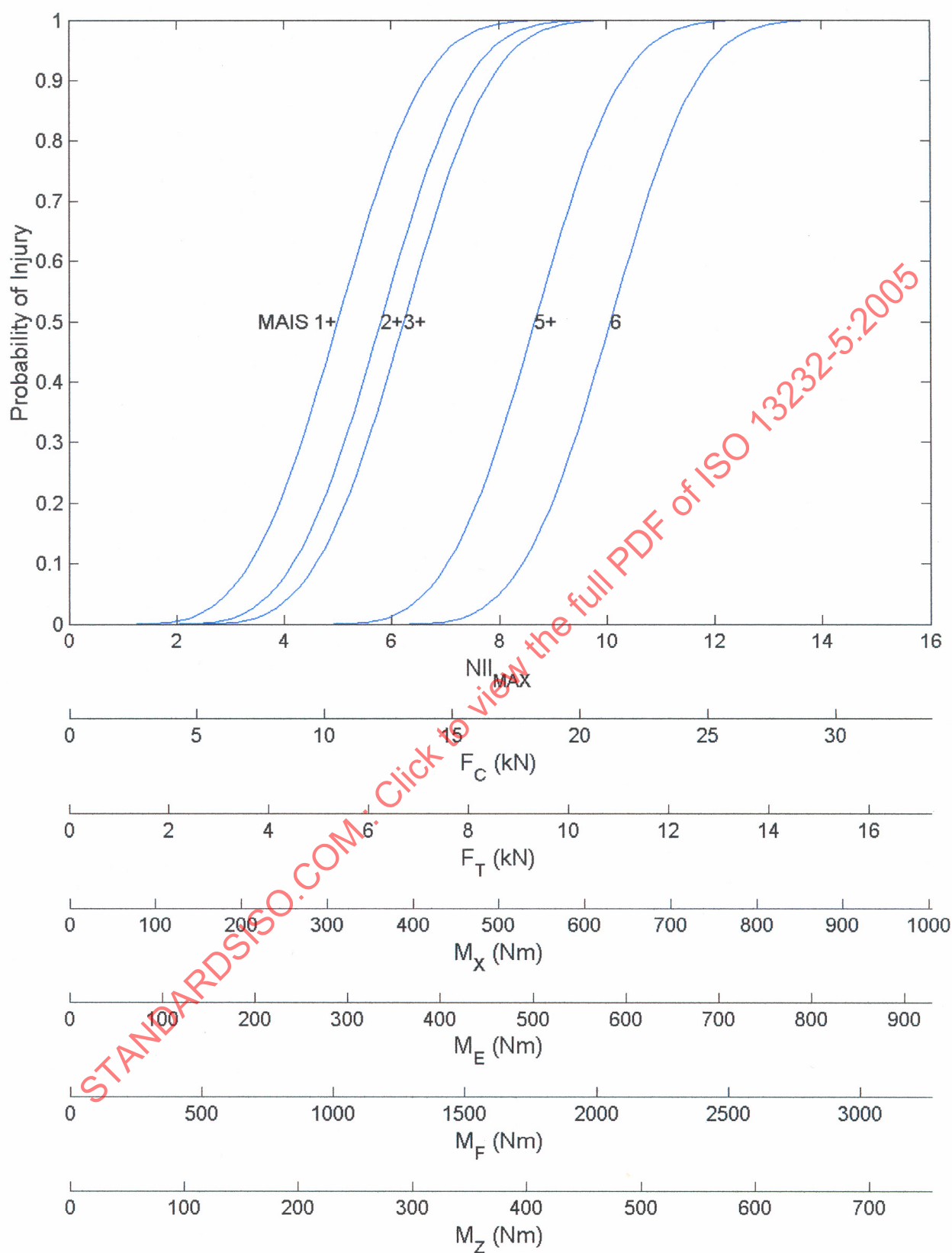


Figure J.4 — Neck AO/C1/C2 injury risk curves for the new MATD neck

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

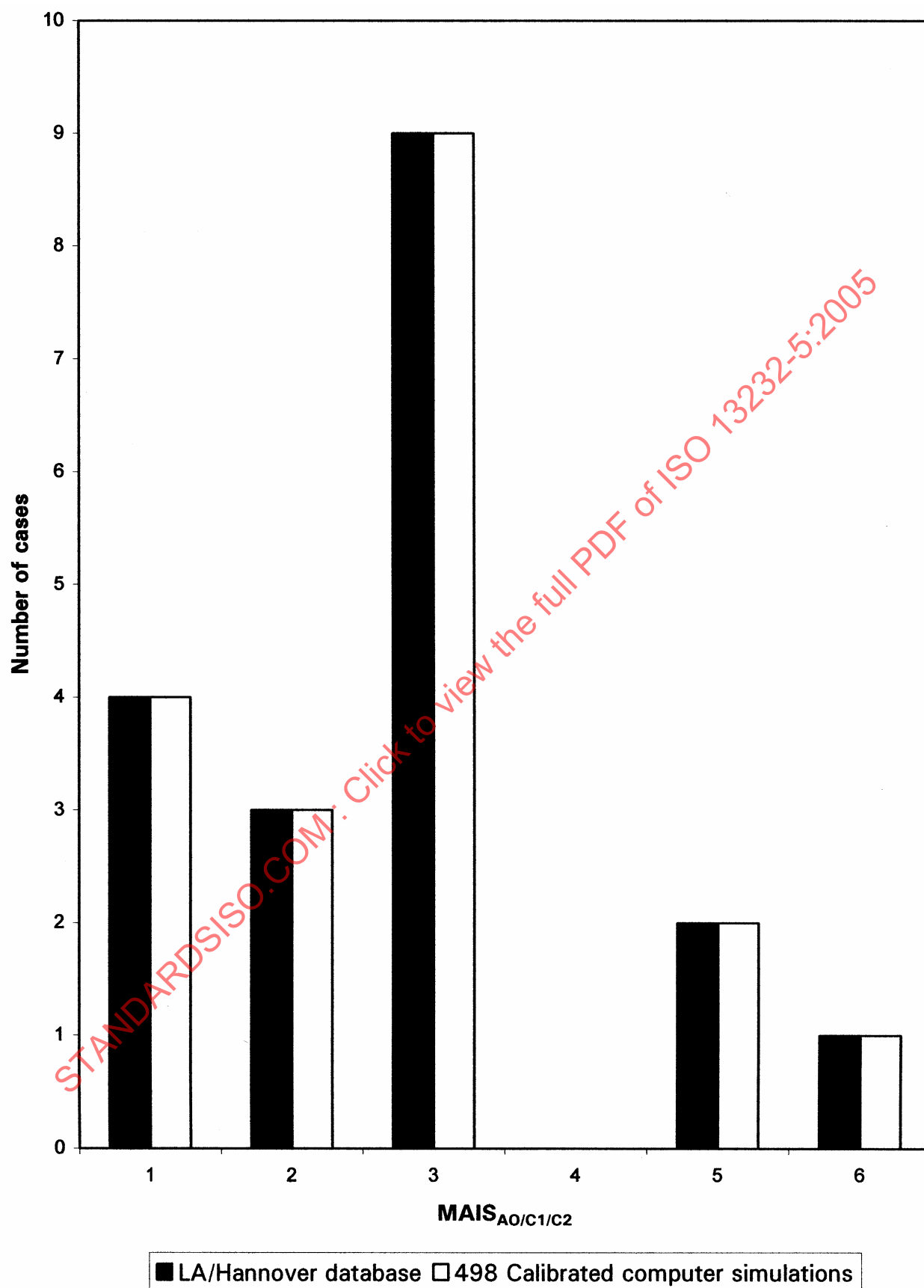


Figure J.5 — Distribution of observed and predicted computer simulations

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 ≥ 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	μ	σ	σ/μ	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^*/α	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) USDOT, NHTSA 00-7013; Notice 1	d
						F_{zc}	6,16	6,16			kN		b		
Tension	AIS 3 +	6,23	1,247	0,20	F_T^*/α	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_3	77,0	70,5		76,4	117,4	Nm
		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.															

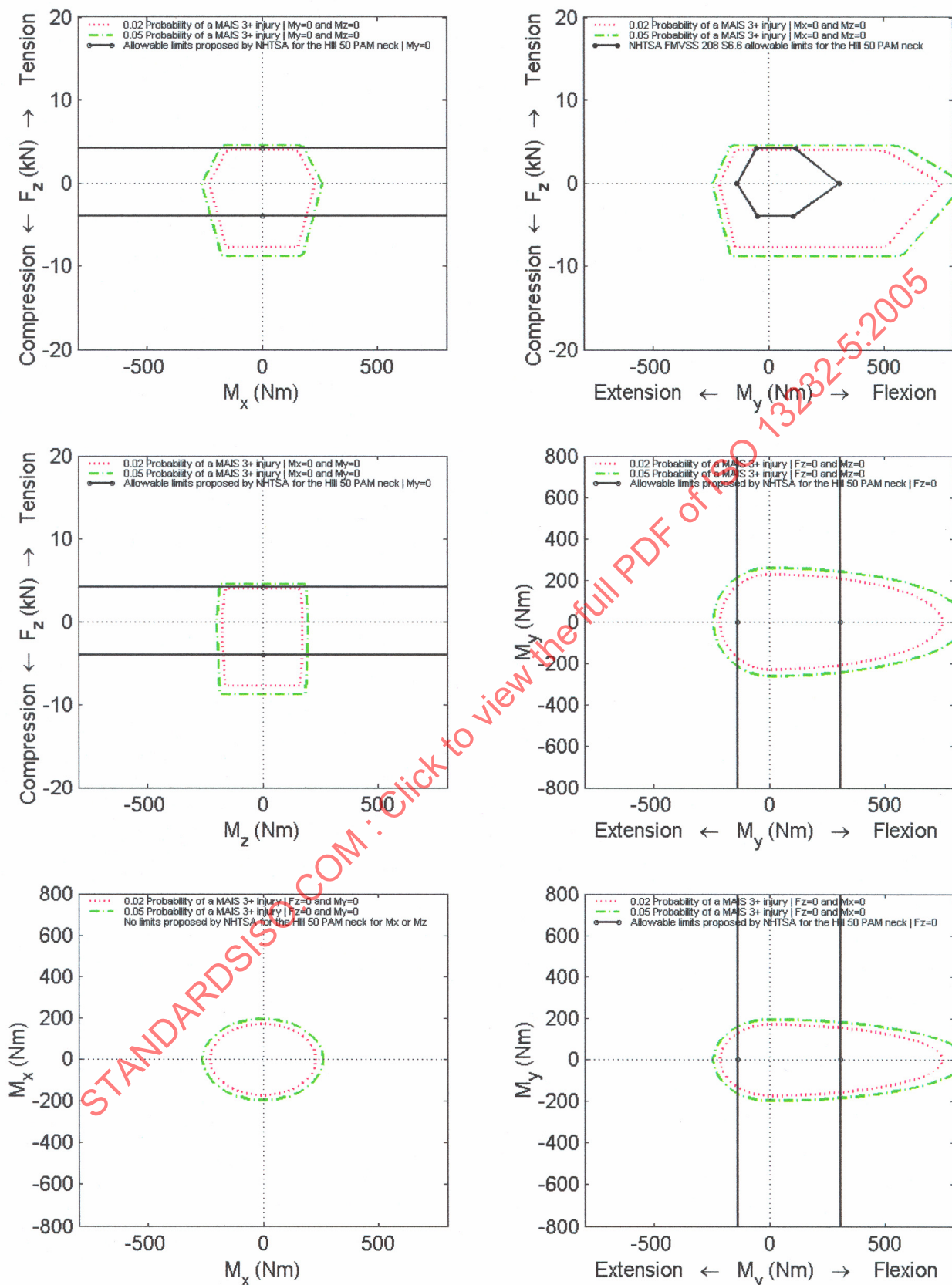


Figure J.6 — Comparison of the general shape and axes of the injury criteria for the new MATD neck to the allowable limits proposed by NHTSA for the Hill 50 PAM neck (recognizing that the necks have very different stiffnesses)

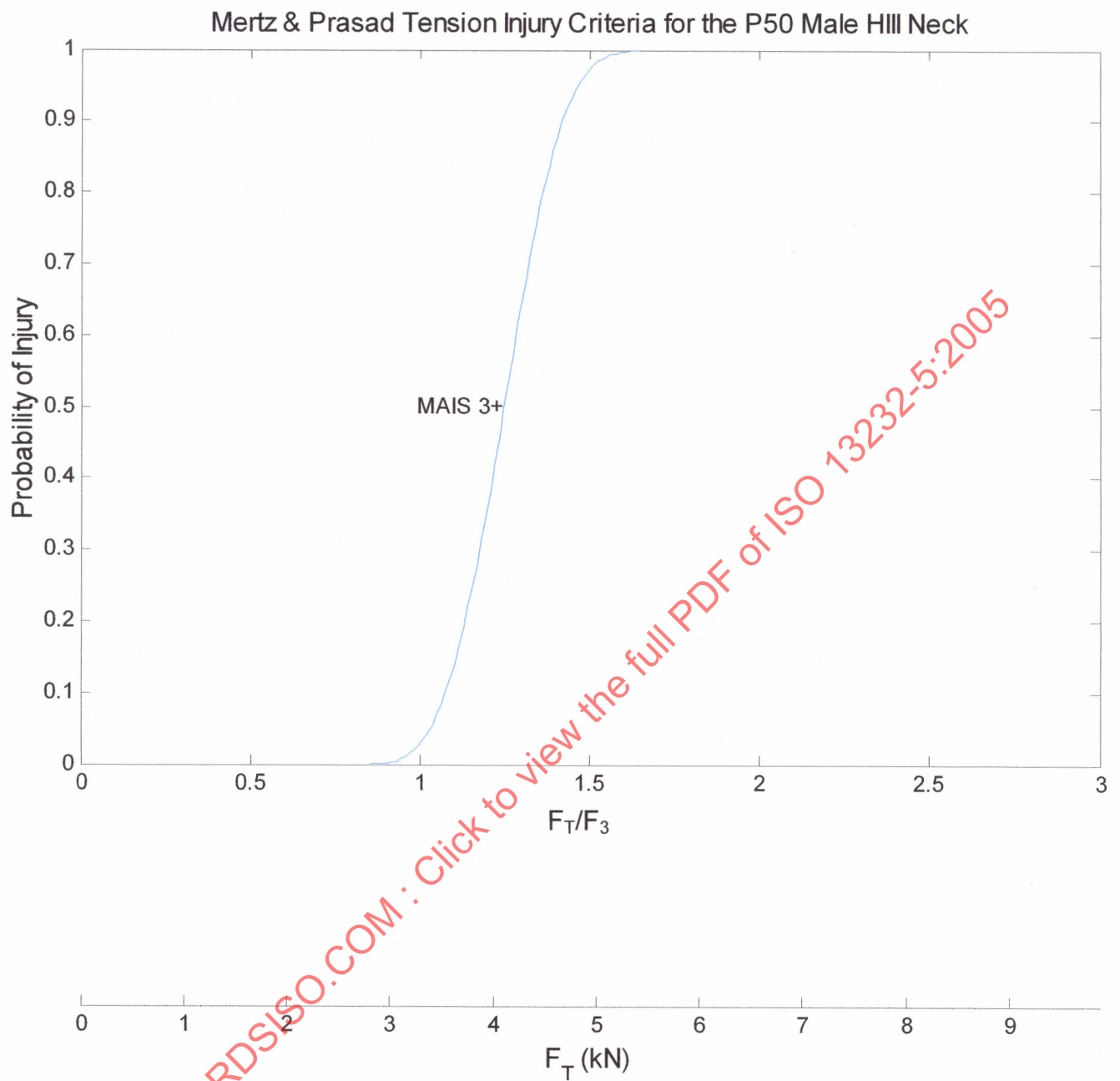


Figure J.7 — Neck AIS 3 + injury risk vs tension for the Hybrid III P50 male neck (Mertz & Prasad 2000)

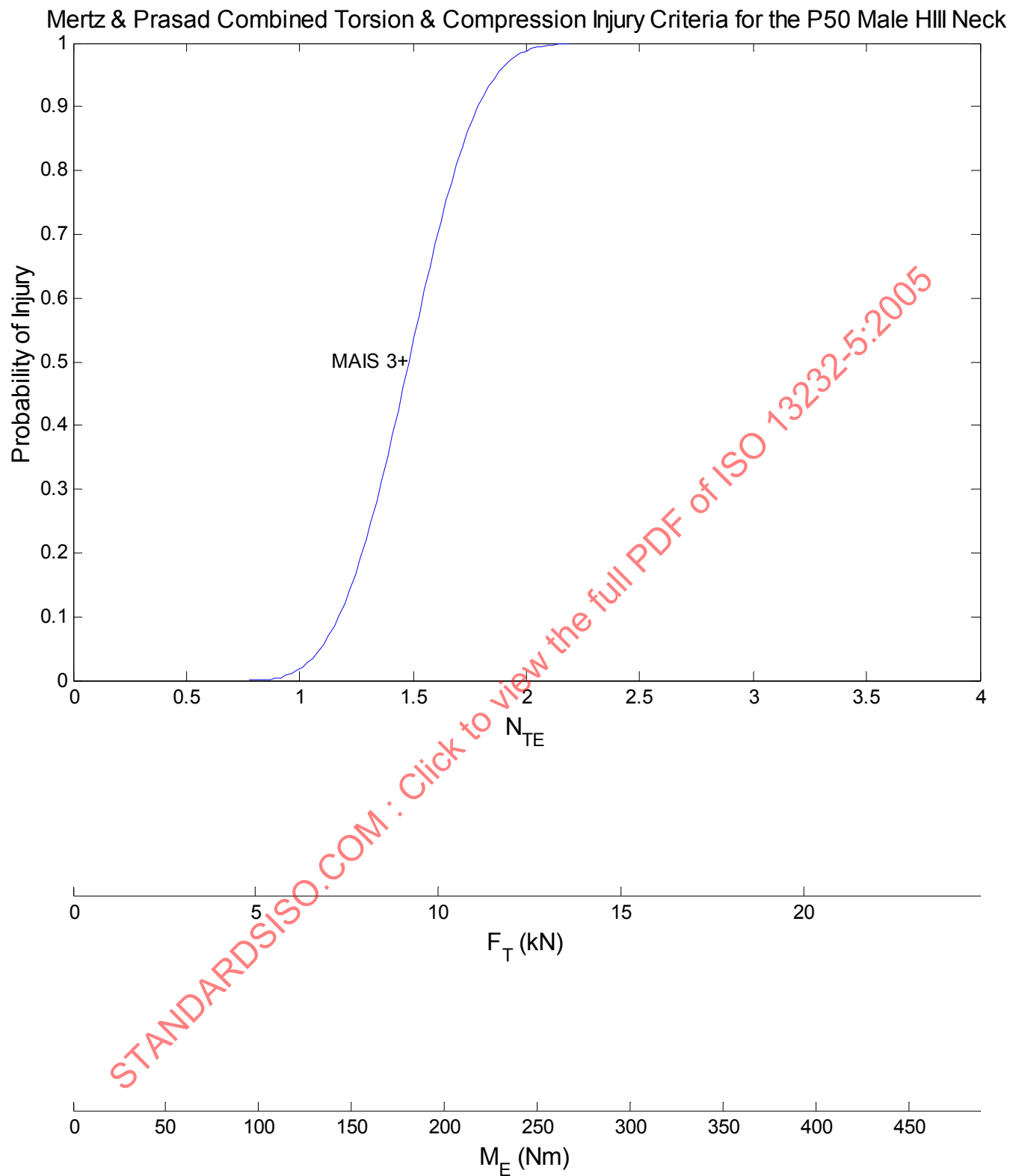


Figure J.8 — Neck AIS 3 + injury risk vs combined tension and extension for the Hybrid III P50 male neck (Mertz & Prasad 2000)

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).

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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)
<i>MAIS</i> _{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%	13	2,61%	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%			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.

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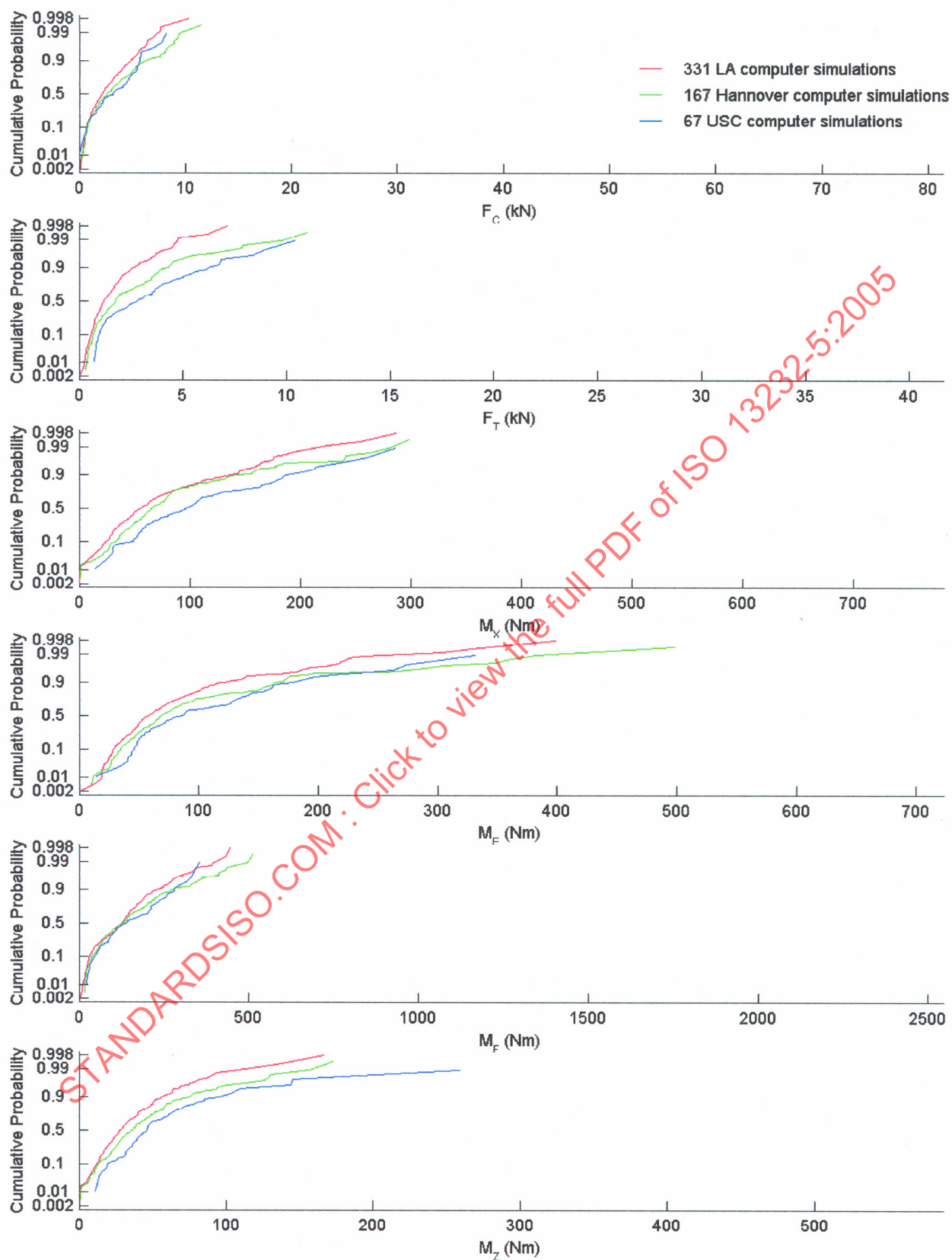


Figure L.1 — Maximum neck force and moment distributions for the new MATD neck (498 LA/Hannover cases and 67 USC fatal cases)

Injury criteria coefficient search algorithm used for neck injury criteria identification