TECHNICAL REPORT

ISO TR 9790-2

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Road vehicles — Anthropomorphic side impact dummy —

Part 2 — Lateral neck impact response requirements to assess biofidelity of dummy

Véhicules routiers — Mannequin anthropomorphe pour essai de choc latéral —

Partie 2 : Caractéristiques de réponse du cou à un choc latéral permettant d'évaluer la biofidélité d'un mannequin

Reference number
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Foreword

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The main task of ISO technical committees is to prepare International Standards. In exceptional circumstances a technical committee may propose the publication of a technical report of one of the following types:

— type 1, when the necessary support within the technical committee cannot be obtained for the publication of an International Standard, despite repeated efforts;

— type 2, when the subject is still under technical development requiring wider exposure;

— type 3, when a technical committee has collected data of a different kind from that which is normally published as an International Standard ("state of the art", for example).

Technical reports are accepted for publication directly by ISO Council. Technical reports of types 1 and 2 are subject to review within three years of publication, to decide whether they can be transformed into International Standards. Technical reports of type 3 do not necessarily have to be reviewed until the data they provide are considered to be no longer valid or useful.

ISO/TR 9790-2, which is a technical report of type 3, was prepared by Technical Committee ISO/TC 22, *Road vehicles*.

ISO/TR 9790 consists of the following parts, under the general title *Road vehicles — Anthropomorphic side impact dummy*:

— *Part 1: Lateral head impact response requirements to assess biofidelity of dummy*

— *Part 2: Lateral neck impact response requirements to assess biofidelity of dummy*

— *Part 3: Lateral thoracic impact response requirements to assess biofidelity of dummy*

— *Part 4: Lateral shoulder impact response requirements to assess biofidelity of dummy*

— *Part 5: Lateral abdominal impact response requirements to assess biofidelity of dummy*

— *Part 6: Lateral pelvis impact response requirements to assess biofidelity of dummy*

Road vehicles — Anthropomorphic side impact dummy —

Part 2 : Lateral neck impact response requirements to assess biofidelity of dummy

1.0 INTRODUCTION

The impact response requirements presented in this Technical Report are the result of a critical evaluation of data selected from experiments agreed to by experts as being the best and most up-to-date information available.

Three lateral neck bending response requirements are defined: one based on the human volunteer data of Ewing et al (1)*, the second based on the human volunteer data of Patrick and Chou (2), and the third based on the cadaver tests of APR (3). An analysis done by Wismans et al (4) is used to define the requirement based on Ewing et al (1) tests. All requirements require the duplication of the respective sled test environments that were used to obtain the human volunteer and/or cadaver data.

2.0 SCOPE AND FIELD OF APPLICATION

This Technical Report is one of six reports that describe laboratory test procedures and impact response requirements suitable for assessing the impact biofidelity of side impact dummies. This Technical Report provides information to assess the biofidelity of lateral neck bending response.

3.0 ISO REFERENCES

ISO DP 9790-1 Road Vehicles - Anthropomorphic Side Impact Dummy - Lateral Head Impact Response Requirements to Assess the Biofidelity of the Dummy.

*Numbers in parentheses designate papers listed in References, Section 7.

ISO DP 9790-3 Road Vehicles - Anthropomorphic Side Impact Dummy - Lateral Thoracic Impact Response Requirements to Assess the Biofidelity of the Dummy.

ISO DP 9790-4 Road Vehicles - Anthropomorphic Side Impact Dummy - Lateral Shoulder Impact Response Requirements to Assess the Biofidelity of the Dummy.

ISO DP 9790-5 Road Vehicles - Anthropomorphic Side Impact Dummy - Lateral Abdominal Impact Response Requirements to Assess the Biofidelity of the Dummy.

ISO DP 9790-6 Road Vehicles - Anthropomorphic Side Impact Dummy - Lateral Pelvis Impact Response Requirements to Assess the Biofidelity of the Dummy.

4.0 REQUIREMENT NO. 1

4.1 Original Data

Ewing et al (1) conducted a series of human volunteer, lateral neck bending tests using their HYGE accelerator. The volunteers were seated on the HYGE sled fixture in nominally upright positions, but facing sideways to the direction of sled travel. They were positioned snugly against a lightly padded wooden board which restricted upper torso rotation and pelvis to sled translation. Both shoulders were restrained by straps. Their pelves were restrained by a lap belt and an inverted V pelvis strap which was tied to the lap belt. They held their heads upright prior to sled accelerations.

The data used for this requirement were taken from an analysis of Wismans et al (4) of 9 tests with 9 subjects. Table 1 summarizes the most important test conditions. The mean sled acceleration-time history (together with standard deviation) for these tests is depicted on the graph of Figure 1.

The most important kinematic test data are summarized below:

4.1.1 T1 Acceleration: Figure 2 presents the mean T1 horizontal acceleration-time history together with standard deviation. The maximum value of this mean acceleration is 15 G.

4.1.2 T1 Displacement: Figure 3 presents the trajectories of the T1 origin with respect to the sled. The mean horizontal displacement is 55 mm and the mean vertical (upward) displacement is 17 mm.

4.1.3 Head C.G. Trajectory: Figure 4 presents the center of gravity trajectories with respect to T1. Rotations of T1 are neglected here; in other words, the X- and Z-axis in this figure are parallel to the laboratory horizontal and vertical axis. Note that all trajectories have been shifted in such a way that they coincide initially. Maximum horizontal and vertical (downward) c.g. displacements are summarized in Table 2. The mean value for the horizontal displacement is 146 mm and for the downward displacement, 79 mm. Table 2 also includes the time of maximum head excursion. The mean value for this time is 0.167 s.

4.1.4 Head C.G. Acceleration: Mean values for the head c.g. acceleration-time histories are shown in Figure 5. Presented are the components in the local head coordinate system (x = + forward, y = + left, z = + upward).

4.1.5 Head Rotation: Table 2 presents the maximum angle of head flexion (i.e. angle between head inferior-superior axis and vertical) and the maximum angle of head twist (i.e. rotation about inferior-superior axis) for each test. For these measurements it is assumed that the T1 target does not rotate.

Mean values for these rotations are 51.8 degrees for flexion and -38.6 degrees for twist.

Most of the above mean data can be used to specify a set of biomechanical response requirements for lateral neck bending and twist.

4.2 Response Requirements

The following are response requirements to be met when the dummy is subjected to the sled test described under Test Set-Up.

4.2.1 The maximum horizontal displacement of T1 with respect to the sled should be between 46 and 63 mm.

4.2.2 The peak horizontal acceleration of T1 should be between 12 and 18 G.

4.2.3 The maximum angular displacement of the inferior-superior axis of the head relative to vertical should be between 44 and 59 degrees (head flexion).

4.2.4 The maximum angle of twist of the head about its inferior-superior axis should be between -32 and -45 degrees.

4.2.5 The maximum head acceleration of the c.g. in the head local coordinate system should be between

8 and 11 G for y-direction (lateral)
8 and 10 G for z-direction (upwards).

4.2.6 The maximum horizontal displacement of the c.g. of the head relative to T1 should be between 130 and 162 mm.

4.2.7 The maximum downward vertical displacement of the c.g. of the head relative to T1 should be between 64 and 94 mm.

4.2.8 The time of maximum head excursion should be between 0.159 and 0.175 s.

4.3 Test Setup

An upright rigid chair, functionally similar to the one used by Ewing et al (1), is to be securely fastened to a HYGE sled in a sideward facing position. A vertical side board is to be rigidly attached to the seat to restrict upper torso rotation and pelvis to seat translation of the dummy. The top of the side board should extend to a level that is 40 mm to 50 mm below the top of the dummy's shoulder level. The dummy is to be seated in the seat in an upright position with its shoulder and hip against the vertical side board. An appropriate belt restraint is to be used to secure the dummy to the seat. The midsagittal plane of the dummy is to be vertical and perpendicular to the direction of sled travel. The anterior-posterior axis of its head is to be horizontal. With this initial position, the dummy is to be subjected to the sled pulse defined by Figure 6. The responses of the dummy are to meet the requirements defined under Response Requirements.

4.4 Instrumentation

The dummy is to be instrumented as follows:

4.4.1 Triaxial accelerometers at the c.g. of the head and chest.

4.4.2 Six-axis neck transducer at the neck to head interface (occipital condyles level) or sufficient accelerometers attached to the head to calculate these reactions.

4.4.3 Uniaxial accelerometer at the base of the neck with its sensitive axis directed laterally.

4.4.4 Photographic targets for measuring head c.g. translation, lateral head rotation, head twist and horizontal translation of the base of the neck.

In addition, sled acceleration is to be measured and sufficient onboard cameras are to be provided to record the required dummy displacements.

All instrumentation is to meet the appropriate SAE J211 filter requirements.

5.0 REQUIREMENT NO. 2

5.1 Original Data

Patrick and Chou (2) conducted a series of human volunteer, lateral neck bending tests using their decelerator sled, WHAM III. A rigid seat with a 15 degree seat back angle was attached to the sled, sideways to the direction of travel. One side of the seat had a rigid, vertically oriented, side support which restricted upper torso rotation and lateral pelvis translation relative to the chair. The volunteer was seated in the chair with his shoulder and hip against the side board. A belt restraint system consisting of cross chest shoulder straps, lap strap, crotch strap and a horizontal chest strap was used to secure the volunteer to the seat. The sled was accelerated gently over a 60 foot distance and then abruptly decelerated at a prescribed constant deceleration level with a hydraulic shock absorber.

The data from the most severe test, SAE 156, will be used to specify the dummy response requirement. In that test, the sled velocity was 5.8 m/s and its constant deceleration level was 6.7 G. Shown in Figure 7 is a graph of the volunteer's internal neck bending moment calculated about the anterior-posterior axis lying in the midsagittal plane of the head at the level of the occipital condyles as a function of the angular displacement of the head relative to the torso. The peak resultant acceleration of the c.g. of the head of the volunteer was 21 G. The peak internal neck reactions at the occipital condyles were:

R-L shear force	=	794 N
Axial force	=	387 N
P-A shear force	=	351 N
M_{A-P}	=	45.2 Nm
M_{I-S}	=	17.4 Nm
M_{R-L}	=	26.2 Nm

The maximum rotation of the S-I axis of the head relative to the torso was 43.2 degrees. Based on these values the following response requirements are defined.

5.2 Response Requirements

The following are response requirements to be met when the dummy is subjected to the sled test described under Test Setup.

5.2.1 The maximum angular displacement of the S-I axis of the head relative to the torso should be between 40 and 50 degrees.

5.2.2 The maximum bending moment about the A-P axis at the level of the occipital condyles should be between 40 and 50 Nm.

5.2.3 The maximum neck twist moment should be between 15 and 20 Nm.

5.2.4 The maximum bending moment about the L-R axis at the level of the occipital condyles should be between 20 and 30 Nm.

5.2.5 The maximum R-L shear force at the level of the occipital condyles should be between 750 and 850 N.

5.2.6 The maximum axial tension force at the level of the occipital condyles should be between 350 and 400 N.

5.2.7 The maximum P-A shear force at the level of the occipital condyles should be between 325 and 375 N.

5.2.8 The maximum resultant acceleration of the c.g. of the head should be between 18 and 24 G.

5.3 Test Setup

A rigid seat with a 15 degree seat back angle and a rigid vertical side board (similar to the seat used by Patrick and Chou [2]) is to be attached securely to a decelerator sled, sideways to the direction of travel. The top edge of the side board is to be within 50 to 75 mm of the top of the dummy's shoulder. A restraint system is to be provided to secure the dummy to the chair, including arms and legs. The dummy is to be placed in the seat with its shoulder and hip against the side board. The midsagittal plane of the dummy is to be vertical and perpendicular to the direction of sled travel. The anterior-posterior axis of the dummy's head is to be horizontal. After the restraint system is securely fastened about the dummy, the sled is to be accelerated gently to a speed of 5.8 m/s without disturbing the dummy's position and then decelerated abruptly to zero velocity at a constant deceleration level of 6.7 G. Variations in sled velocity of 0.2 m/s and constant deceleration of 0.3 G are permitted. An accelerator type sled can be used if the appropriate sled kinematics can be obtained. The responses of the dummy are to meet the requirements described previously.

5.4 Instrumentation

The dummy is to be instrumented as follows:

5.4.1 Triaxial accelerometer at the c.g. of the head.

5.4.2 Six-axis neck transducer at the neck to head interface (occipital condylar level) or sufficient accelerometers attached to the head to calculate these reactions.

5.4.3 Photographic targets for measuring specified head motion.

In addition, sled acceleration is to be measured and sufficient onboard cameras are to be provided to record the required dummy motions. All instrumentation is to be consistent with the appropriate SAE J211 requirements.

6.0 REQUIREMENT NO. 3

6.1 Original Data

Tarriere (3) conducted four high G-level cadaver tests to obtain data that could be used to define human lateral neck bending response in a test environment of greater severity than used for human volunteer testing. A summary of the sled kinematics and cadaver responses is given in Table 1. Unfortunately, each test had an abnormality. The cadaver's neck was fractured in Test MS 249. The cadaver was not initially against the side board in Test MS 297. The cadaver's humerus was fractured in Test MS 360. The shoulder straps were not fastened in Test MS 361. Tarriere selected Test MS 249 as being the most appropriate test to use for defining a set of high-G response requirements. Based on ratios of cadaver response compared to volunteer response obtained for low G-sled tests, the cadaver data for maximum horizontal and vertical head displacement and peak head flexion and torsion angles were modified by Tarriere to reflect human response. These values were 205.8 mm, 102.9 mm, 68.6 degrees, 68.6 degrees, respectively. No corrections were made to the head or T1 accelerations.

6.2 Response Requirements

The following response requirements are to be met when the dummy is subjected to the sled test described under Test Setup.

6.2.1 The peak lateral acceleration of T1 should be between 17 and 23 G. In addition, the lateral acceleration profile of T1 should lie within the envelope shown in Figure 8.

6.2.2 The peak lateral acceleration of the head c.g. should be between 25 and 47 G.

6.2.3 The maximum horizontal displacement of the head c.g. relative to the sled should be between 185 and 226 mm.

6.2.4 The maximum head flexion should be between 62 and 75 degrees.

6.2.5 The maximum head torsion should be between 62 and 75 degrees.

Note:

It may be difficult to develop a dummy neck that meets Requirements 1 and 2 which are based on human volunteer data as well as the above requirements which are based on cadaver tests where the neck was fractured.

6.3 Test Setup

An upright rigid chair, functionally similar to the one used by Ewing et al (1), is to be securely fastened to a HYGE sled in a sideward facing position. A vertical side board is to be rigidly attached to the seat to restrict upper torso rotation and pelvis to seat translation of the dummy. The top of the side board should extend to a level that is 40 mm to 50 mm below the top of the dummy's shoulder level. The dummy is to be seated in the seat in an upright position with its shoulder and hip against the vertical side board. An appropriate belt restraint is to be used to secure the dummy to the seat. The midsagittal plane of the dummy is to be vertical and perpendicular to the direction of sled travel. The anterior-posterior axis of its head is to be horizontal. With the dummy in this position, the sled is to be subjected to an acceleration which lies within the corridors shown in Figure 9 with a velocity change of 22 $\pm$ 0.5 km/h.

6.4 Instrumentation

The dummy should be instrumented as follows:

6.4.1 Triaxial accelerometers at c.g. of head and thoracic spine in region of T1.

6.4.2 Six-axis neck transducer at head/neck interface (occipital condylar level) or sufficient head accelerometers to calculate these reactions.

6.4.3 Photographic targets for measuring head c.g. translation, lateral head rotation, head twist and T1 translation.

In addition, sled acceleration is to be measured and sufficient cameras are to be provided to record the required dummy displacements. All instrumentation is to meet the appropriate SAE J211 filter requirements.

7.0 REFERENCES

1. Ewing, C. L., Thomas, D. J., Majewski, P. L., Black, R., and Lustik, L., "Measurement of Head, T1, and Pelvic Response to -Gx Impact Acceleration", SAE 770927, Twenty-First Stapp Car Crash Conference, Oct. 1977.

2. Patrick, L. M. and Chou, C. C., "Response of the Human Neck in Flexion, Extension and Lateral Flexion", Final Report VRI-7.3, Society of Automotive Engineers, Warrendale, PA, April 1976.

3. Tarriere, C., "Proposal for Lateral Neck Response Requirements for Severe Impact Conditions", ISO/TC22/SC12/WG5 Document N166-Draft 1, May 1986.

4. Wismans, J., Van Oorschot, H. and Woltring, J. H., "Omni-Directional Head-Neck Response", SAE 861893, Thirtieth Stapp Car Crash Conference, Oct. 1986.

TABLE 1: SUMMARY OF TEST CONDITIONS FOR LATERAL NECK BENDING TESTS OF EWING ET AL (1)

Subject	Test Number	Peak Sled Acceleration (G)	Rate of Onset (G/s)	Sled Velocity (m/s)
H00133	LX4125	7.2	164	7.02
H00134	LX4126	7.1	167	6.90
H00135	LX4131	7.3	164	6.94
H00136	LX4153	7.1	157	6.86
H00138	LX4129	7.2	162	6.92
H00139	LX4133	7.2	165	6.91
H00140	LX4130	7.1	161	6.89
H00141	LX4134	7.1	161	6.85
H00142	LX4135	7.2	161	6.87

TABLE 2: HEAD C.G. DISPLACEMENTS (X AND Z) WITH RESPECT TO T1, TIME OF MAXIMUM C.G. EXCURSIONS AND MAXIMUM FLEXION AND TORSION ANGLES

Test Number	Subject	X-max (m)	Time (s)	Z-max (m)	Flexion* (deg)	Torsion* (deg)
LX4125	H00133	0.137	0.174	0.068	52.3	-26.4
LX4126	H00134	0.129	0.166	0.072	49.5	-39.8
LX4129	H00138	0.168	0.172	0.100	57.3	-38.2
LX4130	H00140	0.155	0.166	0.079	41.7	-40.2
LX4131	H00135	0.122	0.168	0.061	41.7	-35.6
LX4133	H00139	0.134	0.148	0.070	67.6	-33.2
LX4134	H00141	0.158	0.170	0.106	51.6	-42.8
LX4135	H00142	0.152	0.177	0.080	52.2	-42.3
LX4153	H00136	0.157	0.166	0.076	52.3	-49.3
Mean		0.146	0.167	0.079	51.8	-38.6
Standard Deviation		0.016	0.008	0.015	7.8	6.5

* T1 is assumed here not to rotate

TABLE 3: RESULTS OF HIGH G-LEVEL CADAVER TESTS OF TARRIERE (3)

	TESTS			
	MS 249	MS 297	MS 361	MS 360
PEAK SLED DECELERATION - G	12.2	14.2	14	14.6
INITIAL SLED VELOCITY - m/s	6.08	6.19	6.25	8.61
PEAK HORIZONTAL ACCELERATION AT T1 LEVEL - G	20	44	31.5	34.4
PEAK HORIZONTAL ACCELERATION OF THE HEAD C.G. - G	36	17.3	8.2	9.7
HEAD LATERAL FLEXION - DEG.	78	36	59	78
PEAK HEAD TORSION - DEG.	42	30	70	102
MAXIMUM HORIZONTAL DISPLACEMENT OF THE HEAD C.G. RELATIVE TO THE SLED - mm	294	445	260	415
MAXIMUM VERTICAL DISPLACEMENT OF THE HEAD C.G. RELATIVE TO THE SLED - mm	79	78	64	110
MAXIMUM HORIZONTAL VELOCITY OF THE HEAD C.G. RELATIVE TO THE SLED - m/s	4.3	5.3	4.8	5.7

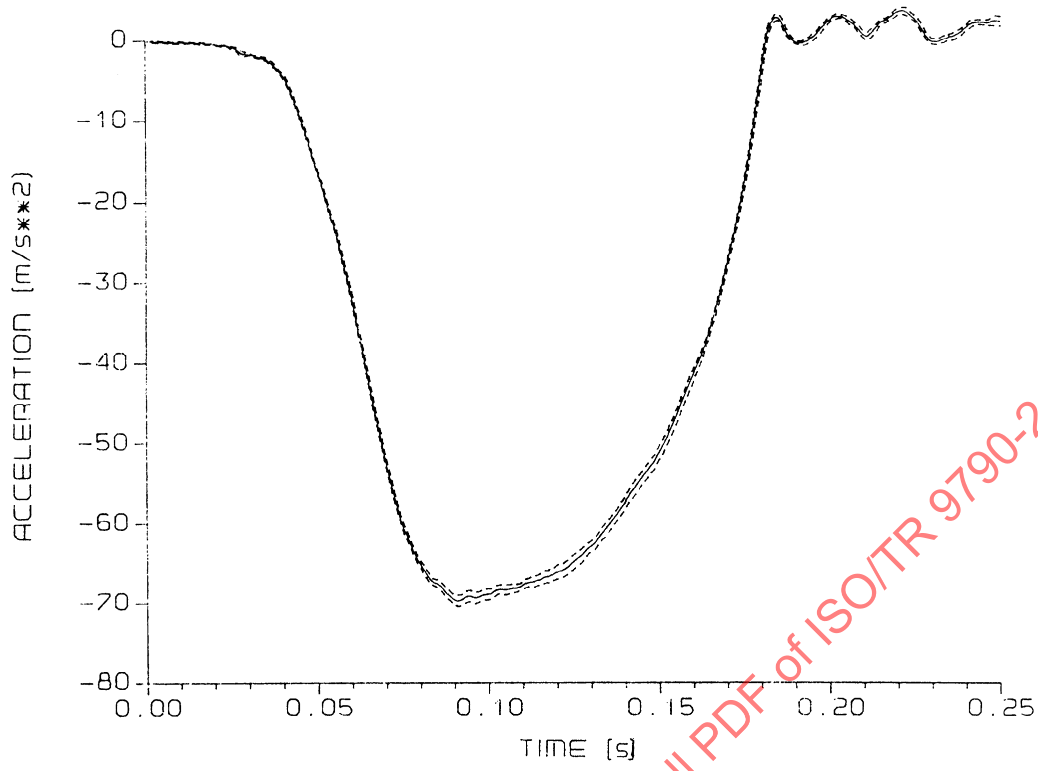

Fig. 1 Mean sled acceleration-time history
(—— mean value; ---- standard deviation)

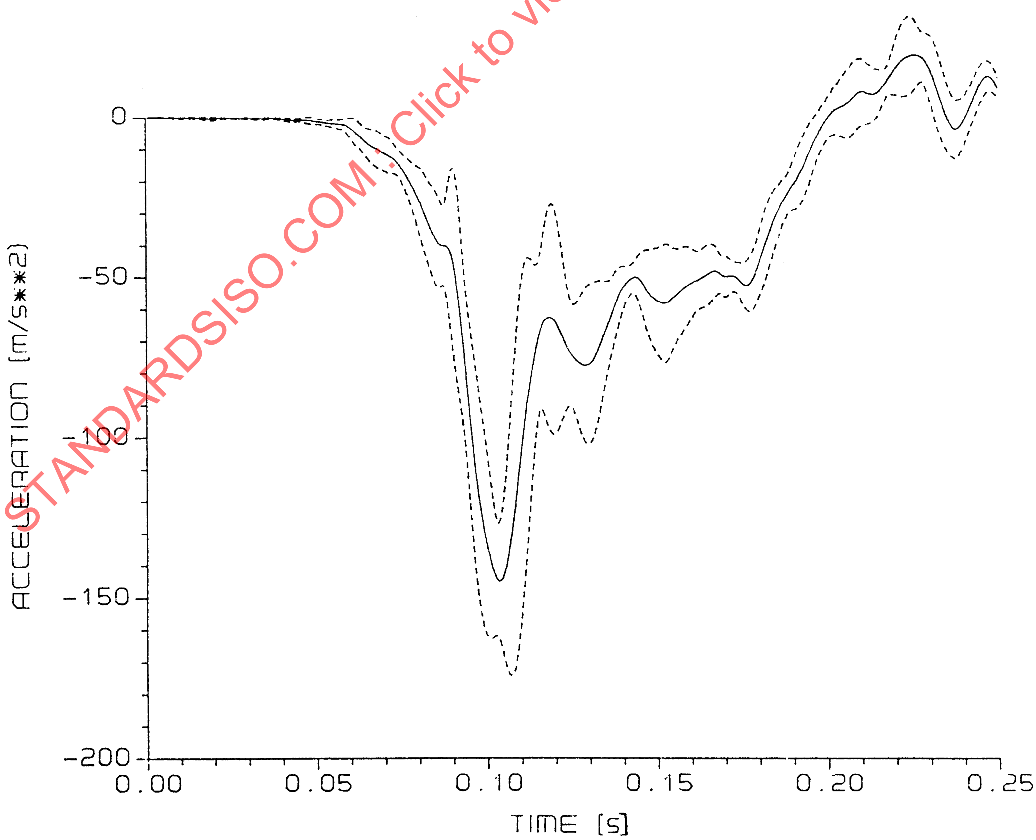

Fig. 2 Mean horizontal T1 acceleration-time history)
(—— mean value; --- standard deviation)

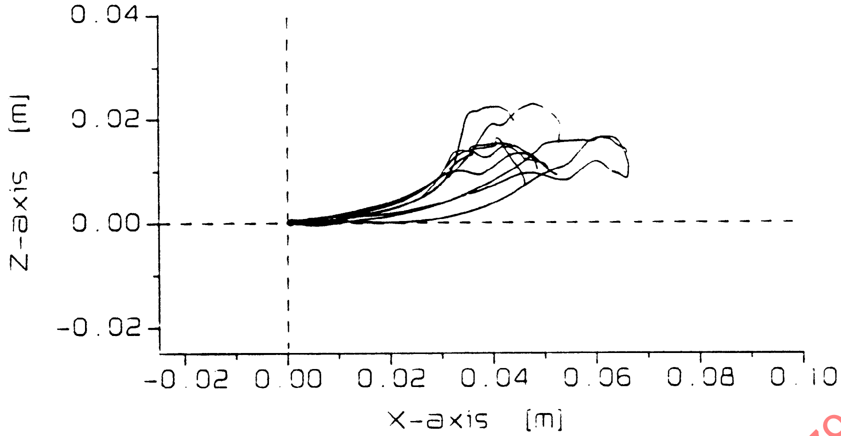

Fig. 3 T1 origin trajectories with respect to sled

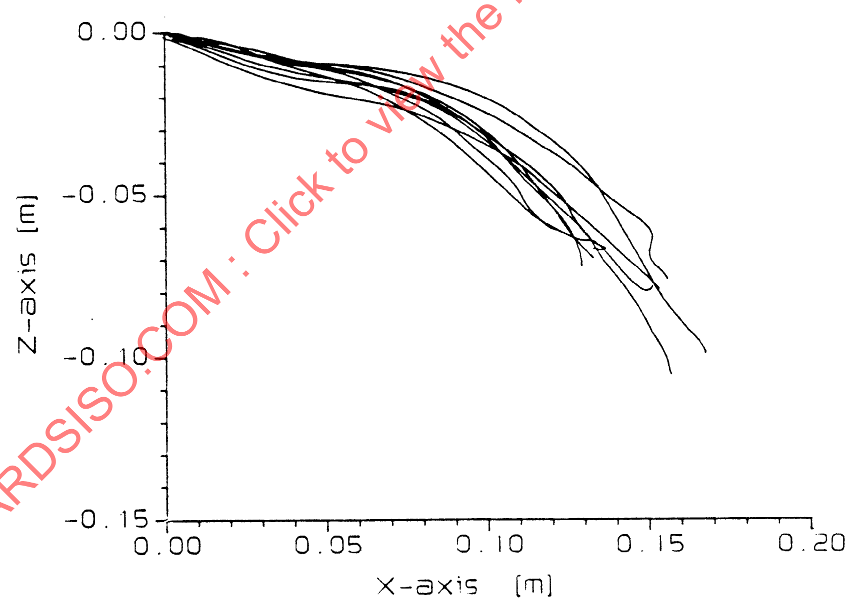

Fig. 4 Head c.g. trajectories with respect to T1
(T1 rotations are neglected)

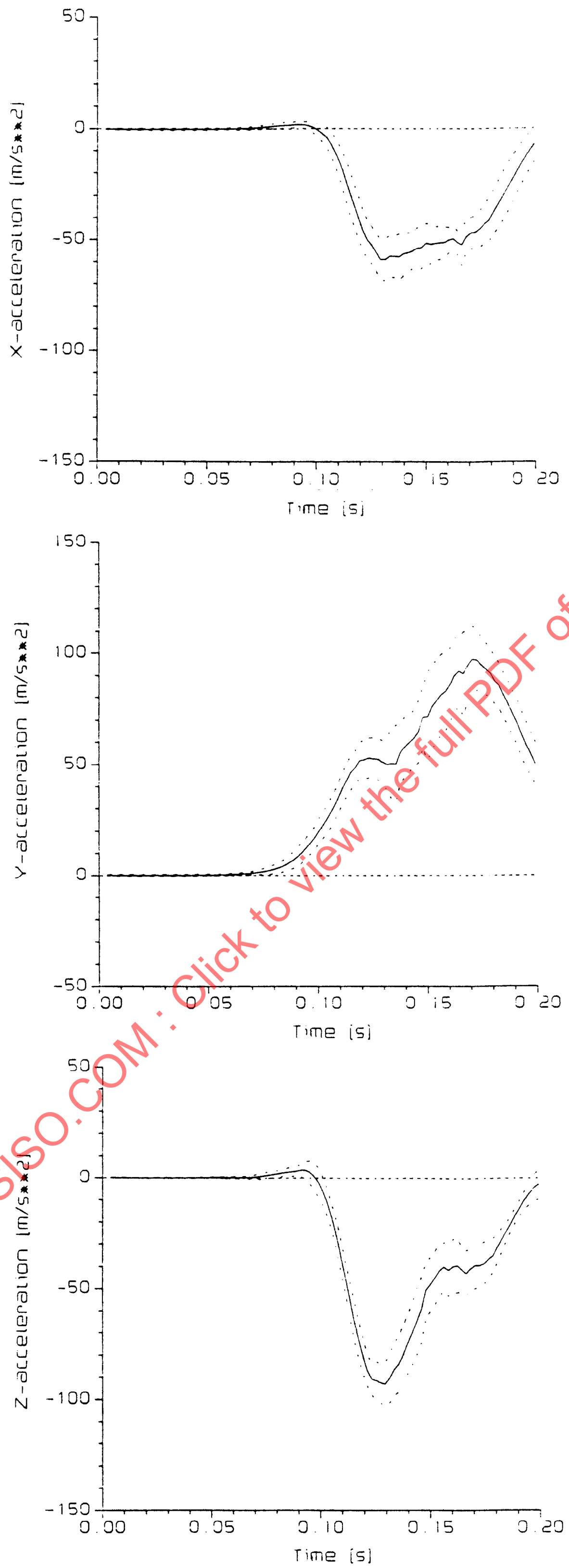

Fig. 5 Mean head c.g. acceleration-time histories: components in head local x, y and z direction

(——mean value;·—·—standard deviation)

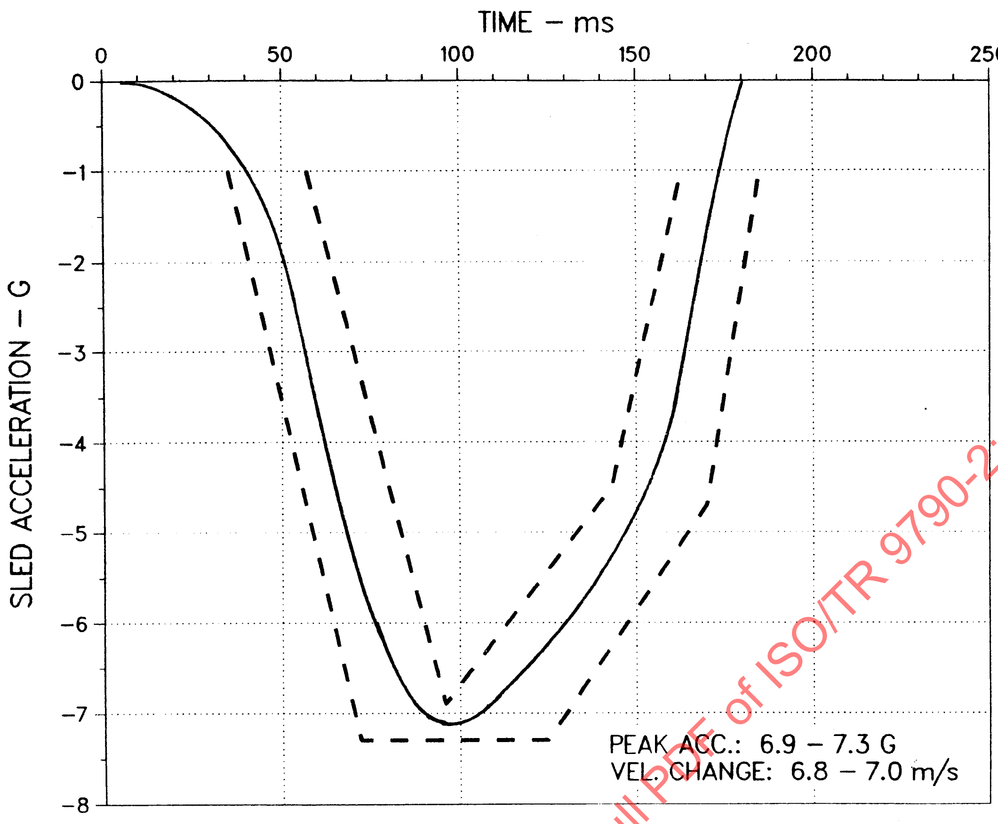

FIGURE 6. SLED PULSE ENVELOPE

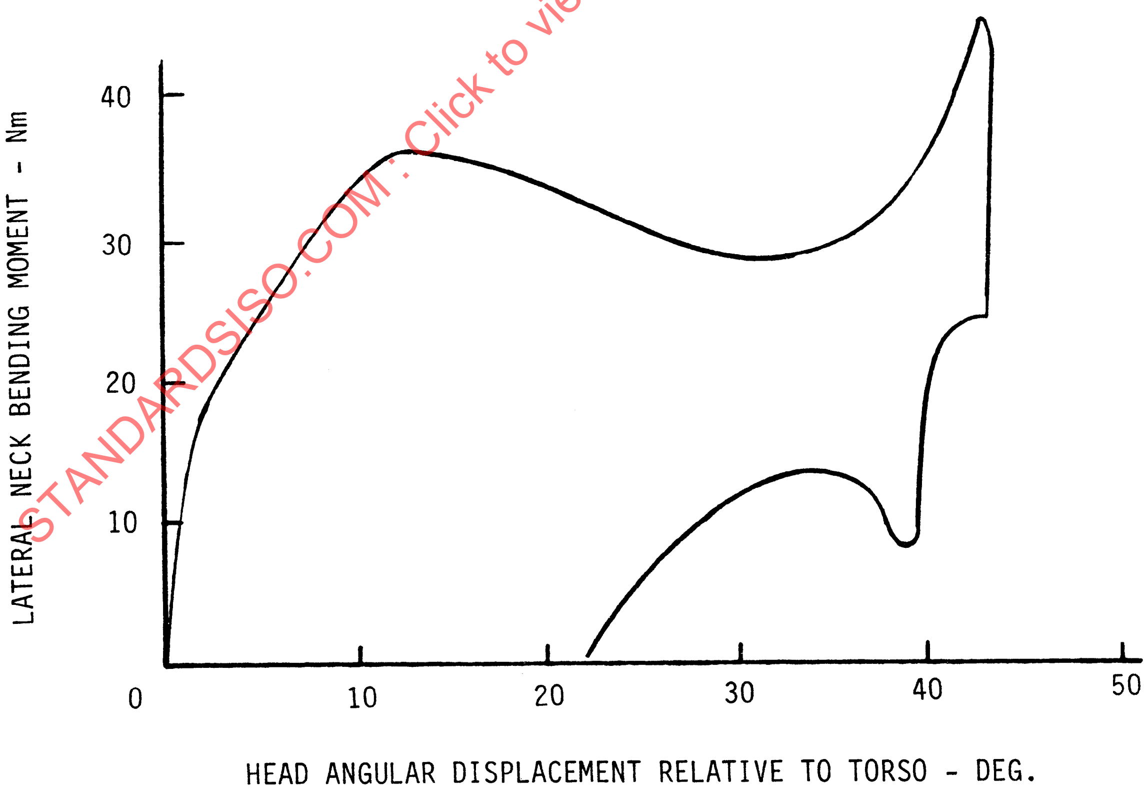

FIGURE 7. LATERAL NECK BENDING MOMENT MEASURED AT THE OCCIPITAL CONDYLES AS A FUNCTION OF THE HEAD ANGULAR DISPLACEMENT RELATIVE TO THE TORSO FOR HUMAN VOLUNTEER KJD, TEST SAE 156 (2).