TECHNICAL REPORT

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Road vehicles — Anthropomorphic side impact dummy — Lateral impact response requirements to assess the biofidelity of the dummy

Véhicules routiers — Mannequin anthropomorphe pour essai de choc latéral — Exigences de réponse en choc latéral pour évaluer la biofidélité du mannequin

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Contents

Foreword

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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.

In exceptional circumstances, 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), it may decide by a simple majority vote of its participating members to publish a Technical Report. A Technical Report is entirely informative in nature and does not have to be reviewed until the data it provides are considered to be no longer valid or useful.

Attention is drawn to the possibility that some of the elements of this Technical Report may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO/TR 9790, was prepared by Technical Committee ISO/TC 22, *Road vehicles*, Subcommittee SC 12, *Restraint systems*.

This first edition cancels and replaces the ISO/TR 9790 parts 1 to 6 (1989), which have been reviewed, updated and organized into a single Technical Report.

Road vehicles — Anthropomorphic side impact dummy — Lateral impact response requirements to assess the biofidelity of the dummy

1 Scope

This Technical Report describes laboratory test procedures and impact response requirements suitable for assessing the lateral impact biofidelity of the head, neck, shoulder, thorax, abdomen and pelvis of crash test dummies, subcomponent test devices, and math models that are used to represent a 50th percentile adult male. The method used by ISO to determine an overall biofidelity rating for a given side impact surrogate has been added to this Technical Report.

2 Biomechanical basis

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. The following describes the biomechanical data used to describe response requirements for the head, neck, shoulder, thorax, abdomen and pelvis.

2.1 Head Tests

Two lateral head impact tests are defined. Head Test 1 is based on the rigid surface cadaver impacts conducted by Hodgson and Thomas (1). Head Test 2 is based on the padded surface cadaver impacts of the Association Peugeot-Renault (APR) (2). Padded surface impact tests of Hodgson and Thomas (1), McElhaney et al. (3), Nahum et al. (4), Nahum et al. (5), Schneider et al. (6) and Got et al. (7) were not used since either the padding characteristics were not specified or a given piece of padding was subjected to multiple impacts, changing its response characteristics. Detailed discussions of the influences of these factors on head acceleration data are given by Mertz (8), Mertz et al. (9) and Mertz (10). The rigid surface impacts of McElhaney et al. (3) were not used because the impact velocities were not given for each test. The rigid surface impact data of Got et al. (7) were not used since significant skull fractures were produced.

2.2 Neck Tests

Three lateral neck bending tests are defined. Neck Test 1 is based on the human volunteer data of Ewing et al. (11), and the requirements are based on the analysis of Wismans et al. (12). Neck Test 2 is based on the human volunteer data of Patrick and Chou (13). Neck Test 3 is based on the cadaver tests of the APR (2). To evaluate if the biofidelity requirements are met, the respective sled test environments that were used to obtain the human volunteer and/or cadaver data must be duplicated.

2.3 Shoulder Tests

Four lateral impact test conditions are defined for the shoulder. Shoulder Test 1 is based on impactor tests conducted by the APR using unembalmed cadavers (14). Shoulder Test 2 is based on the Ewing et al. (11) volunteer sled tests. Shoulder Test 3 is based on the cadaver sled tests of Tarriere (30). In both of these sled tests, the dummy must mimic the shoulder reaction with the rigid vertical side board in order for the kinematics of its upper thoracic spine to meet the T1 response requirements. Shoulder Test 4 is based on the cadaver sled tests of Wayne State University (WSU) (15, 16). Shoulder response data from the APR and WSU were normalized to

represent the response characteristics of a 50th percentile adult male using the method described by Mertz (17). No adjustments were made to the cadavers' responses to account for muscle tone.

2.4 Thorax Tests

Six lateral thoracic impact test conditions are defined. Thorax Tests 1 and 2 are based on cadaver impactor tests conducted by the Highway Safety Research Institute (HSRI) (18) and WSU (19). Thorax Tests 3 and 4 are based on the cadaver drop tests of the APR (20, 21, 22). Thorax Test 5 is based on cadaver sled tests of the University of Heidelberg (23). Thorax Test 6 is based on cadaver sled tests of WSU (15, 16). All thoracic data were normalized to represent the response characteristics of a 50th percentile adult male using either the method described by Mertz (17) or an extension of the method developed by Lowne (24). The force versus time response corridors for Thorax Tests 1 and 2 were constructed around the normalized cadaver curve and then shifted 700 N upward to account for muscle tone. The force versus time response corridors of Thorax Tests 3 - 6 were not adjusted to account for muscle tone. Cadavers with more than 5 rib fractures were not used in defining the response requirements, except for Thorax Test 5 where results from cadavers with 2, 7 and 9 fractured ribs were all used.

2.5 Abdomen Tests

Five lateral abdominal impact test conditions are defined. Abdomen Tests 1 and 2 are based on the lateral cadaver drop tests conducted by the APR (25, 14). Abdomen Tests 3 - 5 are based on cadaver sled tests of WSU (16). All data were normalized to represent the responses of a 50th percentile adult male using the method described by Mertz (17).

2.6 Pelvis Tests

Thirteen lateral pelvic impact test conditions are defined. Pelvis Tests 1 and 2 are based on impactor tests of ONSER (26, 27, and 28). Pelvis Tests 3 - 6 are based on free fall cadaver tests of the APR (29). Pelvis Tests 7 - 9 are based on cadaver sled tests of the University of Heidelberg (23). Pelvis Tests 11 - 13 are based on cadaver sled tests of WSU (16). All pelvic data were normalized to represent the responses of a 50th percentile adult male using the method described by Mertz (17).

Note that it may be difficult to develop a dummy that meets all of the prescribed requirements. For example, some of the neck response requirements are based on the responses of volunteers, while others are based on the response of a cadaver whose neck fractured. In some thoracic requirements, the force has been increased to account for muscle tone present in the driving population, but absent in flaccid, unembalmed cadavers used to define the requirements. In conducting the tests, especially the whole body tests, it is important to duplicate the timing of the impacts to the various body regions in order to meet the requirements.

The response requirements are arranged in terms of the type of tests. Clause 4 requirements are based on pendulum impacts, Clause 5 requirements are based on lateral drop tests, and Clause 6 requirements are based on sled tests. Table 1 lists the various requirements by body region, gives the corresponding clause number that describes each requirement, and identifies which annex describes how the requirements were derived.

3 Overall biofidelity calculation

An overall biofidelity rating of the impact responses of any 50th percentile adult male surrogate (dummy or math model) which is proposed for evaluating side impact collision occupant protection can be calculated using the following formula:

$$B = \frac{\sum_{i=1,2,\ldots 6} U_i B_i}{\sum_{i=1,2,\ldots 6} U_i}$$

where

B The overall rating which will have a value between 0 (poorest) and 10 (best).

B_i The biofidelity rating of each of the six body regions (B_1 - Head, B_2 - Neck, B_3 - Shoulder, B_4 - Thorax, B_5 - Abdomen, and B_6 - Pelvis).

U_i The weighting factor for each body region.

i A subscript which takes on integer values from 1 to 6 to represent specific body regions (i=1 Head, i=2 Neck, i=3 Shoulder, i=4 Thorax, i=5 Abdomen, and i=6 Pelvis).

Values for the body region weighting factors, U_i, were determined by averaging the results of a poll of the ISO/TC22/SC12/WG5 experts and are given in Table S.1 of annex S.

The biofidelity ratings for the six body regions, B_i, are calculated using the following formula:

$$B_i = \frac{\sum_{j=1,2,\ldots m} V_{i,j}\left(\sum_{k=1,2,\ldots n} W_{i,j,k} R_{i,j,k} \Big/ \sum_{k=1,2,\ldots n} W_{i,j,k}\right)}{\sum_{j=1,2,\ldots m} V_{i,j}}$$

where

$V_{i,j}$ The weighting factor for each test condition for a given body region.

$W_{i,j,k}$ The weighting factor for each response measurement for which a requirement is given.

$R_{i,j,k}$ The rating of how well a given response meets its requirement.

i The subscript denoting the body region.

j The subscript denoting the test condition for a given body region, i.

k The subscript denoting the response measurement for a given test condition, j, and body region, i.

Values for the weighting factors for the various test conditions, $V_{i,j}$, and response measurements, $W_{i,j,k}$, were determined by averaging the results of a poll of the ISO/TC22/SC12/WG5 experts and are given in Tables S.2 through S.7 of annex S.

The experts agreed on the following method for assigning values to $R_{i,j,k}$.

$R_{i,j,k} = 10$ If response meets requirement.

$R_{i,j,k} = 5$ If response is outside requirement, but lies within one corridor width of the requirement.

$R_{i,j,k} = 0$ If neither of the above is met.

Using this method, the overall biofidelity rating, B, will have a value between 0 and 10. Five classifications indicating the degree of biofidelity were established for the overall biofidelity rating. These are,

Excellent Biofidelity:	$8,6 \leq B < 10,0$
Good Biofidelity:	$6,5 \leq B < 8,6$
Fair Biofidelity:	$4,4 \leq B < 6,5$
Marginal Biofidelity:	$2,6 \leq B < 4,4$
Unacceptable Biofidelity:	$0,0 \leq B < 2,6$

Further, the WG5 experts stipulated that the overall biofidelity value, B, of a side impact dummy (or math model) had to be greater than 2,6 to be acceptable for assessing side impact occupant protection.

4 Pendulum impacts

4.1 Shoulder Test 1

4.1.1 Original Data

Researchers of the APR subjected 4 cadavers to lateral impact delivered to the shoulder by the flat end of a 23 kg rigid cylinder of 150 mm diameter (14). Each cadaver was seated on a horizontal hardwood surface with a vertical backrest. The impact was delivered laterally to the shoulder. The force of the impactor was recorded. Response data and normalization procedures are summarized in annex A.

4.1.2 Test Setup

A 23 kg rigid, 150 mm diameter cylinder with a flat impact face is required. Seat the dummy upright with its arm down and align the axis of the impactor with the center of the shoulder joint, as illustrated in Figure 1. Impact the dummy's shoulder laterally with an impact velocity between 4,4 and 4,6 m/s.

4.1.3 Instrumentation

Instrument the dummy to monitor acceleration of the thoracic spine. Instrument the impactor to measure its acceleration during impact. Filter the acceleration measurements at channel frequency class 1000 Hz, according to the requirements of SAE Recommended Practice J211. Calculate the impactor force versus time history by multiplying each impactor acceleration value by the impactor mass of 23,4 kg.

4.1.4 Response Requirements

The original force versus time histories of the impactor were normalized (see annex A) using the technique suggested by Mertz (17). The maximum deflection of the shoulder should lie within the bounds given in Table 2 and the force versus time history of the impactor should lie within the corridor described in Table 5.

4.2 Thorax Tests 1 and 2

4.2.1 Original Data

Cadavers were used in two series of impactor tests of the thorax. Lateral impacts were conducted by the HSRI (18) and oblique lateral impacts were conducted at WSU for the General Motors Research Laboratories (GMR) (19). Accelerations of the impactor and thorax were recorded in both studies. Response data and normalization procedures are summarized in annexes B and C for the HSRI and WSU/GMR test series, respectively.

4.2.2 Test Setup

A 23 kg rigid, 150 mm diameter cylinder with a flat impact face is required. Seat the dummy upright with its arm raised so that the side of its thorax can be impacted. Center the face of the impactor, both vertically and fore/aft, on the lateral aspect of the thoracic rib structure. Impact the dummy's thorax laterally at a velocity of 4,3 m/s for Thorax Test 1. Repeat the impact at 6,7 m/s for Thorax Test 2.

4.2.3 Instrumentation

Instrument the dummy with an accelerometer to measure the lateral acceleration of the thorax. Instrument the impactor to measure its acceleration during impact. Record all measurements according to the requirements of SAE Recommended Practice J211. Calculate the impactor force versus time history by multiplying each impactor acceleration value by the impactor mass of 23,4 kg. The impactor force and lateral thoracic spine acceleration must be filtered using the 100 Hz FIR filter (18) in order to compare to the response corridors.

4.2.4 Response Requirements

The original impactor force was normalized using an extension of the method described by Mertz (17), as developed by Lowne (24). The normalization procedure is summarized in annexes B and C for the HSRI and WSU/GMR impactor forces, respectively. For the HSRI tests, the lateral acceleration of T1 was also normalized as summarized in annex B. The lateral acceleration of T1 for the WSU/GMR impacts was not available.

For lateral impacts by a 23,4 kg rigid pendulum at 4,3 and 6,7 m/s, the force versus time histories must lie within the corridors described in Table 6. The thoracic acceleration versus time history for a 4,3 m/s lateral impact by a 23,4 kg rigid pendulum must lie within the corridor described in Table 4. No requirement has been set for the thoracic acceleration resulting from a 6,7 m/s impact.

4.3 Pelvis Tests 1 and 2

4.3.1 Original Data

Researchers of ONSER studied the responses of 22 unembalmed cadavers to lateral impacts delivered to the greater trochanter (26, 27, 28). Pelvic acceleration was measured by an accelerometer attached to the posterior of the sacrum. The unbelted cadavers were seated without lateral support. The impacts were delivered at various speeds by either a rigid or padded impactor. Accelerations of the impactor were measured. Data from these tests are summarized in annex D.

4.3.2 Test Setup

A 17,3 kg, rigid impactor with a spherical segment impact face (R=175 mm, r=60 mm) is required. Seat the dummy upright as illustrated in Figure 2. Impact the greater trochanter region with a velocity of 6 m/s for Pelvis Test 1. Repeat the impact at a velocity of 10 m/s for Pelvis Test 2.

4.3.3 Instrumentation

Instrument the dummy to monitor acceleration of the pelvis. Filter the acceleration measurements at channel frequency class 1000 Hz, according to the requirements of SAE Recommended Practice J211. Calculate the impactor force versus time history by multiplying each impactor acceleration value by the impactor mass of 17,3 kg.

4.3.4 Response Requirements

The peak impactor forces were normalized (see annex D) using the technique suggested by Mertz (17). For dummy impacts between 6 and 10 m/s, the peak impactor force should lie within the corridor described in Table 3.

5 Lateral drops

5.1 Head Test 1

5.1.1 Original Data

Hodgson and Thomas (1) conducted a series of non-fracture, cadaver head impact tests. In these tests, the cadavers were strapped on their sides to a pallet that was free to pivot about one end. The cadaver's head and neck were allowed to extend over the free end of the pallet. The pallet was rotated upwards to achieve a prescribed distance between the head and the impact surface. Then the pallet was released producing the desired head impact. Results from these tests are given in annex E.

5.1.2 Test Setup

A flat, rigid horizontal surface and a “quick-release” mechanism are required. Conduct the test using only the dummy's head. Position the dummy’s head with a 200 mm space between it and the impact surface. Orient the head so that its midsagittal plane makes an angle of 35° with the impact surface and its anterior-posterior axis is

horizontal. The response requirement is for the peak resultant head acceleration of a point on the non-impacted side of the head. Also record the peak resultant acceleration of the center of gravity of the head.

5.1.3 Instrumentation

Instrument the dummy's head with a triaxial accelerometer located at the center of gravity of the head. Attach a second triaxial accelerometer, within the head cavity, to the non-impacted side at a point on the transverse axis that passes through the center of gravity of the head. Filter the accelerations at channel frequency class 1000 Hz, according to the requirements of SAE Recommended Practice J211.

5.1.4 Response Requirement

The peak resultant head acceleration of a point on the non-impacted side of the head should lie within the bounds given in Table 2 for a 200 mm free fall drop onto a flat, rigid surface.

5.2 Head Test 2

5.2.1 Original Data

The APR (2) conducted a series of lateral head impact tests. Four cadavers were dropped from a height of 1200 mm onto a rigid surface covered by a 5 mm thick rubber pad. Two of these cadavers received skull fractures. Results from the remaining two cadavers are given in annex F.

5.2.2 Test Setup

The impact surface consisting of a flat, rigid surface covered with a 5 mm thick pad of natural rubber (Shore A Hardness = 50, Rupture Strength = 14 MPa, Tear Strength = 15 kN/m) is required. Conduct the test using only the dummy's head. Position it with a 1200 mm space between it and the top of the padded impact surface. Orient the head so that its midsagittal plane makes an angle of 10° with the impact surface, thus impacting the temporal/parietal region.

5.2.3 Instrumentation

Instrument the dummy's head with a triaxial accelerometer located at the center of gravity of the head. Filter the accelerations at channel frequency class 1000 Hz, according to the requirements of SAE Recommended Practice J211.

5.2.4 Response Requirement

The peak resultant acceleration at the center of gravity of the head should lie within the bounds given in Table 2 for a 1200 mm drop onto the padded surface.

5.3 Thorax Tests 3 & 4 and Pelvis Tests 3 - 6

5.3.1 Original Data

Unembalmed cadavers were subjected to lateral free falls by researchers of the APR (20, 21 and 22). The cadavers were dropped from heights of 0,5 or 1 m onto rigid impact surfaces, or from heights of 2 or 3 m onto padded impact surfaces. The thoracic impact surfaces were instrumented to measure the contact forces for the 1 and 2 m drops only. Triaxial accelerations of T4 were recorded. Rib cage compression was determined from a high-speed movie of the impact for the 1 and 2 m drops only. Pelvic acceleration was measured by an accelerometer attached to the sacrum. Thoracic response data for the 1 m drop tests onto rigid impact surfaces and 2 m drop tests onto padded surfaces are summarized in annex G. Pelvic response data for the 0,5, 1, 2 and 3 m drops are given in annex H.

5.3.2 Test Setup

Two loading surfaces are required to intercept the dummy's thorax and pelvis separately. For the rigid tests, the thorax loading surface is to be large enough to insure that the shoulder is impacted. For the padded tests, 140 x 140 x 420 mm blocks of open cell urethane foam (APR padding) are to be used. The characteristics of this foam are described in annex I. A "quick-release" device is required to allow the dummy to drop freely. Suspend the dummy over the impact surfaces using ropes to support its shoulders, hips, and legs. This is illustrated in Figures 3 and 4 for the rigid and padded impacts, respectively. Position the dummy such that its sagittal plane is horizontal and its arms are rotated 20° forward of the thoracic spine.

5.3.3 Instrumentation

Instrument the thoracic impact surface with inertia-compensated load cells. Instrument the dummy with transducers to measure the lateral acceleration of the thoracic spine, triaxial acceleration of the pelvis, and the deflection of the impacted ribs relative to the thoracic spine. Filter the impact forces, chest and pelvic accelerations, and deflection measurements at channel frequency class 180 Hz, according to the requirements of SAE Recommended Practice J211. Take high-speed movies of the impact event.

5.3.4 Response Requirements

The normalization procedures are described in annexes G and H for the thoracic and pelvic data, respectively. The thoracic impact force versus time responses for the 1 m rigid and 2 m padded drops should lie within the corridors described in Table 5. Upper and lower bounds for peak deflection of the impacted rib and the peak pelvic accelerations are given in Table 2. The peak thoracic deflection and peak pelvic acceleration of the dummy should lie within these bounds.

5.4 Abdomen Tests 1 and 2

5.4.1 Original Data

Researchers of the APR subjected 11 unembalmed cadavers to lateral free falls onto simulated armrests (25). The cadavers were instrumented to monitor accelerations of T12 and the lateral aspects of their 9th ribs. The simulated armrests were secured to load cells, providing measurements of the force applied to the impacted surface. The data for these tests were provided by the APR (14) and are presented in annex J.

5.4.2 Test Setup

A simulated armrest, constructed of rigid hardwood, is required. The armrest is 70 mm in width and of sufficient height to protrude 41 mm above the surrounding surface. The length must be sufficient to prevent the dummy from striking the ends. The top edges are rounded with a 10 mm radius. Suspend the dummy with its midsagittal plane horizontal and its abdominal region including the "area of the 9th rib" in line with the top surface of the simulated armrest, as illustrated in Figure 5. Use a “quick-release mechanism” to drop the dummy the prescribed distance (1 or 2 meters).

5.4.3 Instrumentation

Instrument the dummy to monitor the acceleration of the spine at the level of T12, the acceleration of the impacted rib, and the deflection of the abdominal region relative to the spine (if such transducers are present). Instrument the simulated armrest with load cells. Filter the load and acceleration measurements at channel frequency class 180 Hz, according to the requirements of SAE Recommended Practice J211. Determine the abdominal penetration from high-speed films if it can not be measured directly.

5.4.4 Response Requirements

The original impact forces, and the peak T12 and impacted rib accelerations of the cadavers were normalized (see annex J) using the technique suggested by Mertz (17). The force versus time history of the dummy should lie within the corridors described in Table 5. The peak acceleration of the lower spine and the peak impacted rib acceleration

should lie within the bounds given in Table 2. For both the 1 and 2 m drops, the abdominal penetration should be at least 41 mm, which is the height that the rigid simulated armrest protrudes above the surrounding surfaces.

6 Sled tests

6.1 Neck Test 1 and Shoulder Test 2

6.1.1 Original Data

Ewing et al. (11) conducted a series of lateral neck bending tests with volunteers. The volunteers were seated upright on a sled fixture that was mounted sideways to the direction of travel of a HYGE sled. They were positioned snugly against a lightly padded wooden board, which restricted upper torso rotation and supported the torso during sled translation. Both shoulders were restrained by straps. Their pelves were restrained by a lap belt and an inverted-V pelvis strap that was tied to the lap belt. They held their heads upright prior to sled acceleration. The data used for this requirement were taken from an analysis by Wismans et al. (12) of 9 tests with 9 subjects. annex K summarizes the most important test conditions.

6.1.2 Test Setup

Fasten a rigid chair, functionally similar to the one used by Ewing et al. (11), to a HYGE sled, facing sideways to the direction of sled travel. Attach a vertical side board to the seat to restrict upper torso rotation and to support the torso during sled translation. The top of the side board should be 40 to 50 mm below the top of the dummy's shoulder. Seat the dummy upright with its shoulder and hip against the side board and the anterior-posterior axis of its head horizontal. Position the dummy with its midsagittal plane vertical and perpendicular to the direction of sled travel. Secure the dummy to the seat with a belt restraint. Subject the dummy to the sled pulse shown in Figure 6.

6.1.3 Instrumentation

Instrument the dummy with triaxial accelerometers at the centers of gravity of the head and chest, a uniaxial accelerometer at the base of the neck with its sensitive axis directed laterally, and a six-axis neck transducer at the neck to head interface (at the level of the occipital condyles). In place of the six-axis neck transducer, the dummy's head may be instrumented with sufficient accelerometers to calculate the reactions at the head to neck interface. Use photographic targets to monitor the translation of the center of gravity of the head, lateral head rotation, head twist and horizontal translation of the base of the neck. Measure the sled acceleration and record the required dummy displacements with onboard cameras. Filter all response data according to the requirements of SAE Recommended Practice J211.

6.1.4 Response Requirements

A dummy subjected to the sled test described in subclause 6.1.2 Test Setup should meet the response requirements given in Table 2.

6.2 Neck Test 2

6.2.1 Original Data

Patrick and Chou (13) conducted a series of volunteer, lateral neck bending tests using their decelerator sled. A rigid seat with a 15° 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 supported the torso during sled translation. 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 results of the most severe test are given in annex L.

6.2.2 Test Setup

Attach a rigid seat with a 15° seat back angle and a rigid vertical side board (similar to the seat used by Patrick and Chou 13) to a decelerator sled, sideways to the direction of sled travel. The top of the side board should be within 50 to 75 mm of the top of the dummy's shoulder. Seat the dummy with its shoulder and hip against the side board and the anterior-posterior axis of its head horizontal. The midsagittal plane of the dummy should be vertical and perpendicular to the direction of sled travel. Use a restraint system to secure the dummy, including its arms and legs, to the chair. Accelerate the sled to a velocity of 5,8 m/s without disturbing the dummy's position and then decelerate 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.

6.2.3 Instrumentation

Instrument the dummy with a triaxial accelerometer at the center of gravity of the head and either a six-axis neck transducer at the neck-to-head interface (occipital condylar level), or sufficient accelerometers attached to the head to calculate these reactions. Use photographic targets to monitor the specified head motion. Measure the sled acceleration and record the required dummy motions with onboard cameras. Filter all response data according to the requirements of SAE Recommended Practice J211.

6.2.4 Response Requirements

A dummy subjected to the sled test described in subclause 6.2.2 Test Setup, should meet the response requirements given in Table 2.

6.3 Neck Test 3 and Shoulder Test 3

6.3.1 Original Data

Tarriere (30) conducted four high-G cadaver tests to obtain data that could be used to define lateral neck bending response in a test environment of greater severity than used for volunteer testing. Unfortunately, each test had an abnormality. Tarriere selected one test 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. annex M summarizes the data.

6.3.2 Test Setup

Fasten an upright rigid chair, functionally similar to the one used by Ewing et al. (11), to a HYGE sled, facing sideways to the direction of sled travel. Attach a vertical side board to the seat to restrict upper torso rotation and to support the dummy during sled translation. The top of the side board should be 40 to 50 mm below the top of the dummy's shoulder. Seat the dummy upright, with its shoulder and hip against the side board and the anterior-posterior axis of its head horizontal. The midsagittal plane of the dummy should be vertical and perpendicular to the direction of sled travel. Use a belt restraint to secure the dummy to the seat. Accelerate the sled to 22 ± 0,5 km/h with a pulse that is within the corridor shown in Figure 7.

6.3.3 Instrumentation

Instrument the dummy with a triaxial accelerometer at the center of gravity of the head, a triaxial accelerometer in the thoracic spine in the region of T1 and a six-axis neck transducer at the head-to-neck interface (occipital condylar level) or sufficient head accelerometers to calculate these reactions. Use photographic targets to track the translation of the center of gravity of the head, lateral head rotation, head twist and T1 translation. Measure the sled acceleration and record the required dummy displacements with onboard cameras. Filter all response data according to the requirements of SAE Recommended Practice J211.

