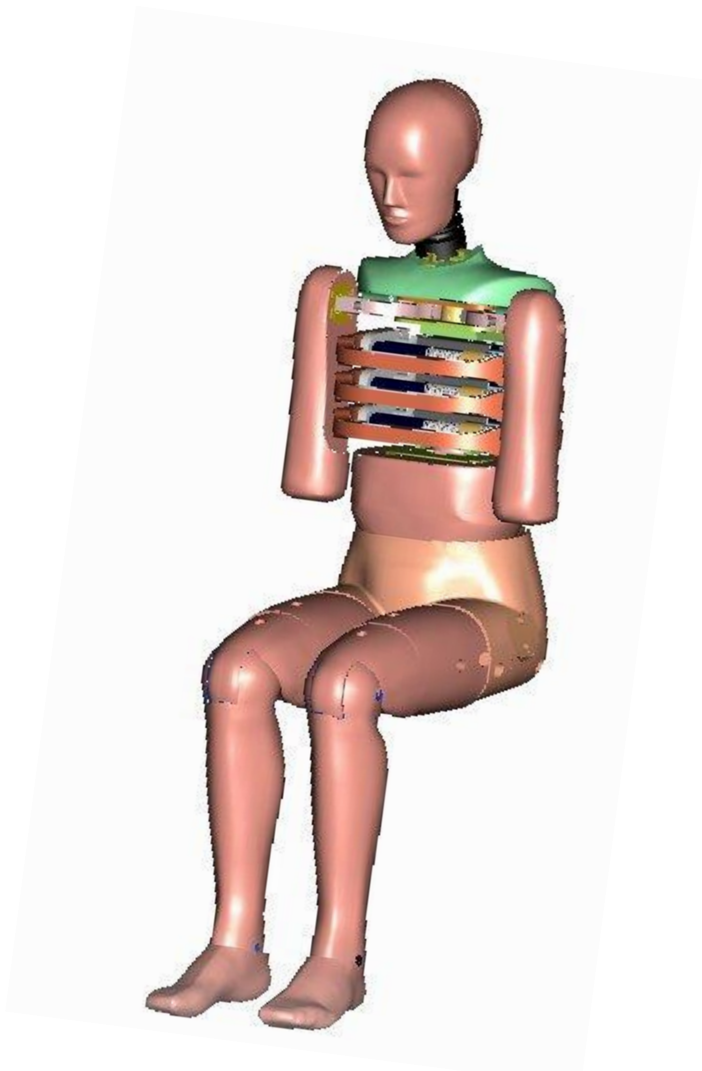
ES-2
User Manual



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Summary

This document provides information for test-engineers and dummy technicians concerning the use of the ES-2 crash dummy in side-impact tests. Information is provided about design, instrumentation, (dis-) assembly, certification and handling of the dummy (if applicable).

The specifications of the ES-2 Side Impact Dummy have been developed within the European Commission funded SID-2000 project. TNO Automotive co-ordinated this project. The participants in the ES-2 development were Transport Research Laboratories (TRL) in the UK, First Technology Safety Systems (FTSS) Europe in Delft, First Technology Safety Systems (FTSS) UK and TNO Automotive in Delft.
Assistance in the development was obtained from Transport Canada, Biokinetics and Associates Ltd, First Technology Safety Systems (FTSS) Inc., Robert A. Denton, Inc., Applied Safety Technologies Corporation (ASTC) and Bundesanstalt für Strassenwesen (BASt).
A worldwide Task group supervised the ES-2 development, as the ES-2 dummy is anticipated to be the crash dummy in the first worldwide harmonised side impact crash test regulations.
The European Enhanced Vehicle-safety Committee EEVC has accepted the ES-2 dummy and submitted their research results to ECE and authorities worldwide. The EEVC believes the ES-2 dummy forms a solid basis for interim harmonisation and will further support activities to help realise this objective. The American National Highway Transport Safety Administration (NTHSA) is well advanced in the process of acceptance, of the dummy as an alternative for the current dummy in their regulations. EuroNCAP will use the dummy in its protocol based on the acceptance by the EEVC.

The ES-2 is manufactured by Humanetics Innovative Solutions, Inc. Documentation and information is available through local Humanetics offices. Comments or remarks on this manual are greatly appreciated and will be used to improve this manual. Please contact your local Humanetics office.

List of contents

ES-2 User Manual

1 General Introduction

1.1 History of ES-2

The ES-2 side impact dummy (see Figure 1) is designed for the evaluation of vehicle occupant protection under conditions of a lateral impact.
The ES-2 development is based on the EUROSID-1 dummy, incorporating modifications to cover concerns, reported by users and governmental organisations in the US as well as Europe and Japan. The EUROSID-1 dummy was developed and constructed by a group of European research laboratories working together under the auspices of the European Experimental Vehicle Committee (EEVC, now called: European Enhanced Vehicle-Safety Committee). A brief description of the development history of EUROSID-1 is given in the EUROSID-1 Assembly and Certification document[1]. The specifications of EUROSID-1 were frozen in April 1990.

An effort to reach worldwide harmonisation based on EUROSID-1 highlighted some areas of concern expressed by American, European and Japanese users. American users petitioned the National Highway Transport Safety Administration (NHTSA) to amend the US federal requirements of the side impact regulations[2]. The proposed amendment comprises among others the use of an EUROSID-1 dummy, upgraded in the areas of concern. In addition, users of the EUROSID-1 dummy in crash tests had indicated that certain areas for improvements.

Improved procedures and structural parts have been developed for all concerned areas. Some of the parts and procedures have already been made available as a "Research tool kit" for the EUROSID-1 dummy in November 1998. Since then an International Task Group has supervised the development towards the ES-2, with the goal to attain swift worldwide harmonisation. With the prototype ES-2 dummy, released in January 2000, a major step towards short-term worldwide harmonisation was taken. Four prototype ES-2 dummies were extensively tested in Europe, Japan and North America. The evaluation is still in progress at NHTSA. EEVC Working Group 12 reported the European evaluation results[3]. In

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1 **TNO Crash Safety Research Centre**
EUROSID-1 Assembly and Certification Procedures
January 1994

2 **American Automobile Manufactures Association (AAMA); Association of International Automobile Manufacturers (AIAM) and Insurance Institute for Highway Safety (IIHS)**
Petition for Rulemaking to National Highway Transport Safety Administration
Rule concerned: FMVSS 214 - 49 CFR 571.214; 49 CFR Part 572; 49 CFR Part 587
Date of petition: December 22, 1997

3 **European Enhanced Vehicle-safety Committee Working Group 12 (EEVC WG12)**
Development and Evaluation of the ES-2 Dummy, August 2001 (Main text and Annex A-I)

their meeting on September 19, 2001 the EEVC steering committee accepted the report and submitted it to the ECE and authorities worldwide.

1.2 Modifications incorporated in ES-2

The modifications incorporated in ES-2 with respect to EUROSID-1 are summarised below.

Head

- Upper neck load cell with 6-axis head.

Neck

- Measures to prevent buffer dislocation and loosening of the half-spherical screw.
- Introduction of lower neck load cell.
- Revised certification procedure.

Shoulder

- Friction reduction to prevent clavicle binding.
- New clavicle allows limited vertical motion.
- Reshaped shoulder foam cap.
- Introduction of clavicle load cell.

Arm

- Introduction of self-locking screw.
- Improved handling with hole in suit.

Thorax

- Improved rib guide system.
- Introduction of torso back plate load cell.
- Curved reduced width seat back interface.

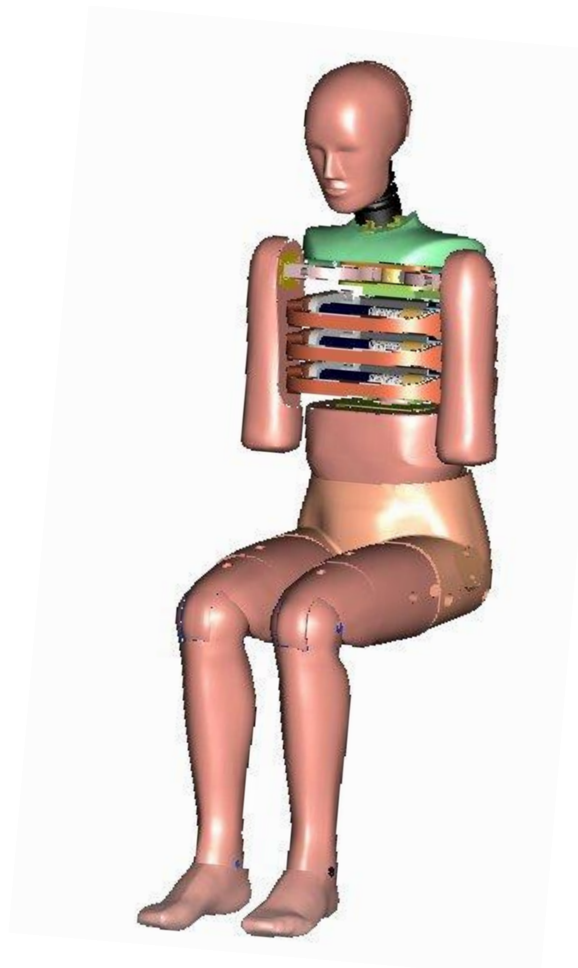


Figure 1: ES-2 dummy

Abdomen

- Introduction of T12 - spine load cell.
- Revised certification procedure.

Lumbar spine

- Revised certification procedure.

- Modification for T12 – spine load cell integration

Pelvis

- Measures to prevent metal to metal contact.
- Simplified pubic attachment hardware.

Legs

- High-mass flesh system in upper leg.
- Introduction of femur load cell.

1.3 How to use this document

This document is divided into five major chapters in addition to this introduction. Each chapter provides information about a topic for the complete dummy.

2 ES-2 Description

2.1 Introduction

The ES-2 Side Impact Dummy represents a 50th percentile adult male, without lower arms. Masses and inertia of dummy parts are based on known anthropomorphic data. The total mass of the dummy (including rib displacement transducers, force transducers in the abdomen, pubic symphysis force transducer, and suit) is 72.0 ± 1.2 kg.
In this chapter a description of the ES-2 per body part will be given.
Although the figures and drawings show a dummy prepared for left hand side impacts, the
ES-2 can easily be converted to right hand side impacts (see Chapter 4).

2.2 Head

The head is based on a 6-axis Hybrid III 50th percentile head comprising of an aluminium skull covered by a pliable vinyl skin (see Figure 2). The changes with respect to the Hybrid III head are in the head-upper neck load cell interface and the mass. The mass of the combination of head and upper neck load cell is tuned. For more details of the Hybrid III head, see ref. [4] and [5].
At the head-neck interface, a 6-axis Upper neck load cell is mounted on the skull base. The interior of the skull is a cavity in which accelerometers can be located. Access is provided by removal of a skullcap at the back of the head.

[4] Hubbard, R.P. and D.G. McLeod: “Definition and Development of a Crash Dummy Head”. SAE p 741193, Proceedings 18th STAPP Car Crash Conference, 1974.

[5] USA Federal Regulations, Part 572 Anthropomorphic Test Dummies Subpart E 50th Percentile Male, issued August 1, 1973; Consolidated as CFR 49 dated October 1, 1991; Amended by Vol. 56. No. 220 November 14, 1991 and Vol. 57 No. 199 October 14, 1992.

Figure 2: ES-2 head showing interface

2.3 Neck

The ES-2 neck consists of three main parts:

- Head/neck interface plate;
- Neck/torso interface plate;
- Central moulded section made of special rubber linking the two interface plates.

The various neck parts are illustrated in Figure 3. In the rubber central moulding intermediate plates are integrated at both ends. These plates are linked to the head-neck and neck-torso interface plates by means of a half spherical screw, providing a point of rotation at the top and bottom of the neck.

Figure 3: ES-2 neck parts: interface plates, central moulding, half-spherical screw

In order to allow head-neck and neck-torso relative movements respectively, two types of buffers are interposed between the plates:

- The triangular section buffers integral with the central moulding rubber.
- The circular section buffers four at the bottom and top of the neck. These buffers are used to tune the neck to comply with its required performance. The circular section buffers are delivered in three sets of eight buffers with a hardness of 60, 70 and 80 Shore A.

This design represents a system with two pivots and three modes of deformation. The centres of the half-spherical screws represent the two pivots. The three modes of deformation are:

- Simple lateral flexion (of the central part);

- Translation and rotation (relative movements of the interface plates);
- Elongation of the central part.

The play, which exists around the buffers and the flexibility of the buffers, may give rise to torsion, i.e. a rotation around the neck's vertical axis.

The neck is mounted on the neck bracket (see Figure 4), which is attached to the shoulder box (see Section 2.4). The angle between the faces of the neck bracket is 25 degrees because the shoulder box is inclined 5 degrees backward the resulting angle between neck and torso line is 20 degrees.

Figure 4: ES-2 neck-bracket including eyebolt

2.4 Shoulder

The ES-2 shoulder consists of four main parts:

- Assembly of top and bottom plate;
- Two clavicles;
- Shoulder foam cap.

The shoulder box mainly consists of an aluminium spacer block and two PTFE coated aluminium plates on the top and bottom of the spacer block (see Figure 5). The shoulder box is attached to the top face of the spine box, which is inclined 5 degrees backwards. The clavicle contact with the spacer block is in the shape of a cam such that the initial point of contact, and the centre of rotation of the clavicle, is at the posterior end of the box. The clavicles are attached to the box with a 'U' shaped spring and guided between the two PTFE coated shoulder plates, with a sliding contact in order to limit their movement to one plane. The clavicles have been changed with respect to the EUROSID-1 clavicles to increase the flexibility in vertical direction. The clavicles are held in their neutral position by two elastic cords, which are clamped to the rear of the shoulder box (See Figure 7).

Figure 5: ES-2 shoulder assembly (exploded view).

On the outer ends of the clavicles, contain a spring-loaded pin. In combination with the pivot stop plates in the arm, this design allows standard arm orientations (see Section 2.6). To enable the optional installation of a 3-axis load cell on the clavicle at the impact side a shortened clavicle (see Figure 6) is available upon request.

A shoulder foam cap, with a modified shape relative to that of EUROSID-1, made of low-density polyurethane foam is attached to the shoulder box using Velcro strips.

Figure 6: ES-2 standard clavicle and shortened clavicle for load cell installation (optional)

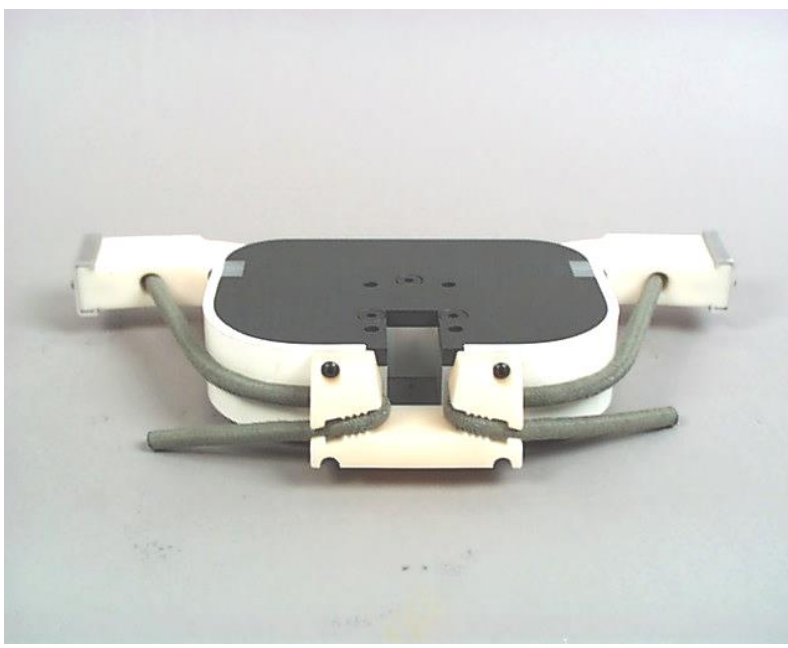


Figure 7: ES-2 shoulder assembly seen from the back (note the elastic chord holder and routing of the cords)

2.5 Thorax

For the ES-2 dummy, a new rib guidance system design is developed to solve the "flat top" issue (ref. 2 see page 6). The friction induced in the journal bearing equipped piston cylinder design of EUROSID-1 is found as one of the causes of the "flat top" effect. The new designed needle bearing linear guidance system eliminates this friction.

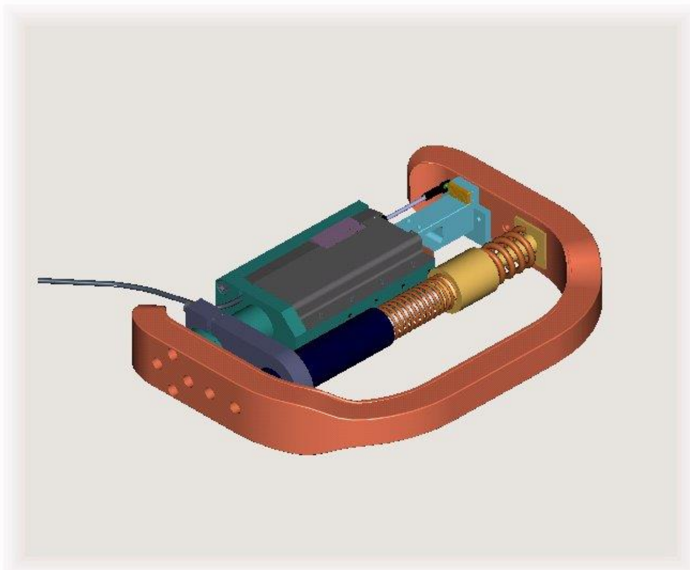


Figure 8: ES-2 rib unit complete.

The linear guidance system for the rib is based on a pair of needle bearing systems positioned back to back in the piston (see Figure 8 and exploded views in section 4). A linear potentiometer is positioned in the rib unit to measure the rib displacement. Three rib units are mounted on a new designed spine box to get the required interfaces with the shoulder, back plate and abdomen assemblies (see Figure 9).

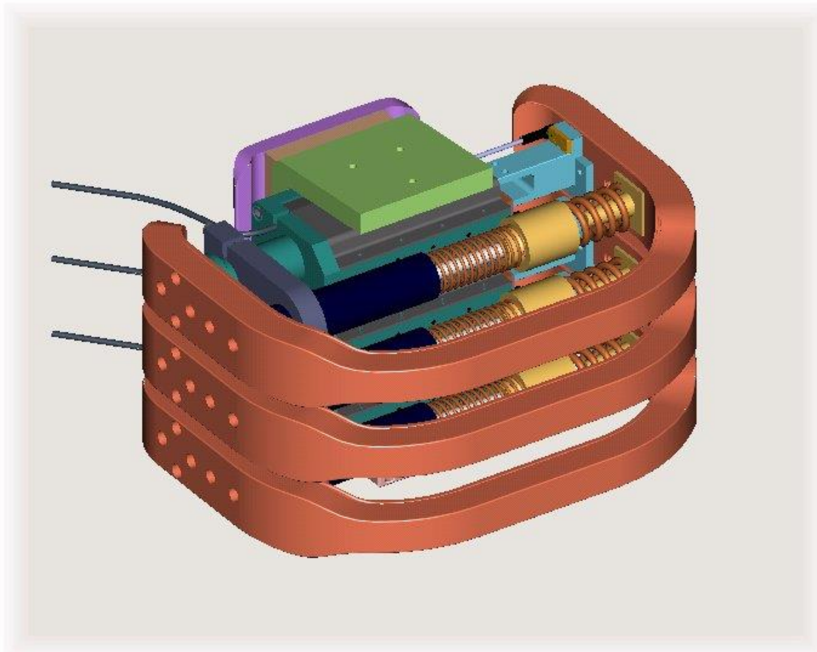


Figure 9: ES-2 thorax assembly

The ES-2 thorax consists of five main parts:

- Rigid thoracic spine box, including back plate.
- T12 - load cell (or its structural replacement).
- Three rib modules individually attached to the spine box.
  A rib module consists of (see Figure 8):
  - A steel rib bow. The rib is covered with flesh simulating foam. The whole flesh system is held to the rib by a sleeve covered with a plastic coating;
  - A linear guidance assembly in the Y (impact) direction of the dummy. The linear guidance attaches to the impacted side and the none-impacted side of the rib to limit the deflection mode to purely lateral. The non-impacted side of the rib is rigidly attached to the spine box (see figure 9).
  - A tuning spring located in the cylinder. This spring is used to 'tune' the performance of the rib module. Springs with different spring rates are available in the dummy toolbox.
  - A hydraulic damper, working parallel to the linear guidance assembly. The damper is equipped with a low-stiffness return spring over the damper piston rod. A spring cup holds this spring in position.
  - A stiff damper spring, connecting the damper piston to the impacted side of the rib.

- A displacement transducer on each rib to measure rib deformation between struck side and non-struck side.

The rib modules are sensitive to impact from only one direction. The three rib modules are bolted to the spine box and can easily be reversed to change the impact direction of the dummy from the left hand to right hand side (see Section 4.7).

2.6 Arms

The ES-2 arms consist of a plastic skeleton covered by flesh simulating foam and a plastic skin. The upper part of the arm is made of a high energy absorbing solid foam, the lower part of soft foam. The arm is attached to the end of the shoulder clavicle. The arm/shoulder joint consists of a pivot stop plate, clamped to the arm skeleton and a small axial bearing between two washers. The assembly is held together by a self-locking bolt. The pivot stop plate allows for reproducible discrete arm orientations at 0, 40 and 90 degrees with respect to the torso line.

2.7 Abdomen

The ES-2 abdomen consists of four main components (Figure 10):

- Cast aluminium abdominal drum.
- Foam covering.
- A set of three identical abdominal force transducers for the impact side.
- A set of three none-measuring blank units for the none-impact side.

The central part of the abdomen section is a metal drum positioned around the lumbar spine and rigidly attached to the T12 - load cell (or its structural replacement) at the bottom side of the thorax. The drum is covered by foam. At both sides of the foam covering, a curved slab of lead pellets filed foam is integrated, in order to obtain the required inertial mass and visco-elastic performance. The foam allows a penetration of 40 mm before 'bottoming out'.

Three abdominal force transducers can be positioned, at each side of the abdomen, between the foam covering and the rigid drum. The three transducers are positioned vertically and parallel to each other on the impacted side of the dummy, while on the opposite side three non-measuring transducer replacements are mounted (see Section 4.9).

A cover plate provides fixation of the foam covering and prevents contact between the foam covering and the lower rib in a test.

Figure 10: ES-2 abdomen seen from the back (dummy upper part removed)

2.8 Lumbar spine

The ES-2 lumbar spine consists of a solid rubber cylinder with metal interface plates at each end. Pre-compression to the lumbar spine can be provided with the longitudinal steel cable running through the lumbar spine. Figure 11 shows the lumbar spine mounted in the pelvis.

Figure 11: ES-2 lumbar spine (after removal of abdomen assembly)

2.9 Pelvis

The ES-2 pelvis consists of eight main parts:

- Lumbar mounting plate;
- Sacrum block;
- Two iliac wings;
- Flesh simulated by foam covered with a plastic skin;
- Two proximal femur hip joints including attachment pins and H-point back plate;
- A pubic force transducer or structural replacement.

The iliac wings are made of plastic resin. The two iliac wings are linked together at the pubic symphysis by a force transducer or a transducer replacement. At the rear of the pelvis, the iliac wings are attached to each side of the sacrum block (see Figure 12). The lumbar mounting plate connects the sacrum block with the lumbar spine. This mounting plate can be replaced with a lower lumbar spine load cell.

A foam plug has been placed against an H-point back plate, fixed on the iliac wing by an axle passing through the ball joint of the upper femur bracket (see Figure 12).

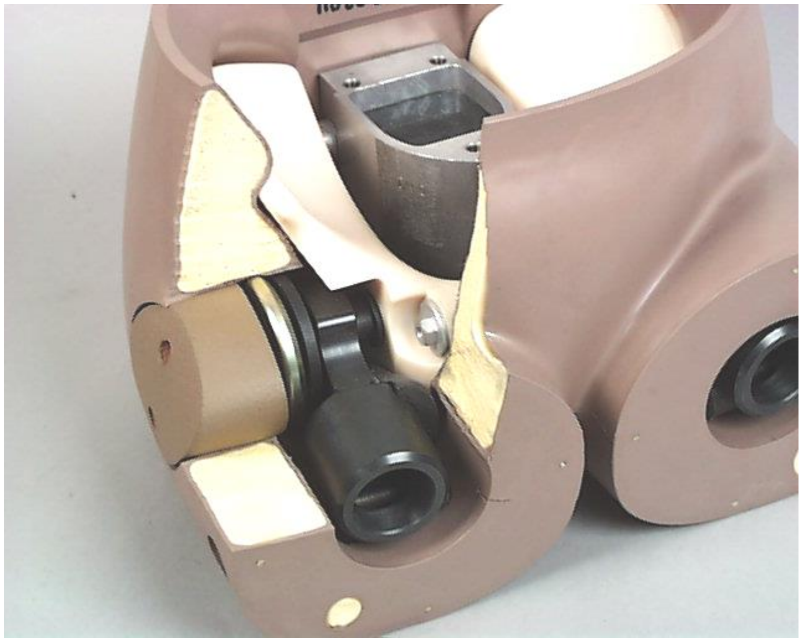


Figure 12: ES-2 pelvis
(Foam partly cut away to show the hip joint. Lumbar mounting plate not shown)

The design of the hip joint allows abduction angles to approximately 19 degrees. Adduction angles are limited to approximately 13 degrees. The later limitation is due to the interaction of the upper femur with the iliac wings in the pubic region. Two rubber buffers at each side prevent the occurrence of metal to metal contact at the ends of the adduction-abduction range of motion. The flesh system, which covers the sacrum-iliac assembly, is made of PVC skin filled with PU foam.
The sacrum block inside the pelvis is angled 5 degrees backward with respect to the horizontal. Therefore, a vertical position of the dummy torso line is achieved with forward bending of the upper part of the dummy to compensate for this angle.
The external shape of the pelvis represents a 50th percentile male in automotive seating posture. Important shape features are in the regions that are potentially hit in a side-impact test, in the regions of interactions with the car seat and at the iliac crests where the seat belt fits around the pelvis.

2.10 Legs

The legs consist of a metal skeleton covered by flesh simulating polyurethane covering. The joints at hip, knee and ankle allow realistic motion of the leg parts. The legs are of the standard Hybrid II design ref. [6] except for the femur bone and the thigh flesh. These parts are modified with respect to the parts used on EUROSID-1 to obtain a more human like mass distribution over the rigid bone structure and the soft flesh simulation. The flesh part is increased in mass and the femur bone is decreased in mass. The mass shift is approx. 2.75 kg. This modification is introduced to achieve a more human-like knee-to-knee interaction performance. (See for details ref. 3 on page 6)

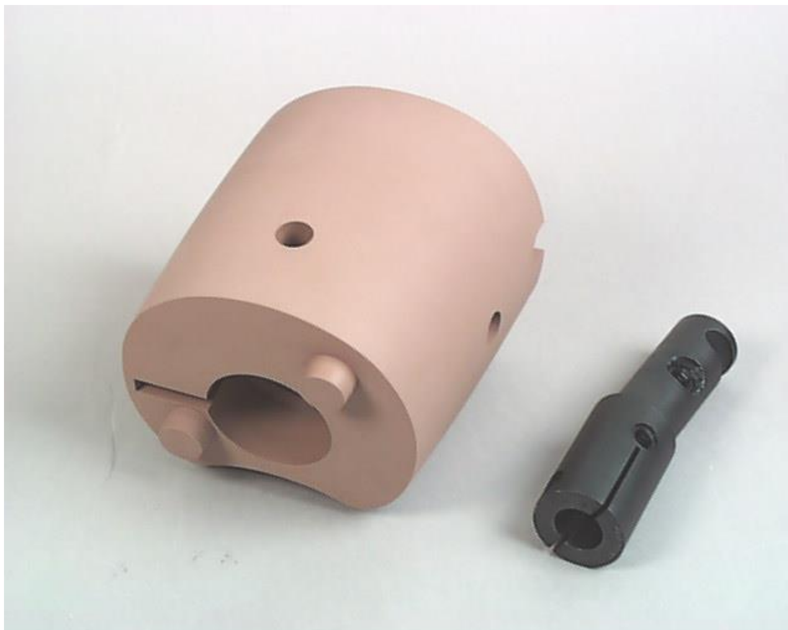


Figure 13: ES-2 upper leg thigh flesh and femur bone

6 USA Federal Regulations, Part 572 Anthropomorphic Test Dummies Subpart B 50th Percentile Male, Drawings SA 150 MO80 and MO81, issued August 1, 1973; Consolidated as CFR 49 dated October 1, 1991; Amended by Vol. 56. No. 220 November 14, 1991 and Vol. 57 No. 199 October 14, 1992.

2.11 Suit

The ES-2 is provided with a neoprene suit that covers the arms, shoulder, thorax, abdomen and the upper part of the pelvis. Figure 14 shows the neoprene suit. Holes are provided in the sleeves to give access to the arm attachment screws.

Figure 14: ES-2 Suit

2.12 Toolbox

The ES-2 dummy is supplied with a toolbox containing all tools required to assemble and disassemble the dummy, as well as some consumables required for maintenance of the dummy. The content of the toolbox is listed below.

Table 1: Toolbox list of content

Item	Description	Used for
E2.CK-H	SHOULDER CAM CLAVICLE ASSY FOR LC	
E2.CH-C-FT	ELASTIC CORD ES-2	
E.IBA-FT	EMPTY TOOL BOX	
175-9501-DN	PULLER TOOL	PELVIS HIP JOINT AND PUBIC SYMPHYSIS LOAD CELL ATTACHMENT
175-9500-DN	NECK COMPRESSION TOOL	
175-2020-DN	NECK BUFFER, SET OF 8, 80 DURO	
175-2010-DN	NECK BUFFER, SET OF 8, 60 DURO	
9002399	3/4" OPEN ENDED SPANNER	ASSEMBLY, DISASSEMBLY
9002398	5/32" ALLEN KEY	ASSEMBLY, DISASSEMBLY
9002389	OIL BOTTLE	
9002397	3/16" ALLEN KEY	ASSEMBLY, DISASSEMBLY
9002370	STRAIN RELIEF BUSHING	
9000591	SCREW, FHCS 1/4-20 X 1	LUMBAR SPINE ADAPTER TO LUMBAR SPINE
8006248	ANTI-SEIZE COMPOUND TUBE	
8006211	DAMPER OIL	RIB DAMPERS
8006209	ADHESIVE, LOCTITE	
5000296	SCREW, LHCS M6 X 16	H-POINT BACK PLATE TO HIP PIVOT PIN
5000288	SCREW, FPSS M4 X 8	
5000283	SCREW, SHCS M2.5 X 16	POTENTIOMETER TO GUIDE ASSEMBLY.
5000281	SCREW, SHCS M6 X 12	HEAD TO NECK
5000129	SET ALLEN KEY	ASSEMBLY, DISASSEMBLY
5000089	SCRW, SHSS M8 X 60	
5000040	M10 X 30 SELF LOCKING SCREW	

2.13 Mass and dimension characteristics

The following paragraphs will describe some of the main ES-2 dummy characteristics, the mass of the dummy parts and the principal dimensions of the complete dummy.

2.13.1 Mass breakdown

In Table 2 mass of the main sub-assemblies and parts they consist of are given.
The mass and mass-tolerance specifications allow the application of the required and optional instrumentation.

Table 2: Mass of dummy sub-assemblies.

Sub Assembly	Mass (kg)	Principal contents
Head	4.0 ± 0.2	Complete head assembly including tri-axial accelerometer and upper neck load cell
Neck	1.0 ± 0.05	Neck, not including neck bracket
Thorax	22.4 ± 1.0	Neck bracket, shoulder cap, shoulders assembly, arm attachment bolts, spine box, torso back plate, rib modu-les, rib deflection transducers, T12 - load cell or structural replacement, abdomen central casting, abdominal force transducers, torso back late load cell or replacement, 2/3 of suit
Arm	1.3 ± 0.1	Upper arm, including arm positioning plate (each)
Abdomen	5.0 ± 0.25	Abdomen flesh covering and lumbar spine
Pelvis	12.0 ± 0.6	Sacrum block, lumbar spine mounting plate, hip ball joints, upper femur brackets, iliac wings, pubic force transducer, pelvis flesh covering, 1/3 of suit
Leg	12.7 ± 0.6	Foot, lower and upper leg and flesh as far as junction with upper femur bracket (each)
Total	72.0 ± 1.2	

2.13.2 Principal dummy dimensions

The principal dimensions of the ES-2 dummy as indicated in Figure 15 are given in Table 3.

The measurements are valid for the following boundary conditions:

- Dummy is position on a flat table.
- Upper torso put in vertical position with a water level on the torso back plate.
- Head lifted to obtain a straight neck, with parallel end plates.
- Suit is not included.
- Play of the clavicles is taken out to the bottom.

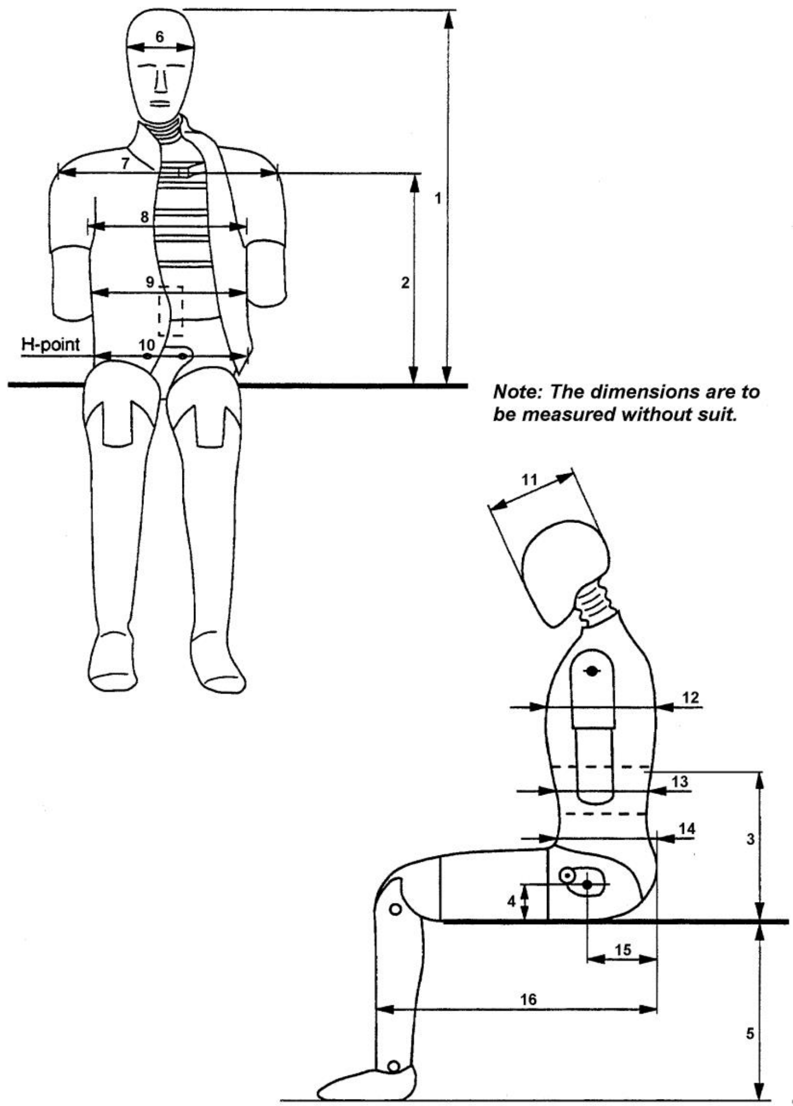


Figure 15: ES-2 Principle dimensions (measured without suit)

Table 3: ES-2 Principle dimensions as indicated in Figure 15

No.	Dimension	Value (mm)
1	Sitting height	909 ± 9
2	Seat to shoulder joint	565 ± 7
3	Seat to lower face of thoracic spine box	351 ± 5
4	Seat to hip joint (centre of bolt)	100 ± 3
5	Sole to seat, sitting	442 ± 9
6	Head width	155 ± 3
7	Shoulder / arm width	470 ± 9

8	Thorax width	327 ± 5
9	Abdomen width	280 ± 7
10	Pelvis lap width	366 ± 7
11	Head depth	201 ± 5
12	Thorax depth	267 ± 5
13	Abdomen depth	199 ± 5
14	Pelvis depth	240 ± 5
15	Back of buttocks to hip joint (centre of bolt)	155 ± 5
16	Back of buttocks to front knee	606 ± 9

3 Instrumentation

3.1 Introduction

In this chapter, the standard and optional instrumentation of ES-2 will be presented.

Section 3.2 gives an overview of the instrumentation. The following sections describe the instrumentation per body part. Specific transducers are proposed for the optional instrumentation.

Furthermore, channel filter classes according to ISO 6487 or SAE J211 are recommended.

3.2 Overview of the instrumentation

The ES-2 dummy is designed to accept the following instrumentation (see also Figure 16):

- Head
  - Upper neck load cell (6-axis: F_x, F_y, F_z and M_x, M_y, M_z)
  - Three uni-axial accelerometer in the head centre of gravity
- Neck
  - Lower neck load cell (6-axis: F_x, F_y, F_z and M_x, M_y, M_z)
- Shoulder
  - Clavicle load cell (3-axis: F_x, F_y, F_z)
- Thorax
  - Seating angle indicator (2-axis: static angle about x and y)
  - Torso back plate load cell (4-axis: F_x, F_y and M_y, M_z)
  - Tri-axial accelerometer (or three uni-axial ones) at T1 in shoulder cavity
  - Three uni-axial accelerometer at T12 location
  - Uni-axial accelerometers on each rib in x and y direction
  - Three linear potentiometer one for each rib
- Abdomen
  - T12 - load cell (4-axis: F_x, F_y and M_x, M_y)
  - Three force transducers (uni-axial, F_y)
- Pelvis
  - Seating angle indicator (2-axis: static angle about x and y)
  - Lower lumbar spine load cell (3-axial: F_x, F_y, and M_x, M_y)
  - Pubic symphysis load cell (uni-axial: 3 x F_y)
  - Tri-axial accelerometer (or three uni-axial ones) in sacrum block.
- Legs
  - Femur load cell (6-axis: F_x, F_y, F_z and M_x, M_y, M_z)

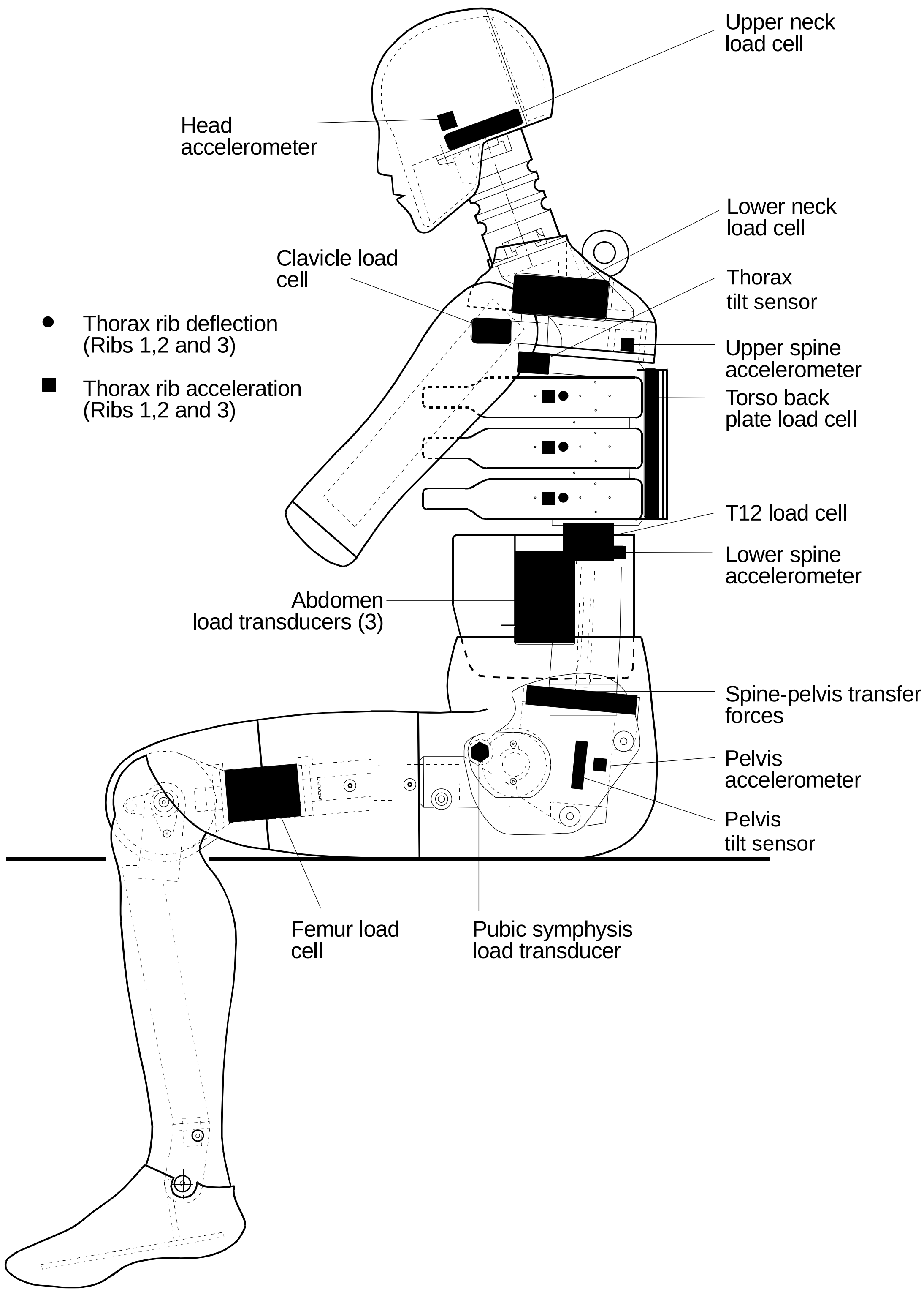


Figure 16: ES-2 instrumentation scheme (standard and optional)

3.3 Head

3.3.1 Load cell

The head-neck interface is equipped with a 6-axis upper neck load cell. The capacity specification of this load cell is

- Fx = 10 kN (2247 lb)
- Fy = 10 kN (2247 lb)
- Fz = 15 kN (3371 lb)
- Mx = 300 Nm (2654 in-lb)
- My = 300 Nm (2654 in-lb)
- Mz = 300 Nm (2654 in-lb)

Appropriate load cells for this application are the Humanetics IF-240 or equivalent. A structural replacement of the load cell is available (see Figure 17).

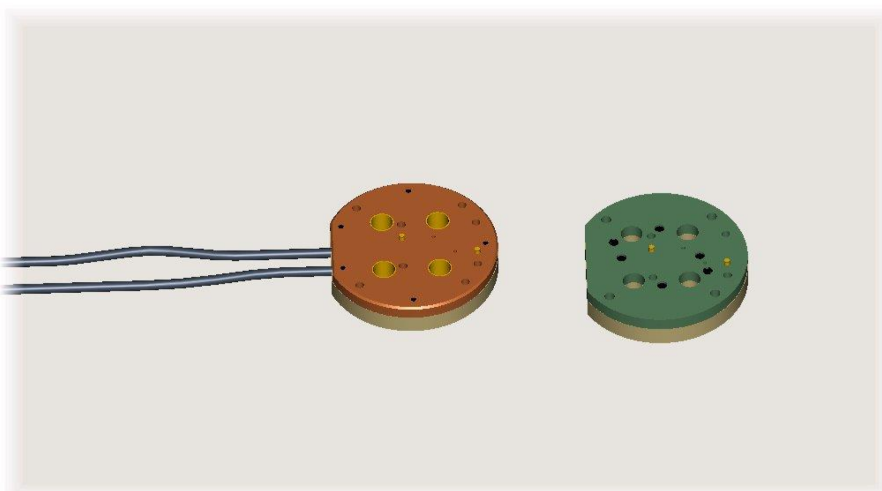


Figure 17: ES-2 upper neck load cell and the structural replacement.

3.3.2 Accelerations

Three uni-axial accelerometers can be mounted, on the upper face of the load cell or the load cell replacement, at the centre of gravity of the head.
Appropriate transducers are the Endevco model 7264A and Entran EGAS-500 or Endevco model 7264A-2000 and Kyowa ASM-200BA uni-axial accelerometers.

A Channel Filter Class of 1000 according to ISO 6487 or SAE J211 is recommended for the head acceleration signals.

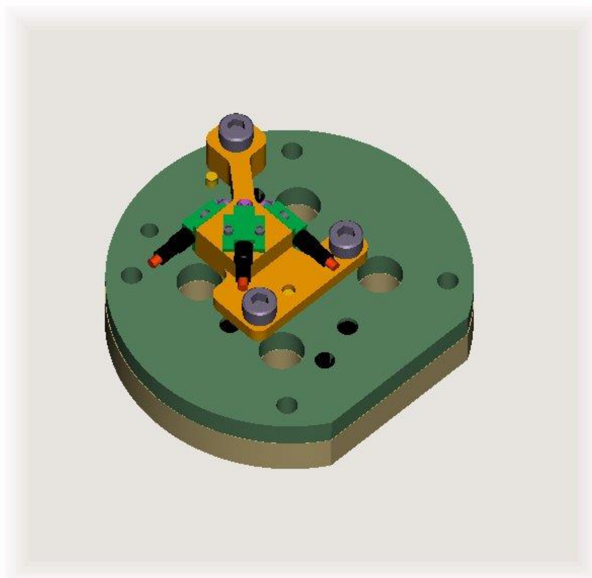


Figure 18: ES-2 Head accelerometer orientation on top of upper neck load cell replacement

3.4 Neck

3.4.1 Load cell

The neck-shoulder interface can be equipped with a 6-axis lower neck load cell. The capacity specification of this load cell is

- Fx = 12 kN (2697 lb)
- Fy = 12 kN (2697 lb)
- Fz = 14 kN (3146 lb)
- Mx = 450 Nm (3981 in-lb)
- My = 450 Nm (3981 in-lb)
- Mz = 300 Nm (2654 in-lb)

Appropriate load cells for this application are the Humanetics IF-221 or IF-226 or equivalent. The load cell replaces the standard neck bracket shown on figure 4.

3.5 *Shoulder*

3.5.1 Load cell

The shoulder-arm interface at the impact side can be equipped with a 3-axis Clavicle Load cell. The capacity specification of this load cell is:

- Fx = 4 kN (899 lb)
- Fy = 8 kN (1798 lb)
- Fz = 4 kN (899 lb)

Appropriate load cells for this application are the Humanetics IF-317 or IF-306 or equivalent.

NOTE:
Application of the load cell requires an optional available shortened cam, see Figure 6. This clavicle can be used at the right and left side of the dummy.

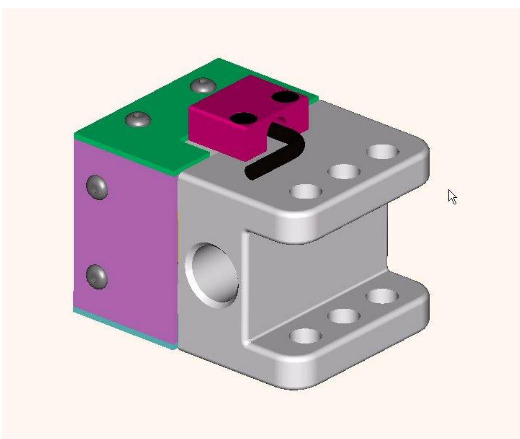


Figure 19: Shoulder load cell IF-317

3.5.2 Position indicator

Provisions are made to apply a thorax tilt sensor to the lower face of the shoulder assembly at the non-impact side. This sensor can be used to read the roll and pitch angle of the thorax during positioning of the ES-2 dummy prior to a test.

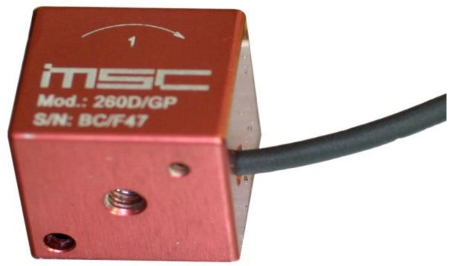


Figure 20: Shoulder tilt sensor

Appropriate equipment for this application is the MSC sensor model 260D/GP-M, to be used with a display unit.

3.6 Thorax

3.6.1 Load cell

The torso back plate can be equipped with a 4-axis load cell. The capacity specification of this load cell is:

- Fx = 3 kN (674 lb)
- Fy = 3 kN (674 lb)
- My = 160 Nm (1415 in-lb)
- Mz = 160 Nm (1415 in-lb)

An appropriate load cell for this application is the Humanetics IF-437 or equivalent. The Denton and FTSS load cells have different bolt pattern at the interface with the spine box. The spine box has provisions to accept both load cells. A structural replacement of the load cell is available (see Figure 21:).

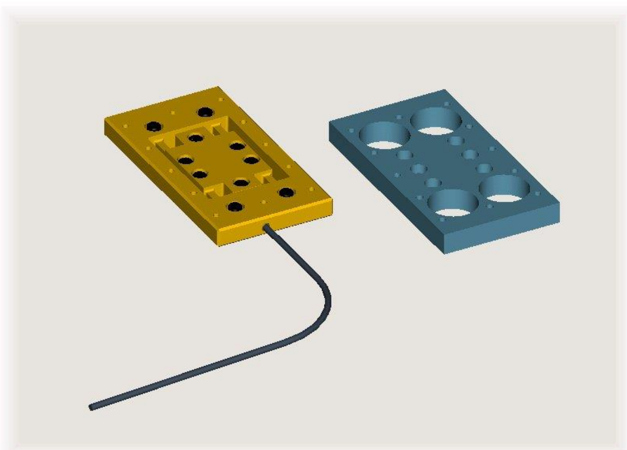


Figure 21: ES-2 torso back plate load cell (FTSS) and the structural replacement (The spine box has provisions to accept both attachment bolt patterns)

3.6.2 Accelerations

Provisions are made to mount an tri-axial accelerometer or three uni-axial accelerometers at the top of the thoracic spine to the shoulder bottom plate (see figure 22). If rib acceleration measurements are required, uni-axial accelerometers measuring X and Y accelerations can be mounted on the faces near the spigot of the rib displacement transducer (figure 23). Furthermore, it is possible to attach three uni-axial accelerometers to a mounting block fixed on the T12 - load cell to obtain lower thoracic spine acceleration measurements (see figure 24).

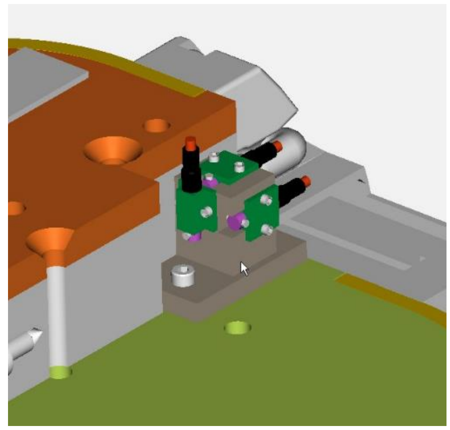


Figure 22: Upper Spine Accelerometers

Appropriate transducers are the Endevco model 7264A and Entran EGAS-500 or Endevco model 7264A-2000 and Kyowa ASM-200BA uni-axial accelerometers or at the shoulder the Endevco 7267A-1500 or equivalent tri-axial accelerometer, which has sensitive axes through a single point. Mounting blocks to fit the different uni-axial transducer types on the shoulder and T12 location are available through Humanetics.

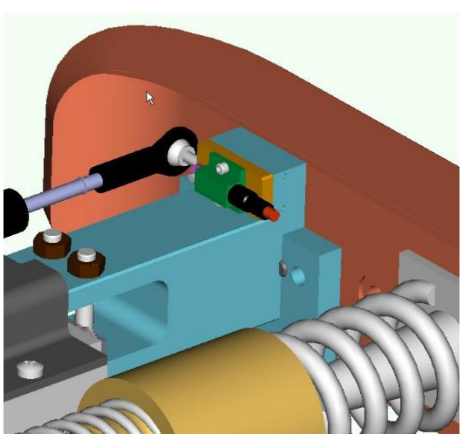


Figure 23: Rib Accelerometer, Y

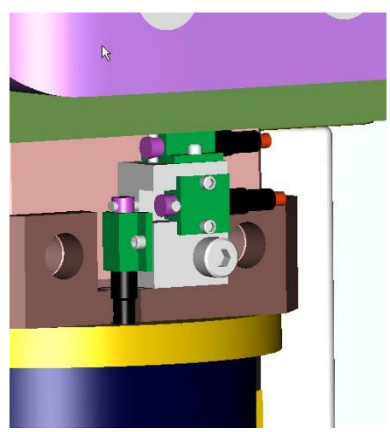


Figure 24: Accelerometers on T12 location.

A Channel Filter Class of 180 according to ISO 6487 or SAE J211 is recommended for both the thoracic spine and the rib accelerations. A special FIR 100 filter should be used for the TTI calculation.

3.6.3 Rib displacement

Linear potentiometers are used to measure the rib displacement in lateral direction relative to the spine box. The potentiometer with 76 mm (3") stroke is clamped on the housing to the guidance bracket and the rod is connected to the piston with a ball joint.
The main specifications of the potentiometer are:

- Resistance 4.5 kΩ
- Resistance tolerance ± 20%
- Linearity ± 0.1%
- Resolution infinite.

The wiring code is shown in Figure 25.

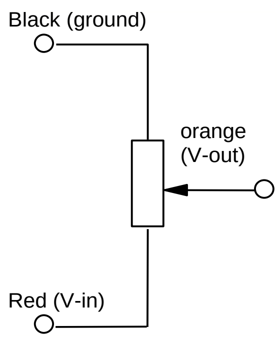


Figure 25: ES-2 linear potentiometer wiring code

A Channel Filter Class of 180 according to ISO 6487 or SAE J211 is recommended for the displacement signals.

3.7 Abdomen

3.7.1 Load cell

The thorax-abdomen interface is equipped with a 6-axis T12 - load cell. The capacity specification of this load cell is:

- Fx = 14 kN (3146 lb)
- Fy = 14 kN (3146 lb)
- Mx =1000 Nm (8848 in-lb)
- My =1000 Nm (8848 in-lb)

An appropriate load cell for this application is the Humanetics IF- 420 or equivalent. A structural replacement of the load cell is available.

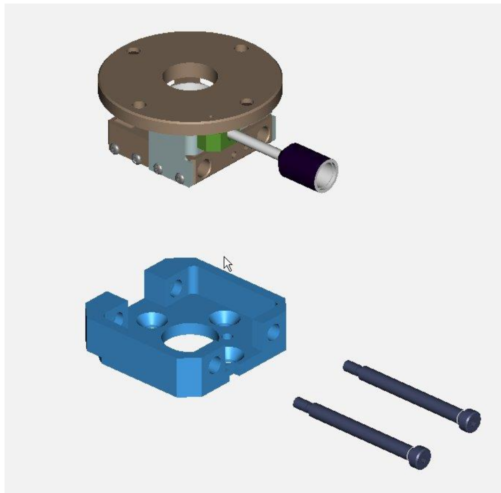


Figure 26: ES-2 T12 - load cell, lumbar spine adapter and shoulder screws

> **NOTE:**
> The attachment of the load cell to the lumbar spine adapter with the shoulder bolts has tight tolerances. Application of high-pressure 'Never Seez®'- grease on the shaft of the shoulder bolts is recommended (supplied in the toolbox).

Three uni-axial force transducers are positioned on the abdomen drum at the impact side. The three transducers are identical and their capacity specification is:

- ♦ Maximum load : 5 kN (1124 lb)

Appropriate load cells for this application are the Humanetics IF-600 or equivalent. Structural replacements of the load cell are available and used at the non-impact side (see Figure 28).

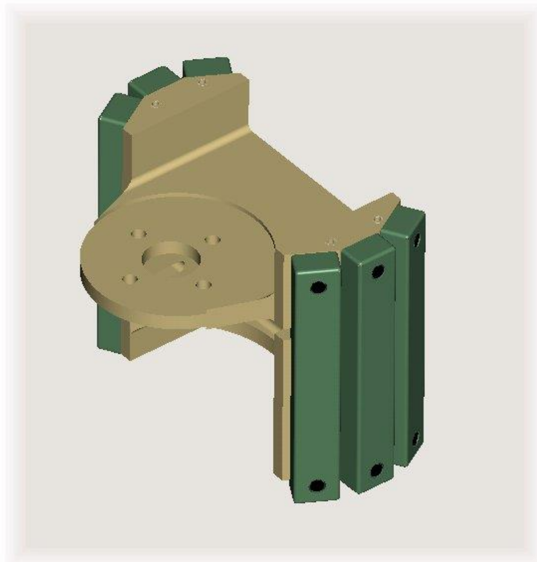


Figure 27: ES-2 abdomen drum with load transducer structural replacements

3.8 Lumbar Spine

3.8.1 Load cell

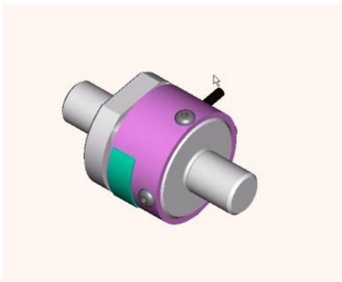
The lumbar spine-sacrum interface can be equipped with a 3-axis lower lumbar spine load cell. The capacity specification of this load cell is:

- ♦ Fy = 4.5 kN (1011 lb)
- ♦ Fz = 4.5 kN (1011 lb)
- ♦ Mx = 200 Nm(1769 in-lb)

Appropriate load cells for this application are the Humanetics IF-413 or equivalent. A structural replacement of the load cell is available (see Figure 11).

3.9 Pelvis

3.9.1 Load cells



The pelvis is equipped with a pubic symphysis load cell. The capacity specification of this load cell is:

♦ Maximum load : 20 kN (4494 lb)

Appropriate load cells for this application are the Humantics IF-556 or equivalent. A structural replacement of the load cell is available.

Figure 28: Pubic Load cell IF 556

NOTE:

The use of a Sensotec load cell (model T31) is discouraged. This type of load cell can cause errors, as it is found sensitive for bending. This is not the case for the Eurrosid-1.

3.9.2 Accelerations

The sacrum block of the ES-2 pelvis is designed to accept, an tri-axial accelerometer or three uni-axial accelerometers to measure the pelvis accelerations.

Appropriate transducers are the Endevco model 7264A and Entran EGAS-500 or Endevco model 7264A-2000 and Kyowa ASM-200BA uni-axial accelerometers or the Endevco 7267A-1500 or equivalent tri-axial accelerometer, which has sensitive axes through a single point. Mounting blocks to fit the different uni-axial transducer types in the pelvis are available through Humanetics Europe.

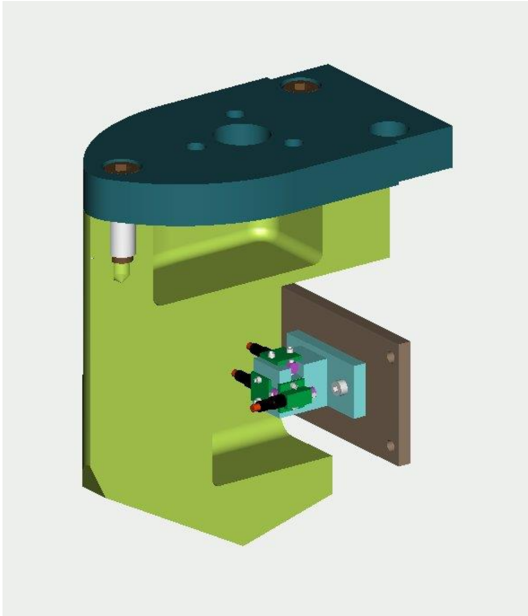


Figure 29: Pelvis accelerometers

A Channel Filter Class of 180 according to ISO 6487 or SAE J211 is recommended for the pelvis acceleration signals.

3.9.3 Position indicator

Provisions are made to apply a pelvis tilt sensor in the cavity at the aft side of the sacrum block. This sensor can be used to read the roll and pitch angle of the pelvis during positioning of the ES-2 dummy prior to a test.

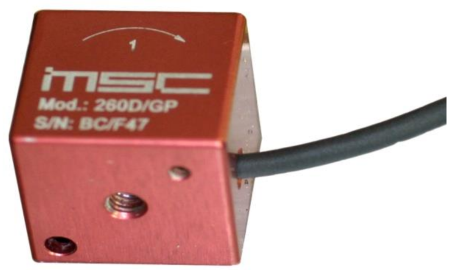


Figure 30 Pelvis tilt sensor

Appropriate equipment for this application is the MSC sensor model 260D/GP-M, to be used with a display unit.

3.10 Legs

3.10.1 Load cells

The upper leg can be equipped with a 6-axis Femur Load cell. The capacity specification of this load cell is

- Fx = 13.4 kN (3000 lb)
- Fy = 13.4 kN (3000 lb)
- Fz = 22.3 kN (5000 lb)
- Mx = 339 Nm(3000 in-lb)
- My = 339 Nm(3000 in-lb)
- Mz = 339 Nm(3000 in-lb)

  Appropriate load cells for this application are the IF-631 (6 AXIS femur with aluminium end caps 350 ohms) or IF-632 (6 AXIS femur with aluminium end caps 120 ohms) or equivalent.

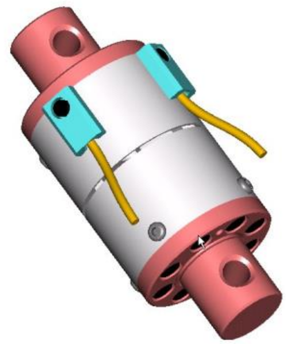


Figure 31: Femur load cell IF-631

NOTE:

The appropriate load cells each have a mass that is 0.370 kg higher than that of the leg parts they replace. To reduce this mass increase, aluminium end parts are available for the load cell at both suppliers. With these end parts installed a mass increase of only 0.120 kg per leg remains. This increase is considered acceptable. The end parts are shown in Figure 32.

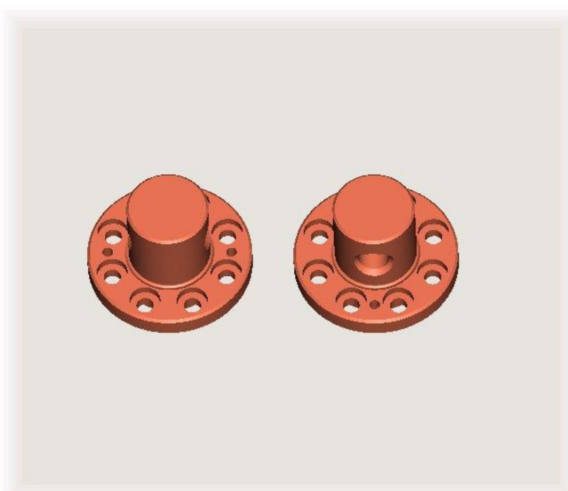


Figure 32: ES-2 high strength aluminium end parts for femur load cell

4 Disassembly and Assembly

4.1 Introduction

Disassembly and assembly of ES-2 is described in this chapter. Disassembly may be necessary in order to inspect, certify or repair the dummy or its parts. The body parts can usually be assembled by reversing the order described for the disassembly. Some instructions are given for important assembly actions. The description will be presented for each body part.

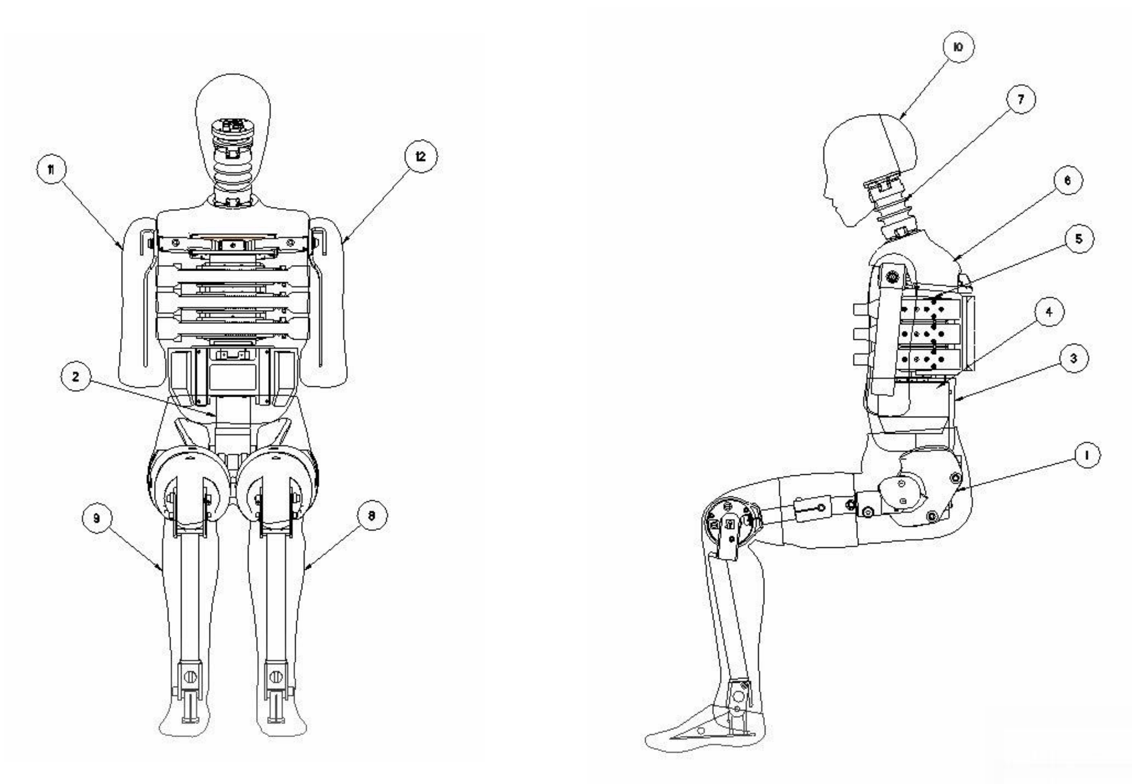


Figure 33: Overview

4.2 Special tools

A pelvis puller-tool and a neck compression tool (see Figure 34) are necessary for (dis-) assembly of the dummy. These tools are supplied with the dummy in the toolbox.

Figure 34: ES-2 pelvis puller tool (left) and neck compression tool (right)

4.3 Fasteners

The fasteners used in the ES-2 dummy are metric. However, there are two exceptions:

- The top and bottom interfaces of the lumbar spine are threaded imperial UNC ¼"-20. The spine cable and the nut with UNF ½"-20
- The fasteners and threads in the legs remain non-metric (because the Hybrid II legs are used).

Table 4 shows size, type, quantity and, if applicable, torque specification of all fasteners used in the dummy.

Table 4: Fasteners used

WHERE	LOCATION	TYPE	SIZE	QTY	TORQUE
Head	Skull Cap - skull	Cap head	M6x16	4	
	Load cell - skull	Cap head	M6x22	4	
	Accelerometer mounting block - Load cell	Cap head	M2.5x14	2	
Neck	Load cell - neck	Cap head	M6x12	4	
	Neck - Interface plates	Special half spherical	M12	2	10 Nm

WHERE	LOCATION	TYPE	SIZE	QTY	TORQUE
	Neck – neck bracket	Cap head	M6X18	4	
Shoulder	Neck bracket – Shoulder	Cap head	M6x35	4	
	Eye bolt		M12	1	
	Cam spring – Shoulder	Button head	M5x10	1	
	Cam spring – Clavicle	Button head	M4x16	4	
	Cam cover – Shoulder	Button head	M4x20	4	
	Accelerometer Plate – Shoulder	Cap head	M3x12	2	
	Elastic cord holder	Button head	M4x25	4	
	Shoulder – Spine box	Countersunk	M6x50	3	
Arm	Arm – Shoulder	Button head lock screw	M10x30	2	
Thorax	Rib unit – spine box	Cap head	M8x20	3x2	
	Torso back plate load cell – Spine box	Cap head	M6x20	6	
	Torso back plate – load cell	Countersunk	M6x20	12	
Rib unit	Protection cover – bracket	Cap head	M3x8	3x4	
	Transducer mount – bracket	Countersunk	M3x25	3x2	
	Transducer head –piston	Cap head	M2.5 x 16	3x1	
	Rib – piston & cylinder	Button head	M4x10	3x8	
	Damper – Cylinder	Cap head	M6x35	3x2	
	V-bearing to Piston	Countersunk	M4 x 20	3 x 6	
	V-bearing to piston	Lock nut	M4	3 x 6	
	M-bearing to bracket	Cap head	M4 x 20	3 x 6	
	Spring locator to piston	Cap head	M5 x 10	3 x 1	
	Cylinder to bracket	Cap head	M6 x 18	3 x 3	
	Accel mount to piston	Cap head	M1.6 x 6	3 x 2	
	Spring locator – Rib	Button head	M4x10	3x1	
T12 Load Cell	T12 load cell – spine box	Cap head Countersunk	M6x12 M6x12	2 2	
	T12 load cell – Lumbar spine adapter **(see below)**	Socket shoulder bolt	M6x60	2	

WHERE	LOCATION	TYPE	SIZE	QTY	TORQUE
	Accelerometer mounting block – T12 load cell	Socket Head	M4x18	1	
Abdomen & Lumbar spine	T12 load cell – abdomen drum – lumbar spine	Counter sunk	UNC¼"-20x1"	4	
	Lumbar spine – Lumbar mounting plate	Cap head	UNC¼"-20x¾"	4	
	Nut for spine cable	Hex	UNF ½"-20	1	
	Cover Plate – Drum	Countersunk	M4x10	4	
	Transducers – Drum	Cap head	M4x16	12	
	Latching Plate – Drum	Cap head	M4x8	2	
	Accelerometer block to T12	Cap head	M4x18	1	
Pelvis	Lumbar mounting plate – Sacrum block	Cap head	M8x25	4	
	Iliac – Sacrum block	Cap head	M10x40	4	
	Sacrum cover plate	Button head	M4x12	3	
	Accelerometer Plate – Sacrum cover plate	Cap head	M3x12	2	
	Hip pivot pin – iliac wing	Cap head	M8x25	2	
	H-point back plate – Hip pivot pin	Low cap head	M6x16	2	
	Buffer Assembly – Upper Femur	Low cap head	M5x18	4	
	Upper femur – leg	Shoulder bolt	M12x16x40	2	
Legs	Femur load cell – femur bone and knee structure	Cap head	UNC⅜x16x1 ¾"	4	

CAUTION:

The attachment of the load cell to the lumbar spine adapter with the shoulder bolts has tight tolerances. The M6x60 shoulder bolts in T12 load cell must be mounted with high-pressure grease applied to prevent fretting. (High pressure 'Never Seez®'-grease available in the toolbox)

4.4 Head

The head-neck interface of the ES-2 dummy differs from that of EUROSID-1 because of the integration of the upper neck load cell.

Although it is not necessary, it is easier to remove the head/neck assembly from the thorax (see Section 4.5) before disassembling the head.

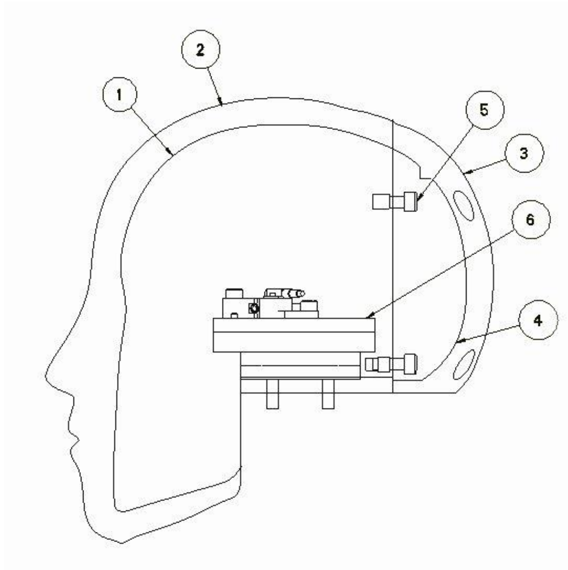


Figure 35: Head assembly (E2.J)

Part list Head assembly, Figure 35

Item	Part No.	Qty	Description
1	250-1002	1	Skull machined Eurosid-2
2	E.JB	1	EuroSID Head skin, Tested / Certified
3	78051-229	1	Skin, cap skull
4	78051-220	1	Skull cap machined
5	5000081	4	Screw SHCS M6 x 16
6	E2.JC	1	Upper neck load cell Structural replacement

To separate the head from the neck, first remove the skullcap by unscrewing four M6x16 screws (5000081) in the back of the head. Secondly, remove the four M6x12 screws (5000281) in the upper neck load cell (or structural replacement) inside the head and take the head-load cell combination from the neck. Finally, unscrew the four M6x22 screws (5000282) from the head bottom interface and remove the upper neck load cell (or structural replacement) from the head, through the opening at the back of the head.

4.5 Neck

4.5.1 Disassembly

Unscrew the four M6x30 screws connecting the neck bracket to the shoulder assembly and separate the head/neck-assembly from the shoulder. Turn the assembly upside down and unscrew the four M6x16 screws at the base of the neck to separate neck and neck bracket. To remove the head, see Section 4.4.

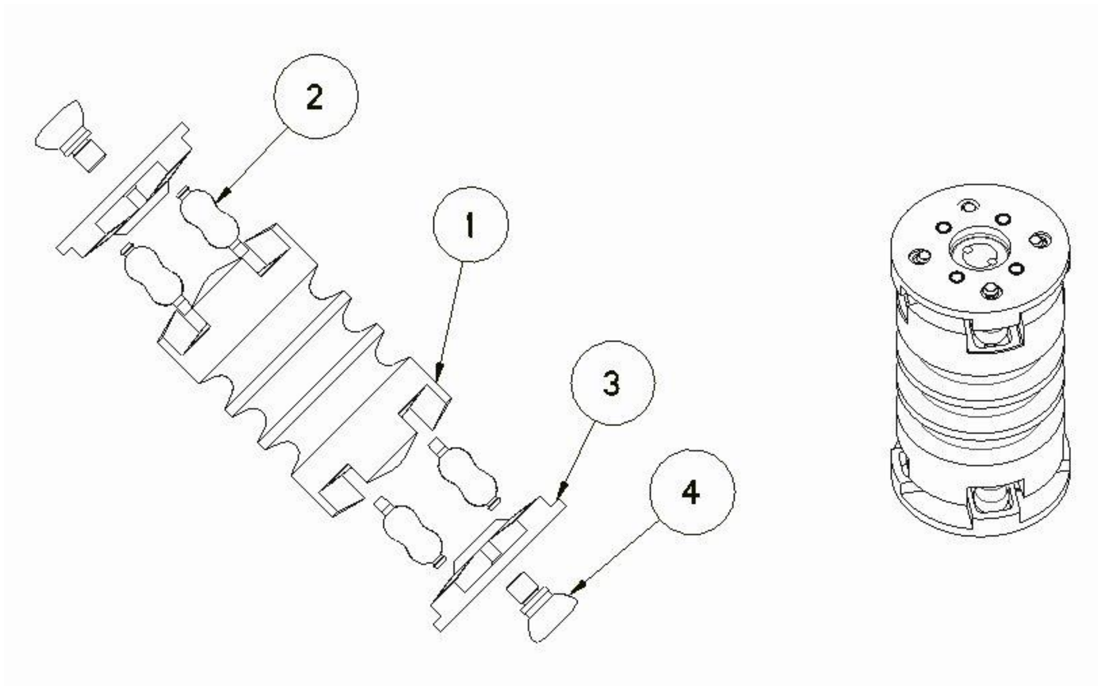


Figure 36: **Eurosid-2 Neck assembly (E2.B)**

Parts list Eurosid-2 Neck assembly, Figure 36

Item	Part No.	Qty	Description
1	E2.BA	1	Skull machined Eurosid-2
2	E2.BB..	8	Neck buffer moulded (60, 70 or 80 shore)
3	E2.BD	2	Neck Head & Torso Interface Plate
4	E2.BC	2	Half Spherical Screw Eurosid-2

Use the neck compression tool for disassembly of the neck. To remove the top and bottom interface plates and the eight circular section buffers from the central part, unscrew the half-spherical screw on the top and the bottom of the neck.

4.5.2 Assembly

The circular section buffer has one mushroom-shaped end and one cylindrical end (see Figure 37). The mushroom-shaped ends must be pressed firmly into the four holes of the interface plates. Check that the complete mushroom top protrudes in the counter bore at the flat face of the interface plate. Application of some non-oil based lubricant and a turning action during assembly may help to get the buffer into the correct position. The cylindrical end of circular section buffers should be positioned correctly into the intermediate plate (fixed to the central mounding part), when reassembling the top and bottom interface plates. Check that the bottom and top interfaces are aligned according to the marks 'top-rear' and 'bottom-rear'. Now the half-spherical screws can be refitted. Before assembly, the half-spherical surfaces of the screws should be greased with high-pressure 'Never Seez®'- grease, which is supplied in toolbox. Tighten the half-spherical screws with 10 Nm.

On further assembly of the neck in the dummy, make sure of the correct orientation with respect to head and thorax. This is indicated on the top and bottom interface plates.

Figure 37: ES-2 neck circular section buffers. Three hardness' 60 (red), 70 (yellow) and 80 Shore A (blue)

4.6 Shoulder

4.6.1 Disassembly

To start, the arms should be removed from the shoulder clavicles (refer to 4.8.).
Remove the head-neck assembly from the dummy (see section 4.5). Unscrew three M6x50 (5000009) countersunk screws that attach the shoulder to the spine box and remove the shoulder.

To take off the clavicles, the elastic cords should first be released from the elastic cord holder by pulling the loose ends backward out of the teethed grooves. The clavicles can now be removed from the shoulder assembly by removing the central M5x10 screw (5000003) located at the front of the spacer. The clavicles/U-spring assembly can then be pulled out of the shoulder box. The clavicles can be separated from the U-spring by releasing the four M4x16 screws.

For a complete disassembly of the shoulder box, remove eight M4x20 screws from the sides and back of the assembly. Now the coated top and bottom plates, the spacer block, the cover plates, the cam stops and the elastic cord holder come apart.

Figure 38: Shoulder assembly

Partlist Shoulder assembly, Figure 39

Item	Part No.	Qty	Description
1	E2.CC	1	Shoulder bottom plate (E2-3003)
2	E.CB	1	Shoulder spacer block (A30112)
3	E.CD	1	Shoulder U-spring (A30114)

4	E2.CF	2	Shoulder Cam Clavicle (includes items 9, 19 and 10)
5	E.CE	1	Shoulder Cover Plate (A30115)
6	E2.CM	1	Elastic Cord Holder (R30135)
7	E2.CA	1	Shoulder Top Plate (E2-3002)
8	E.CG	2	Cam Stop Block
9	Pivot Stop pin (INCLUDED IN SHOULDER CAM CLAVICLE)		
10	Shoulder Cam Clavicle End Plate (INCLUDED IN SHOULDER CAM CALVICLE)		
11	E2.CH	2	Elastic Cord and End Bushes (includes item 18)
12	Velcro (INCLUDED WITH SHOULDER FOAM CAP)		
	E2.CJ	1	Shoulder foam Cap (includes item 12) NOT SHOWN
14	5000005	4	Screw BHCS M4 x 12
15	5000003	1	Screw BHCS M5 x 10
16	5000007	4	Screw BHCS 20
17	5000004	4	Screw BHCS M4 x 25
18	End Bushing (INCLUDED IN ELASTIC CORDS)		
19	Spring (INCLUDED IN SHOULDER CAM CLAVICLE)		

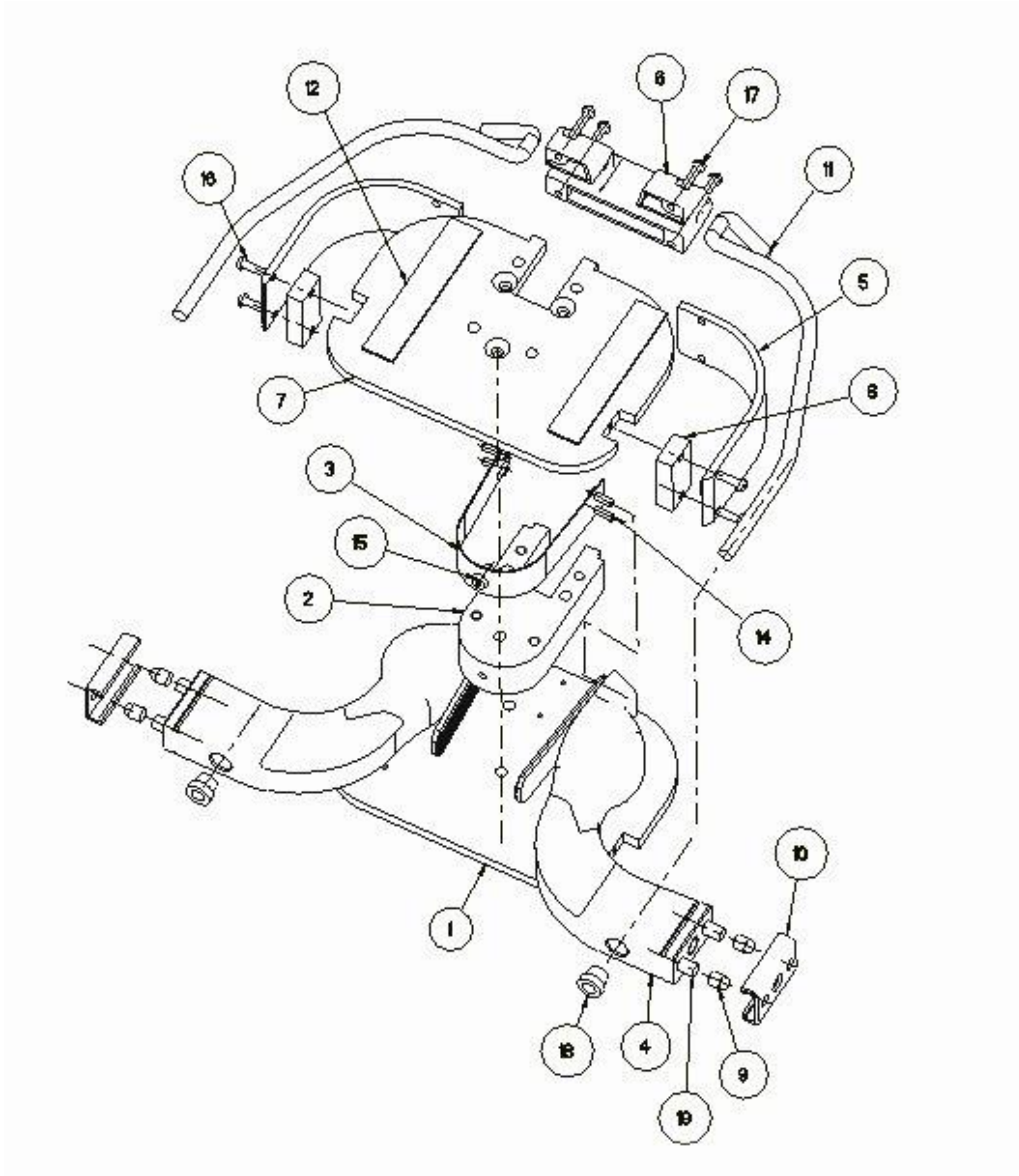


Figure 39: Shoulder assembly (exploded view)

4.6.2 Assembly

When reassembling the shoulder all surfaces of the clavicles and inner surfaces of the top and bottom plates should be clean. The two clavicles should be fitted to the U-spring and be mounted in the shoulder assembly. The elastic cords should be reattached to the elastic cord holder and adjusted according to the certification procedure (see section 5.8). The correct routing of the elastic cord is shown in figure 40. First feed the cord through the hole, then pull the cords back out into the teethed groove and secure it in the open hole at the end of the groove. The left and right cords should not cross.

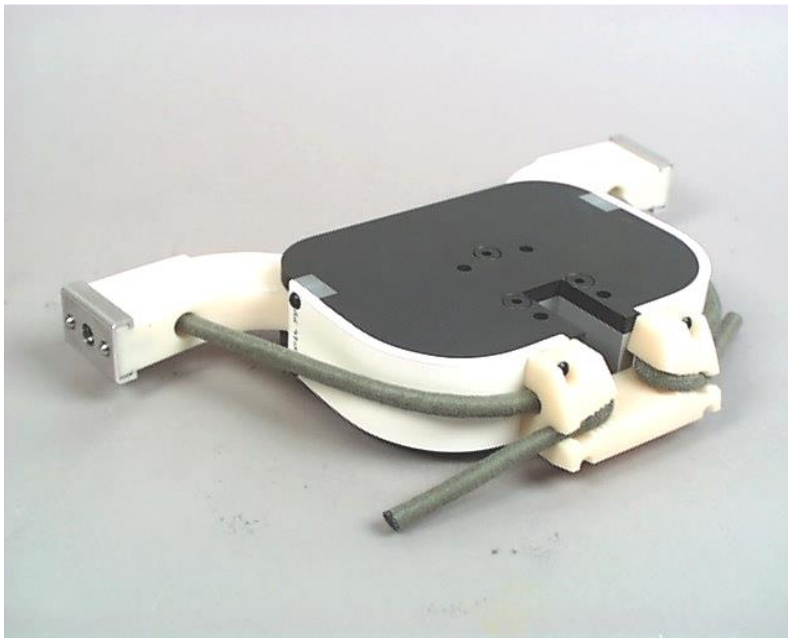


Figure 40: ES-2 elastic cord routing through clavicle and elastic cord holder

4.7 Thorax

In some cases, the work on the ES-2 thorax is easier if the dummy is split at the thorax-abdomen interface at the T12 location. To separate upper and lower body parts of the dummy remove the two M6x60 shoulder screws located at the rear in the T12 - load cell. When the screws are removed, the upper part of the dummy can easily be lifted off the lower part of the dummy using the eyebolt in the neck bracket Figure 4.

Parts list Thorax assembly, Figure 41

Item	Part No.	Qty	Description
1	E2.DA	1	Spine Box Eurosid-2
2	E2.DW	3	Complete Rib Module (A40200)
3	E2.DCA	1	Replacement torso back plate load cell (BV1016)
4	E2.DDA	1	T12 Structural Replacement (B-4338)
5	E2.DCC	1	Narrow Back Plate Curved (R40124)
6	5000036	12	Screw FHCS M6 x 20
7	5000075	6	Screw SHCS M8 x 20

8	5000001	6	Screw SHCSM6 x 20
9	5000281	2	Screw SHCS M6 x 12
10	5000139	2	Screw FHCS M6 x 12

CAUTION:

Never lift the upper body by the ribs.

Use the eyebolt in the neck bracket Figure 4.

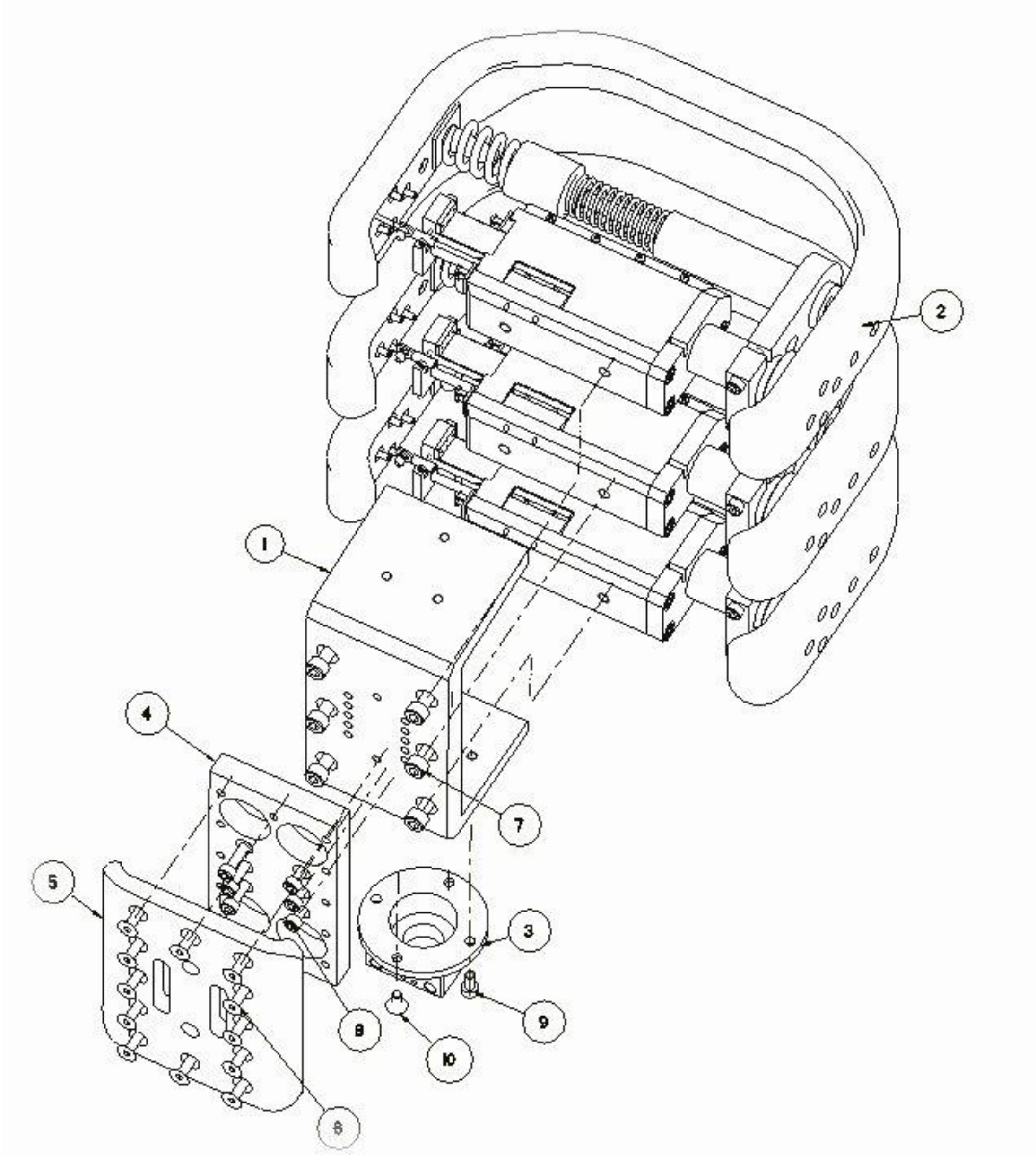


Figure 41: Thorax assembly

4.7.1 Disassembly of the thorax

To take a rib unit from the thorax remove the torso back plate and load cell assembly or structural replacement (six M6x20 cap heads) accessible from the back of the dummy. Each rib unit can be removed by unscrewing two M8x20 screws. The complete rib unit is shown in Figure 42.

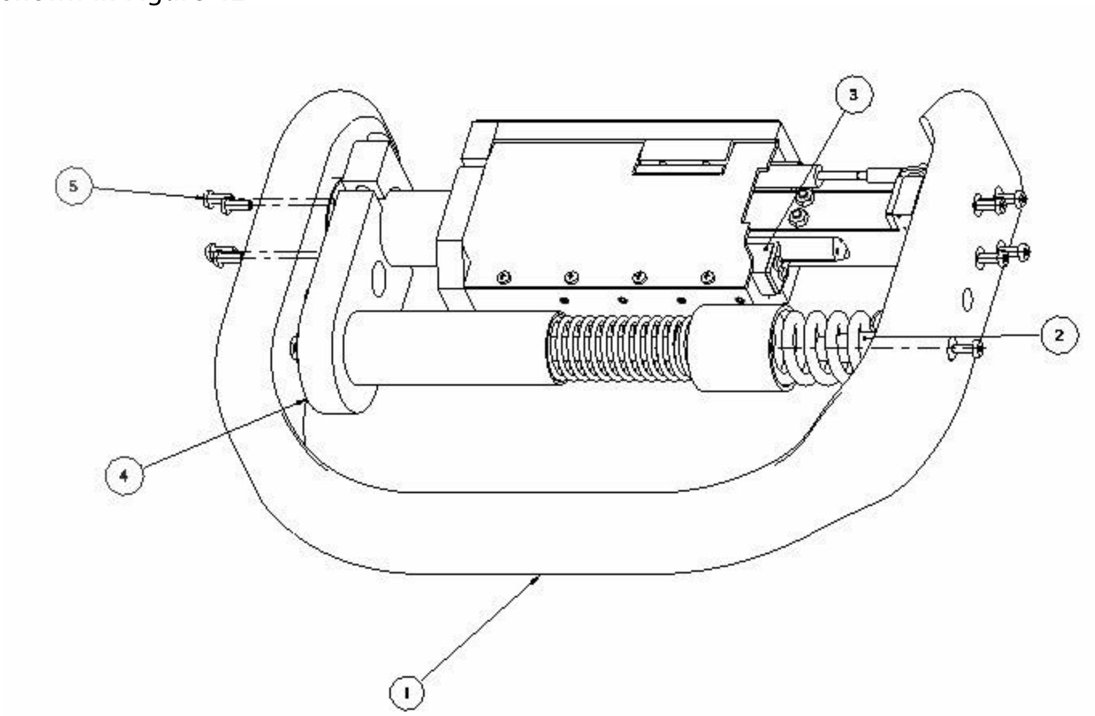


Figure 42: ES2 Rib unit complete

Figure42: ES-2 rib unit complete

Item	Part No.	Qty	Description
1	E.DG	1	Rib Covered with Foam, certified. (A-40211-A)
2	E.DK	1	Damper Spring Locator (A40215)
3	E2.DMM*	1	Rib rail assembly
4	E2.DH*	1	Damper spring assembly
5	5000010	9	Screw BHCS M4 x 10

*Not available as a sales assembly item.

4.7.2 Disassembly of rib unit

The rib unit guide system linear bearings are protected with a transparent plastic cover. To remove the protection cover from the rib unit, unscrew the four M3x8 screws at the forward side of the guidance bracket. Pull the cover forward to disengage it from the groove at the rear of the guidance bracket.

4.7.2.1 Disassembly transducer

Unscrewing the two M3x25 countersunk screws from the mounting block and detaching the rod end from the piston side by unscrewing the M2.5 screw can remove the linear displacement transducer.

4.7.2.2 Disassembly damper system and rib bow

The damper can be removed from the rib unit by unscrewing the two M6x35 screws in the mounting clamp. With the mounting clamp removed, the damper can be rotated and taken out of the rib unit. The piston is attached to the rib bow by four M4x10 button head screws. At the opposite end, the rib bow is also attached to the cylinder by four M4x10 button head screws. These screws can be reached through the holes in the rib flesh. The damper system can now be checked following the steps given in section 4.7.3.

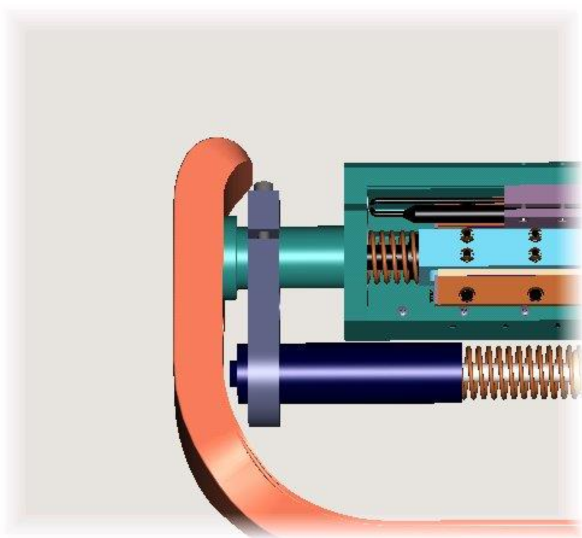


Figure 43: ES-2 assembly of damper in rib module

4.7.2.3 Disassembly the rib linear guide system

For normal servicing the needle bearing guide system must be checked on proper performance the following functions.

1. Check free movement of the piston, without any play or friction, over the full stroke
2. Check that needle cages are aligned with the end stops in the two extreme positions.

For in-depth checks and trouble shooting the needle bearing guide system can be checked following the steps given section 4.7.4. The needle bearing system can be disassembled by unscrewing the remaining screws and nuts in a sequence reversed to that describe in section 4.7.4 for assembly.

RECOMMENDATION

It strongly recommended NOT to disassembly the rib guide system during normal servicing.

4.7.3 Checking and bleeding of the damper

The damper should be bled when the damper fails to pass its inspection test described in Section 5.9.5. Bleeding instructions in this paragraph should be followed.

1. Hold the damper vertical with the piston rod up. Move the piston and listen for any squishing noises of air in the oil. (This procedure causes air collection at the top end of the damper).
2. Reverse the orientation of the damper by 180 degrees (piston rod down) and move the piston, again listen for any squishing noises. (This procedure will cause air collected in action 1 to pass through the damper piston, causing the squishing noise referred to).
3. If necessary repeat actions specified under 1 and 2. If air is heard in the oil repeat action 2 slowly, using strokes of decreasing amplitude and with the piston rod nearly fully withdrawn. Support the damper vertically for a few moments. (This procedure causes all air to be collected on the annular side of the piston and the rest period allows the air that has been emulsified in the oil to be collected at the bleed hole).
4. Carefully remove the bleed screw and either add some extra oil to the damper or carefully push in the piston, pushing the oil up to the top of the bleed hole.

NOTE:

Use only the special damper oil supplied in the toolbox. Other hydraulic oils are not suitable and will ensure the damper to be out of specification.

5. Replace bleed-screw.
   CAUTION: DO NOT over-tighten the bleed screw.
6. Having bled the damper, recheck for air, operations 1 and 2.
7. In addition, check that the stroke of the damper is at least between 46 - 50 mm.

This procedure guarantee's that the damper has not inadvertently been overfilled

NOTE:

If a damper is overfilled, it might lock during a test.

4.7.4 Assembly of rib unit

When assembling the rib unit cleanliness of the working area is of utmost importance. Use a clean and dust free assembly table and tools for this job.

4.7.5 Assembly of rib unit

When assembling the rib unit cleanliness of the working area is of utmost importance. Use a clean and dust assembly table and tools for this job.

4.7.5.1 Assembly of linear guide system

The parts of the linear bearing system can be recognised by their shape and are referred to as M-rail and V-rail.

1. Put the piston buffers (O-ring lace, D=8mm, L=14 mm) in the recesses. Make sure that these buffers do not protrude above the M-rail mounting faces of the guidance bracket.
2. Assemble the guidance bracket and the cylinder by the three M6 cap head screws.
3. Mount end stop plates to both ends of the M-rails using M3 button head screws. Push all the play out in direction to the non-guiding side of the M-rail.
4. Put bushings in the V-rails, with little Loctite 222 on it to secure them, slide them back to back in the slot of the piston and assemble the M4 countersunk screws and the self-locking nuts at the top. Do not tighten the nuts at this stage.
5. Attach the tuning spring support on the left side of the piston with one M5x10 screw.
6. Make sure that the guidance bracket cylinder combination (including the piston buffers) is ready for assembly on the table with the cylindrical part to the left and the rail mounting recess up.
7. Wipe M-rail and V-rail -faces with clean cloth, making sure they are free of dust and extraneous particles.
8. Now stack in one hand in this sequence: M-rail, needle cage, piston with V-rails, needle cage and M-rail and drop the stack in the guidance bracket. Make

sure that the M-rails counter boreholes are facing up and the large piston end is facing to the right. Make sure that the plastic that connects the needle cages to each other is as far as possible of the point of the V of the V-rail. Otherwise rotate them 180° around its Z-axis.

9. Assemble all six screws (M4 cap heads) to hold the bearing assembly. Do not tighten the screws at this stage.
10. Screw in the four M4 set screws in the front face of the guidance bracket, not tightening them now.
11. Move the piston and needle cages to the most left e.g. retracted position. The piston must touch the end stop. Set the piston in 'half way position' that the nuts of the piston are on the same height with the bolds of the M-rail.
12. Give some pretension on the four M4 set screws in front face of the guidance bracket.
13. Tight the six M4 screws of the M-rail. In combination with 11. all the play is pushed out into direction of the non-adjustable guidance bracket side.
14. Tight the v-rails in the piston firmly after alignment. To tighten the V-rail screws and nuts put the assembly on the rear face. A small amount of play allows the piston to be aligned with the V-rails before tightening the screws. This alignment is important for the installation of the transducer (see section 4.7.4.2 assembly step 5) (Note: The hexagon sockets of the screws can be reached through holes in the bottom face of the guidance bracket. Move the piston to mid position, to align the screw heads with the holes.)
15. Set the 3 M4 M-rail screws at non-adjustable side on 8 Nm.
16. Release the tension of the 4 M4 set screws and 3 M4 M-rail screws at the same side.
17. Check that the piston moves freely, without play, with even resistance over the complete length of the stroke. If not, the buffers installed in assembly step may protrude and interfere with the V-rail.
18. Hand tight the 3 screws in such way that movement of the M-rail (with a minimum of play, mount 3 screws of the M-rail so hand tight, that no initial angle can be introduced between guidance bracket and M-rail.) still is possible. Move the M-rail by turning gently the 4 M4 screws towards the M-rail. Do this in such way that the rail is as parallel as possible regarding to the V-rail. Feel the movement of the piston in the guidance bracket every adjustment

19. If there is not any play and is the piston moving smoothly, fasten then these 3 screws on the adjustable side of the M-rail also with 8 Nm.
20. Check the movement of the piston again. If movement of piston has changed, start over with point 20.
21. Insert the tuning spring as used during certification test.
22. Install the rib bow and attach it to the cylinder and to the piston with four M4 screws at each side.
23. For transducer installation reference in made to section 4.7.4.2
24. For damper assembly installation reference is made to section 4.7.4.3
25. Install the bright plastic protection cover by inserting it in the guidance bracket groove at the aft side and with four M3 screw at the forward side (see figure 44).

Table 5: ES-2 Tuning springs colour codes

Tuning spring colour	Spring rate [kN/m]	Wire gauge [mm]
White	13.8	3.25
Black	16.4	3.50
Blue	19.0	3.75

4.7.5.2 Assembly transducer

To mount the linear potentiometer the following assembly steps must be performed:

1. Insert the transducer in the plastic-mounting block.
2. Attach the rod end of the transducer to the piston with the transducer spigot M2.5 and retainer ring.
3. Screw the mounting block to the guidance bracket with two M3x25 countersunk screws. Do not tighten the screws at this time.
4. Slide the transducer through the plastic-mounting bracket to obtain the required 60 mm free retraction length of the transducer rod. Figure indicates the measurement to be taken.
5. Tighten the M3x25 screw in the mounting block.
6. Check the alignment of the transducer housing and the rod. If the rod is bent the piston must be re-aligned in the guide system (see section assembly step 4)

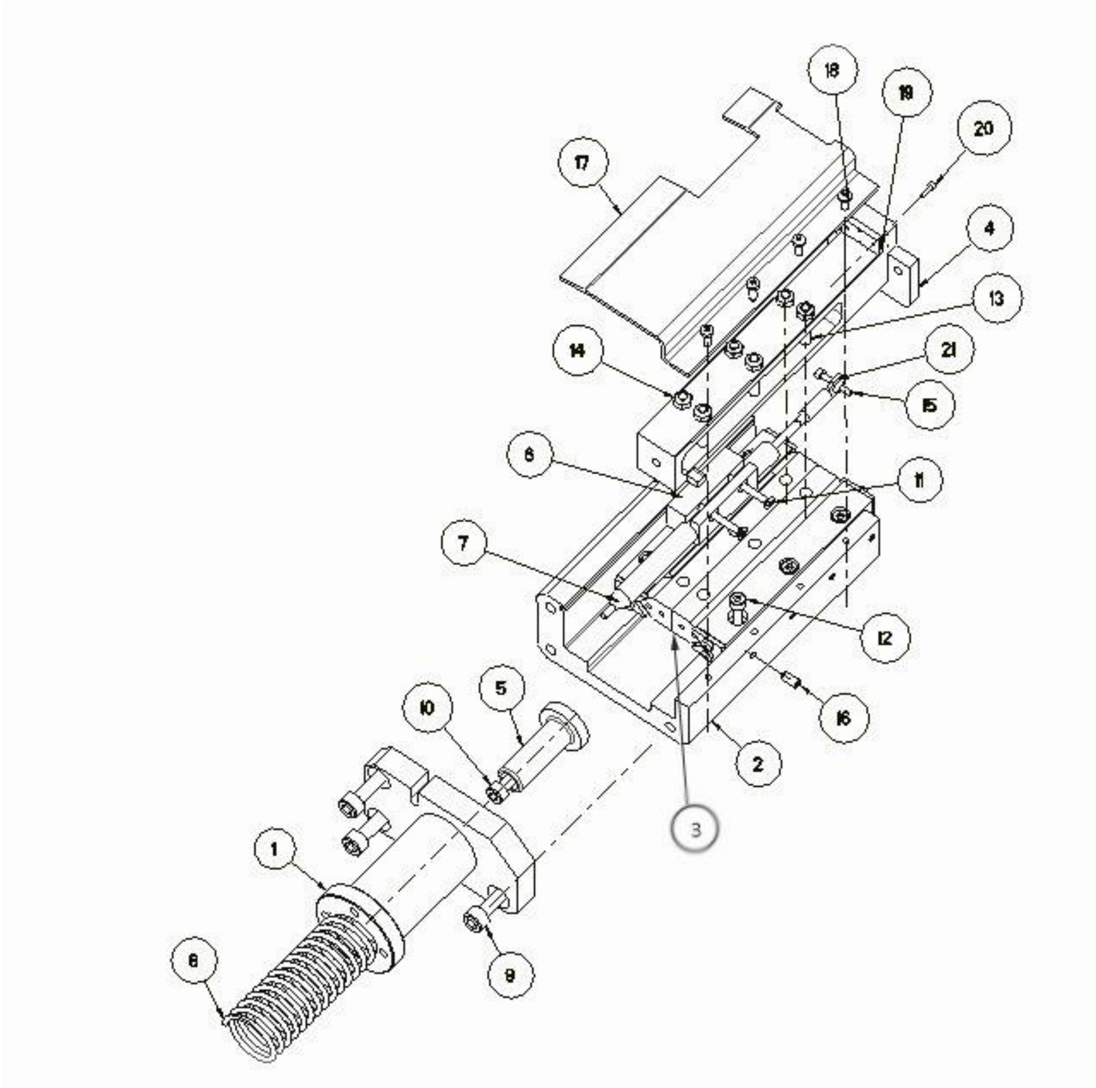


Figure 44: Rib rail assembly

Parts list Rib Rail Assembly: Figure 44

Item	Part No.	Qty	Description
1	E2.DMA	1	Cylinder Eurosid-2
2	E2.DME	1	Guidance Bracket
3	E2.DMD	1	Linear Guide Bearing Assembly
4	E2.DMB	1	Piston Eurosid-2
5	E2.DMH	1	Tuning Spring Support
6	E2.DX	1	Transducer mount.
7	E2.LB	1	Potentiometer assembly (includes item 21)

8	E2.DP..	1	Tuning Spring (3 different stiffness available) E2.DPB, E2.DPC,E2DPD
9	5000285	3	Screw SHCS M6 x 18
10	5000291	1	Screw SHCS M5 x 10
11	5000355	2	Screw FHCS M3 x 25
12	5000287	6	Screw SHCS M4 x 20
13	5000289	6	Screw FHCS M4 x 30
14	5000290	6	Nut M4 Self Locking
15	5000283	1	Screw SHCS M2.5 x 16
16	5000288	4	FPSS M4 x 8
17	E2.DB	1	Rib Guidance cover
18	5000294	4	Screw Pan Head Philips M3 x 8
19	E2.DML	1	Rib Accelerometer Mount Eurosid-2
20	5000343	2	Screw SHCS M1.6 x 6
21	E2.DY	1	Rod End for transducer (included in E2.LB)

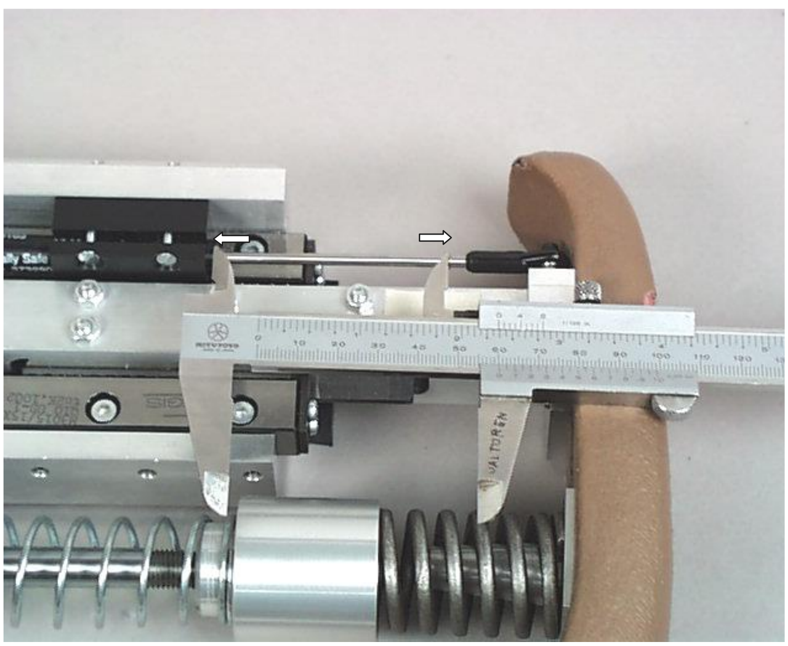


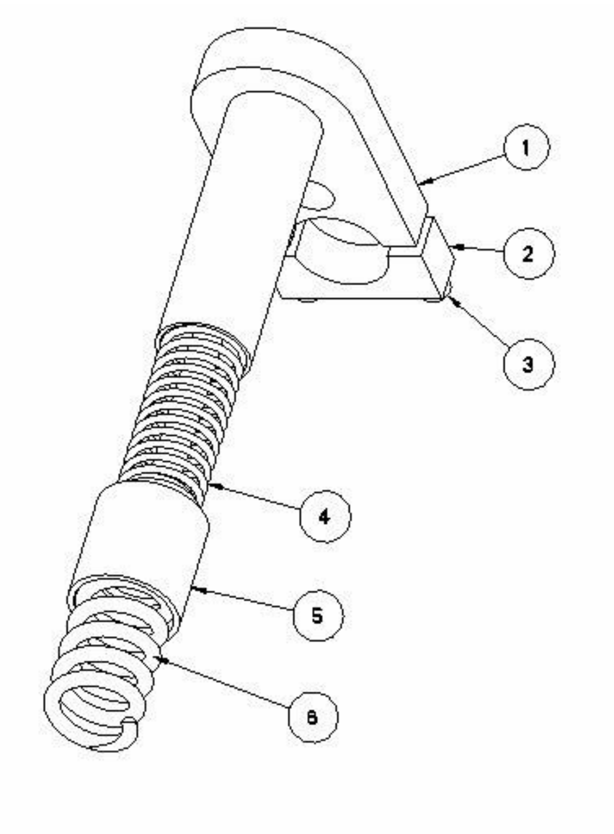
Figure 45: ES-2 transducer rod minimum free retraction length is 60 mm.

4.7.5.3 Assembly damper system

The installation of the damper includes the following assembly steps:

1. Put the return spring over the damper rod.
2. Screw the damper cup on the damper rod, compressing the return spring. The thread on the damper rod should protrude through the damper cup.

3. Insert the stiff damper spring into the damper cup
4. Position this damper-spring combination in the rib bow with the stiff damper spring engaged with the spring locator on the rib and the clamp-bracket on the cylinder. A small gap (2-5 mm) between the rib and bleed plug of the damper in required. (See Figure 43).
5. Install the clamp with two M6x35 screws. Make sure that the damper clamp bracket is parallel to the bottom face of the guidance bracket.



6. Remove the axial play of the stiff damper spring between the damper cup and the spring locator on the rib. This can be done by unscrewing the damper cup.

CAUTION:
DO NOT un-screw the cups too much so that the damper stroke is reduced. If this does occur, the performance of the rib will be adversely affected. The rib may fail to meet the requirements during certification.

After certification (see section 5.9), the rib modules can be assembled in the spine box for either left- or right-hand side impacts.

Figure 46: Damper assembly

Parts List Damper assembly, Figure 46

Item	Part No.	Qty	Description
1	A40112-A	1	Damper Assembly, tested
2	E.DO	1	Damper clamp (A40219)
3	5000014	2	Screw SHCS M6 x 35

4	E.DI	1	Damper Return Spring (A40213)
5	E.DL	1	Damper Spring Cup (E2-4208)
6	E.DJ	1	Stiff Damper Spring (A40214)

4.8 Arms

The arm is attached to the shoulder cam clavicle by a single M10x30 button head screw. This screw is self-locking by a prevailing torque plastic coating.

Between the arm skeleton and the head of the screw, a ball bearing cage is fitted between two washers. Between the arm skeleton and the shoulder cam clavicle, a Pivot Stop Plate (transparent plastic) is fitted allowing discrete arm orientations at 0, 40 and 90 degrees with respect to the torso line. Tighten the M10 screw to obtain a 1 - 2G holding force of the arm.

NOTE:

The Pivot Stop Plates for the left and right side are not interchangeable. The plates carry the indication LH and RH for respectively left hand and right hand application.

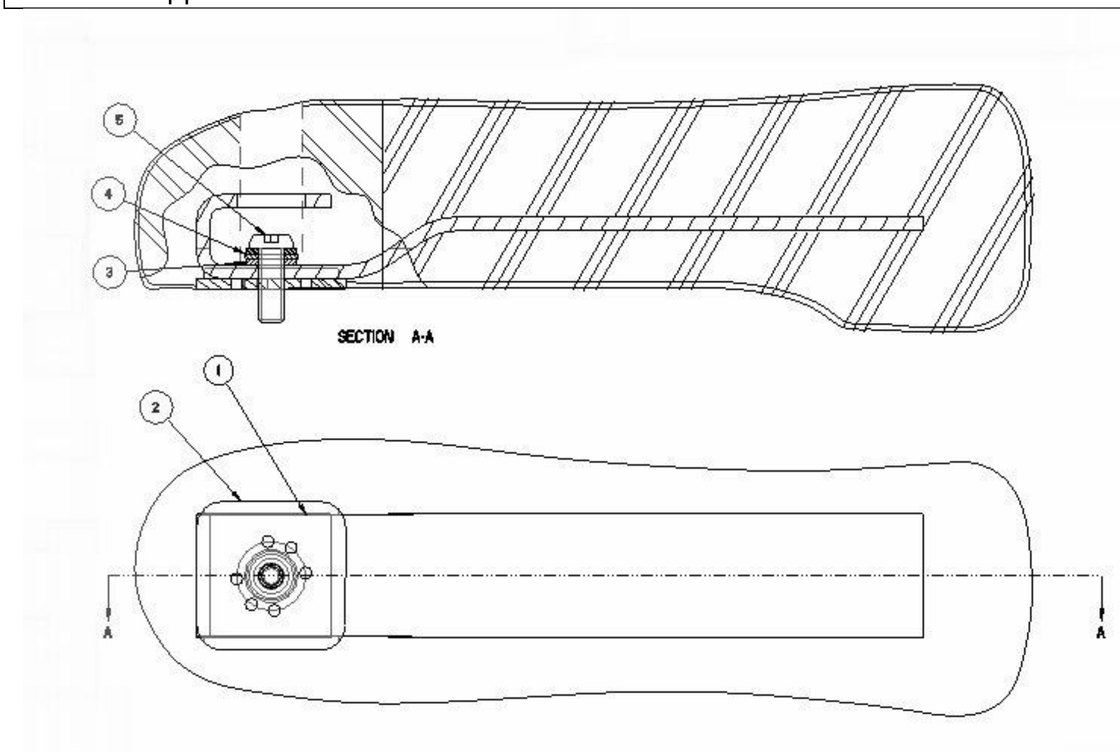


Figure 47: Arm assembly

Parts list: Arm (LH shown), Figure 47

Item	Part No.	Qty	Description
1	E.HA	1	Upper Arm Left or Right
2	E.HCL	1	Pivot Stop plate Left
	E2.HD	1	Arms Screws and Bearing (includes items 3, 4 and 5)
3		2	Washer flat (5000105)
4		1	Bearing thrust (5000104)
5		1	Self Locking Screw BHCS M10 x 30 (5000040)

4.9 Abdomen

To disassemble the abdomen, separate the dummy at the T12 location e.g. the top of the lumbar spine (see Section 4.7). Remove four UNC1/4"-20 countersunk screws connecting the T12 load cell base adapter and abdomen drum to the lumbar spine. Lift the complete abdomen assembly from the lumbar spine and turn it upside down (See Figure 49).

CAUTION:

Do not attempt to separate the abdomen foam covering from the drum while the abdomen is still assembled inside the dummy, this will damage to the covering.

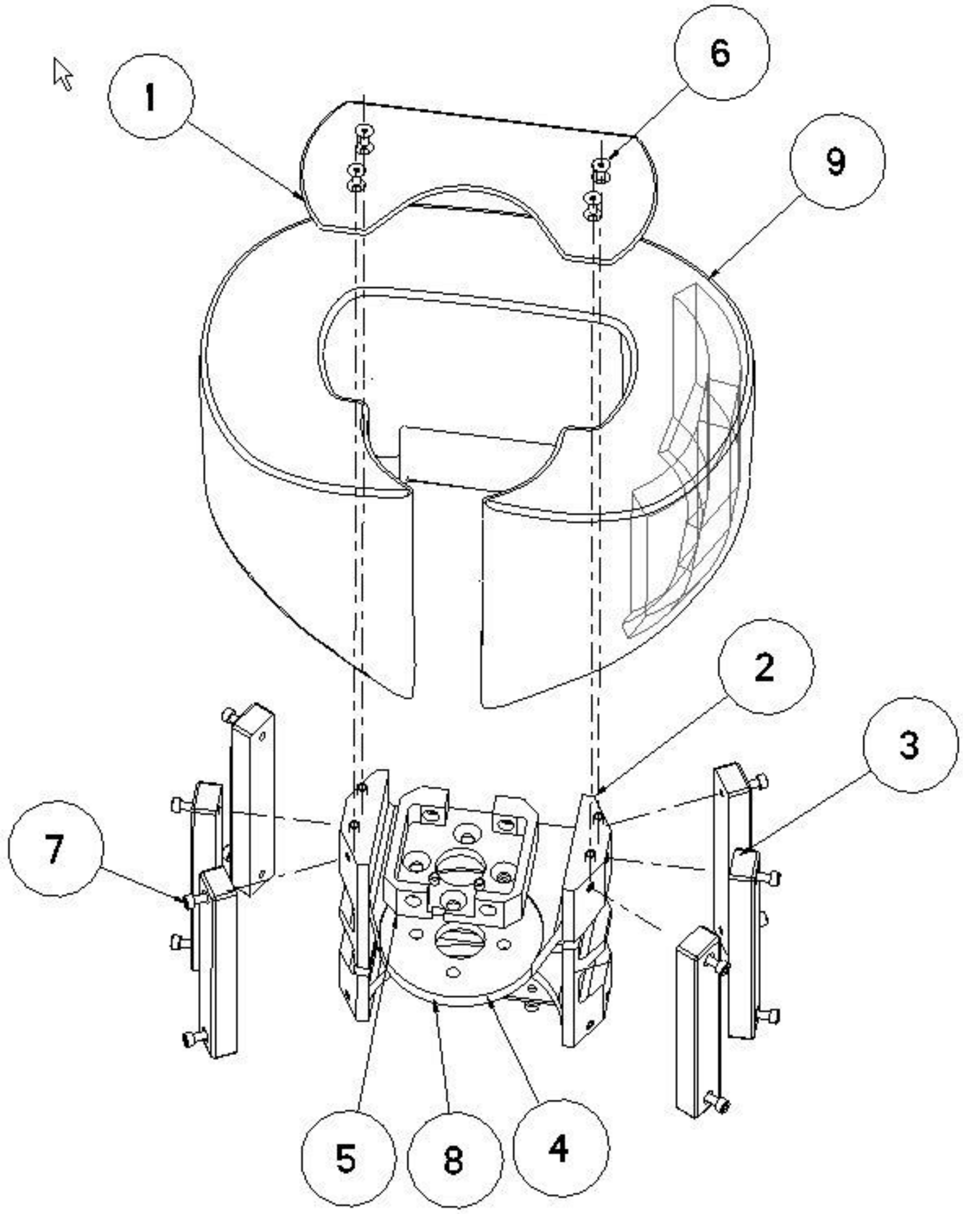


Figure 48: Abdomen assembly

Parts list Abdomen assembly, Figure 48

Item	Part No.	Qty	Description
1	E.FC	1	Cover plate
2	E2.FB	1	Abdominal Drum
3	E.FE	3	Non Measuring dummy unit
4	E.FD	1	Latching Plate
5	E2.DDB	1	T-12 Base adaptor (B-4328)
6	5000023	4	Screw FHCS M4 x 10
7	5000025	12	Screw SHCS M4 x 16
8	5000024	2	Screw SHCS M4 x 8

To remove the abdomen foam covering, unscrew two M4x8 cap head screws to remove the small latching plate, see Figure 48. The foam covering can be separated from the drum by slightly bending it open and lifting it off.

The force transducers and the non-measuring structural replacements can be removed by unscrewing the two outer M4x16 cap head screws per unit (see Figure 50).

Figure 49: ES-2 abdomen (shown up side down)

Figure 50: ES-2 abdomen drum and force transducer structural replacements

When changing the force transducers to the other side (to change the impacts direction of the dummy) and/or reassembling the force transducers, ensure the correct the routing of the cables. The cables should be feed through the scallops in the drum and should not be squashed between the force transducers and the drum. First, position, the front transducer followed by the middle and finally the rear one.

When reassembling the foam covering, it should fit closely around the drum and the force transducers.

4.10 Lumbar spine

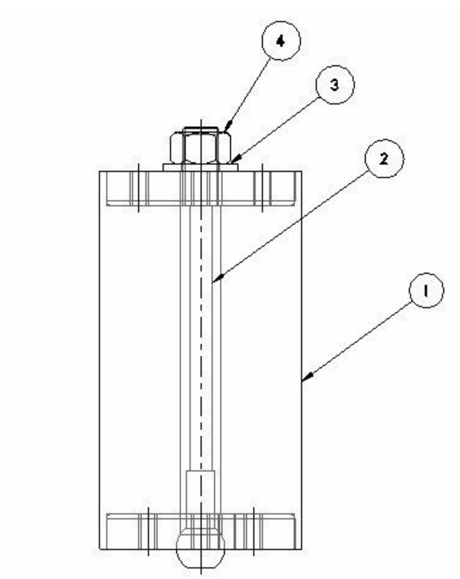


Figure 51: Lumbar spine assembly

Before the lumbar spine can be reached, the abdomen has to be taken off. Refer to section 4.9 for abdomen disassembly. After the abdomen is removed the lumbar spine is exposed, see Figure 52. To remove the lumbar spine, unscrew three M8x25 cap head socket screws at the sacrum cover plate or the lower spine load cell to remove it from the sacrum block in the pelvis. The sacrum cover plate can be removed from the lumbar spine by unscrewing three UNC ¼"-20 x ¾" screws underneath the lumbar spine. In case of application of the lower lumbar spine load cell, there are four UNC ¼"-20 x ¾" screws underneath the lumbar spine.

The steel cable can be removed from the rubber central part by unscrewing the UNF ½"-20 nut on top of the lumbar spine. To prevent the spine cable from twisting during release and fastening of the nut, the cable must be held with a screwdriver.

Re-assembly of the lumbar spine is in reverse order

Parts list Lumbar Spine assembly, Figure 51

Item	Part No.	Qty	Description
1	E2.EB	1	Lumbar Spine moulded, tested (E2-6100)
	E.EA	1	Lumbar Cable Assembly (includes items 2, 3 and 4)
2	78051-69	1	Cable, Lumbar
3	5000267	1	Washer 13mm ID x 24m OD x 2.5mm THK.
4	9000057	1	Nut Hex ½-20

Figure 52: ES-2 lumbar spine and bottom plate mounted on pelvis assembly

4.11 Pelvis

4.11.1 Disassembly

Once the upper part of the dummy has been detached (see section 4.7) and the abdomen and the lumbar spine have been removed (see sections 4.9 and 4.10), the pelvis can be disassembled.

The legs can be removed from the pelvis by unscrewing the M12x16x40 shoulder bolts. These can be reached through the most forward holes on the side of the pelvis.

Pull out the H-point foam blocks from the pelvis flesh. Unscrew the M6x16 low cap head screws in centre of the H-point back plate (see figure 53). The H-point back plate and its buffer assembly will come out easily, see Figure56

To remove the pubic symphysis force transducer or the structural replacement, unscrew the transducer bushes at both sides using an extended socket wrench 13 mm across flats. The bushes can be reached through the openings were the H-point assemblies were fitted. After unscrewing them completely from the transducer thread, bushes will still be held in the iliac wings. Now screw the pelvis puller tool into the head of the transducer bush and pull it out. Then the force transducer and spacers can be removed from topside.

Figure 53: ES-2 pelvis with H-point foam block removed showing H-point back plate

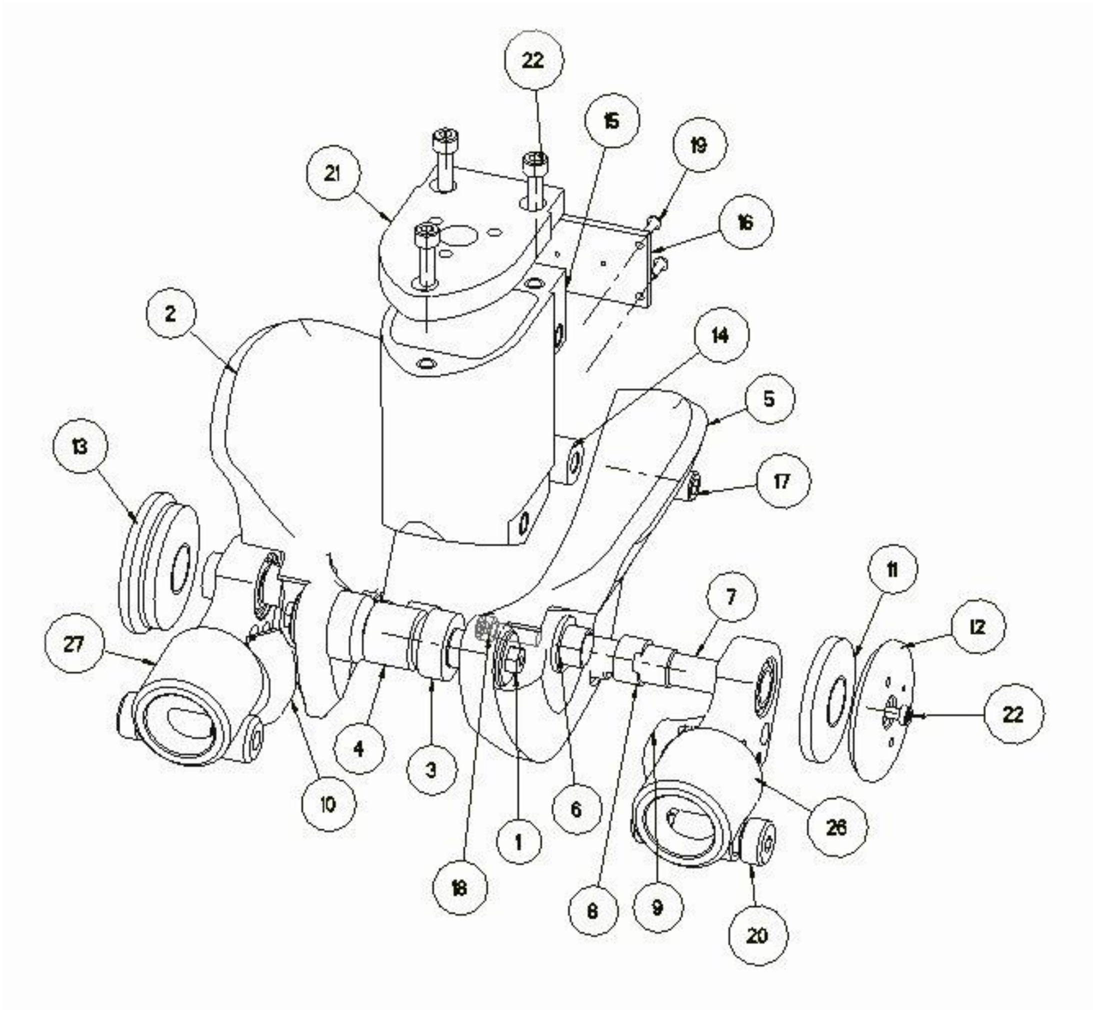


Figure 54: Pelvis bone assembly

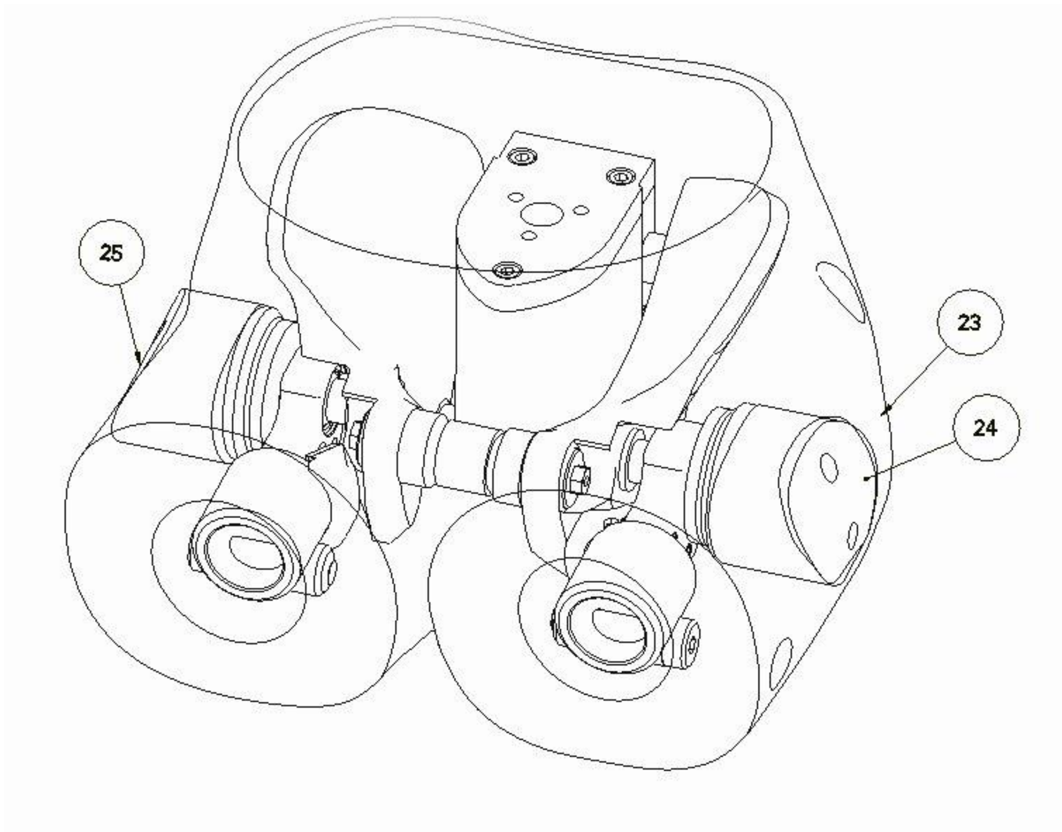


Figure 55: Pelvis flesh assembly

Parts list Pelvis, Figure 54 and 55

Item	Part No.	Qty	Description
1	E2.GK	2	Transducer bushing (R70146)
2	E2.GB	1	Iliac Wing Assembly Right (R70143)
3	E2.GW	2	Transducer Spacer (R70141)
4	E.GJ	1	Load cell Structural replacement (A70119)
5	E2.GC	1	Iliac Wing Assembly Left (R70142)
6	E2.GS	1	Spacer Ring (R70132)
7	E2.GG	2	Hip Pivot Pin (R70131)
8	E2.GT	2	Tube Stop (R70135)
9	E2.GQL	1	Femur Buffer Assembly Left (R70139)
10	E2.GQR	1	Femur Buffer Assembly Right (R70140)
11	E2.GR	2	Back plate Buffer (R70147)
12	E2.GIL	1	H-point Back plate Left (R70134)
13	E2.GIR	1	H-point Back plate Right (R70133)
14	E.GO	4	Sacrum Spacer (A70113-C)

15	E2.GD	1	Sacrum Block (E2-7013)
16	E.GN	1	Sacrum Cover plate (A70113-B)
17	5000032	4	Screw SHCS M10 x 40
18	5000030	5	Screw SHCS M8 x 25
19	5000005	4	Screw BHCS M4 x 12
20	5000298	2	Screw SHSS Shoulder screw M12 x40 (16)
21	E.GP	1	Lumbar mounting plate (A70113-D)
22	5000296	2	Screw LHCS M6 x 16
23	E.GA	1	Pelvis moulded (A70111)
24	E2.GHL	1	H-point foam block Left (R70144)
25	E2.GHR	1	H-point foam block Right (R70145)
26	E2.GE	1	Upper Femur including Bearing Left
27	E2.GF	1	Upper Femur including Bearing Right

Figure 56: ES2 H-point back plate and its buffer assembly removed

Disassembly of the upper femur is easier if the pubic force transducer is removed from the pelvis. The upper femur can be removed by unscrewing the M8 cap head screw located at the inside of the iliac wing. The hip pivot pins are held against rotation by a rectangular fit in the iliac wing. After pulling the hip pivot pins out, the upper femurs come out at the front, see figure 57.

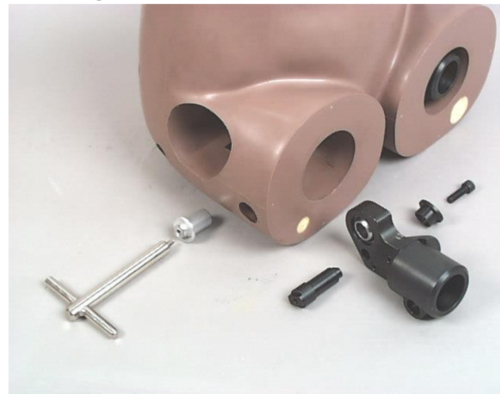


Figure 57: ES-2 pelvis, transducer bush and upper femur removed

Once the upper femurs and pubic force transducer have been removed, the iliac wings and sacrum block can be separated from the pelvis flesh moulding. First, remove the sacrum block by unscrewing the two M10x40 cap head screws, at each side, that can be reached through the rearward holes in the sides of the pelvis (see Figure 53). Pull the sacrum-block out of the pelvis and note the two spacer rings between sacrum block and iliac wing on both sides. When the sacrum block has been removed, the iliac wings can be pulled out of the pelvis flesh moulding.

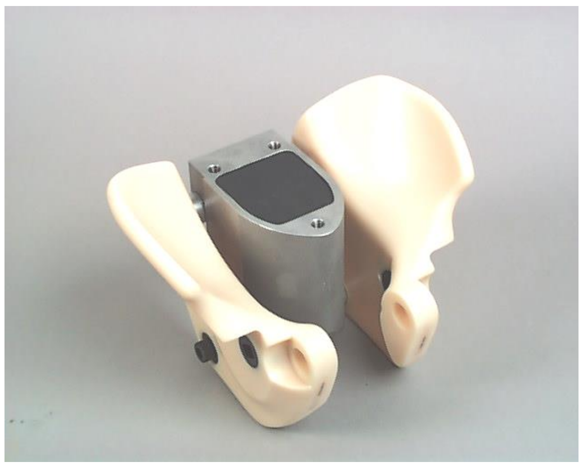


Figure 58: ES-2 pelvis internal parts sacrum block and iliac wings

4.11.2 Assembly

Assembly of the pelvis is in reverse order of disassembly. When reassembling the pelvis, attention should be paid to the tightening of the transducer bushes. The direction of the cable coming out of the transducer should point towards the lumbar mounting plate to prevent damaging the cable in tests. Tighten the transducer bushes with a torque of 10 Nm.

The H-point left and right back plates are not interchangeable. When assembling the H-point back plates note that the flat side is facing downward.

4.12 Legs

The legs can be removed from the pelvis by unscrewing the M16x40 shoulder bolts. These can be reached through the most forward holes on the side of pelvis flesh moulding.

To disassemble the femur load cells unscrew the two UNC 3/8"-16x1¾" screws accessible from the forward face of the upper leg.

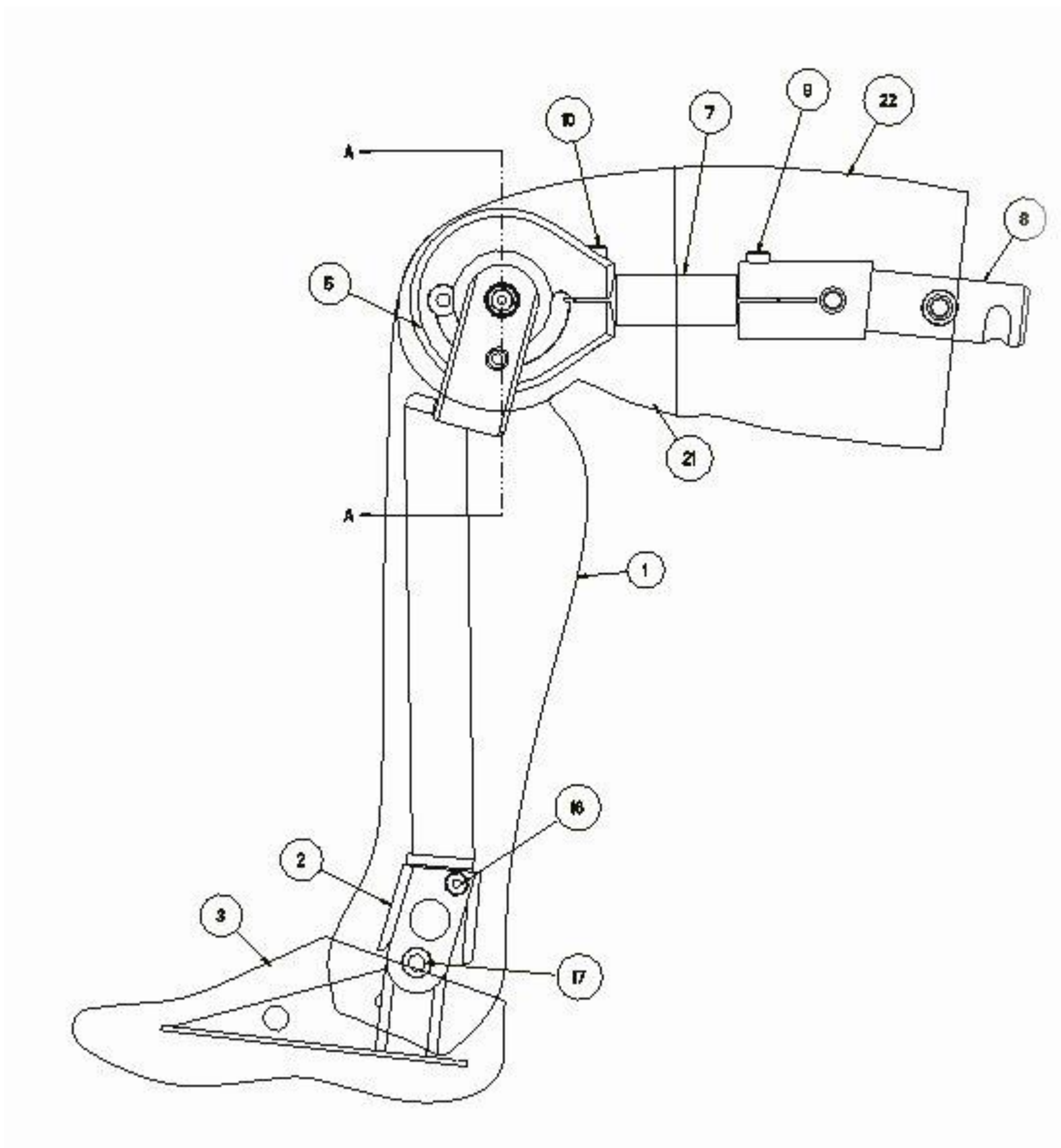


Figure 59: Legs

5 Certification

5.1 Introduction

The certification procedures for the various body parts are primarily based on the use of standard Part 572 (ref. 5) equipment. An exception is made for the thorax. The rib modules are separately tested in three series of drop tests.

Depending on the side to be impacted, dummy parts should be certified on the left or right side. The direction of the rib modules (including instrumentation) and the abdominal force transducers should be converted to the desired impact side (see Section 4.7 and 4.9 for thorax and abdomen respectively).

The certification tests on the dummy can be distinguished into two categories: component tests and full body tests.

Component tests:

- Head : a free-fall drop test with the side of the head impacting a flat rigid surface. Equipment needed is similar to equipment used in Part 572 subpart E;
- Neck : a test with a Part 572 subpart E pendulum using the EUROSID-1 head form and ES-2 interface, causing lateral flexion, as well as rotation and translation of the neck top interface;
- Thorax : impactor drop tests on each rib module;
- Lumbar spine : a test with a Part 572 subpart E pendulum using the EUROSID-1 head form and ES-2 interface, causing lateral flexion, as well as rotation and translation of the lumbar spine top interface.

Full body tests:

- Shoulder : a lateral impact with the Part 572 subpart E, four wire suspended 23.4 kg impactor on the upper arm pivot;
- Abdomen : a lateral impact with the Part 572 subpart E, eight wire suspended 23.4 kg impactor equipped with an 1.0 kg armrest-face, on the centre of the abdomen; Total weight 24.4 kg.
- Pelvis : a lateral impact with the Part 572 subpart E, eight wire suspended 23.4 kg impactor on the H-point of the dummy.

The certification procedure of each body part is described in Sections 5.5 - 5.12. Special tuning and certification equipment necessary to perform the tests is described in Section 5.2. In Section 5.3, time interval requirements for the ES-2 certification tests are given and Section 5.4 deals with the trigger levels and time shift to be used for processing ES-2 certification data.

NOTE: The ES-2 certification tests are in general equivalent to those applicable to its predecessor, EUROSID-1. Some details of the certification procedures for the neck, thorax, abdomen and lumbar spine are revised.

5.2 Certification and tuning equipment

For the free-fall head drop test a support and release mechanism, as well as a rigid, flat impact surface is necessary. The release mechanism and impact surface can be similar to that of the Standard Part 572 subpart E head drop test [ref. 5]. The ES-2 head drop support can be used or any user-made item which ensures the correct orientation of the head and a mass is 0.075 ± 0.005 kg.

Figure 60: ES-2 head drop support (part no H.AB2)

For the neck and lumbar spine tests, a pendulum is required similar to the Standard Part 572 subpart E, neck-bending pendulum (ref. 5). The pendulum is decelerated by aluminium honeycomb (crush strength 1.8 lbs./cu. ft). The exploded view of the EUROSID-1 head form is presented in Appendix 4. The head form includes three rotational potentiometers so that no additional instrumentation is needed to measure the rotations of the head form. For use of the EUROSID-1 head form with ES-2 neck and lumbar spine, an interface plate is required (see figure 61.) This interface is available through your local Humanetics office.

NOTE:

The slotted holes in the interface plate allow assembly to all known head form configurations.

Figure 61: ES-2 neck and lumbar spine interface plate for certification (H.AD)

For the impacts on the shoulder, abdomen and pelvis, a wire suspended Standard Part 572 subpart E pendulum is necessary [ref. 5]. In the abdomen test, this pendulum is equipped with an 'armrest' face. This impactor-face as shown in the Figure 62 below is equivalent to that of EUROSID-1.

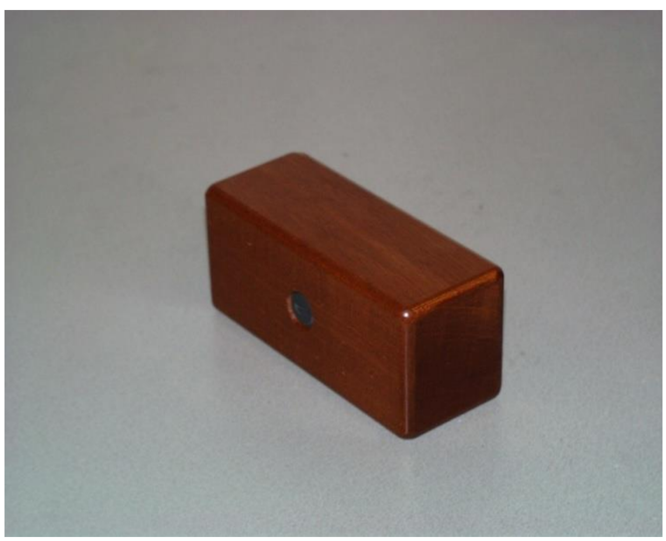


Figure 62: Armrest for Abdomen calibration (H.AA)

For the certification of the rib modules and for the inspection tests on the dampers and rib only, a drop test rig is required. This drop rig consists of two different impactor faces, a release system, drop mass guiding cables, two different mounting brackets, a displacement measuring system and a support table. The general assembly drawing is incorporated in Appendix 4. The drop rig is equivalent to the drop rig used for Eurosid-1 calibration, except for the ES2 rib support shown below.

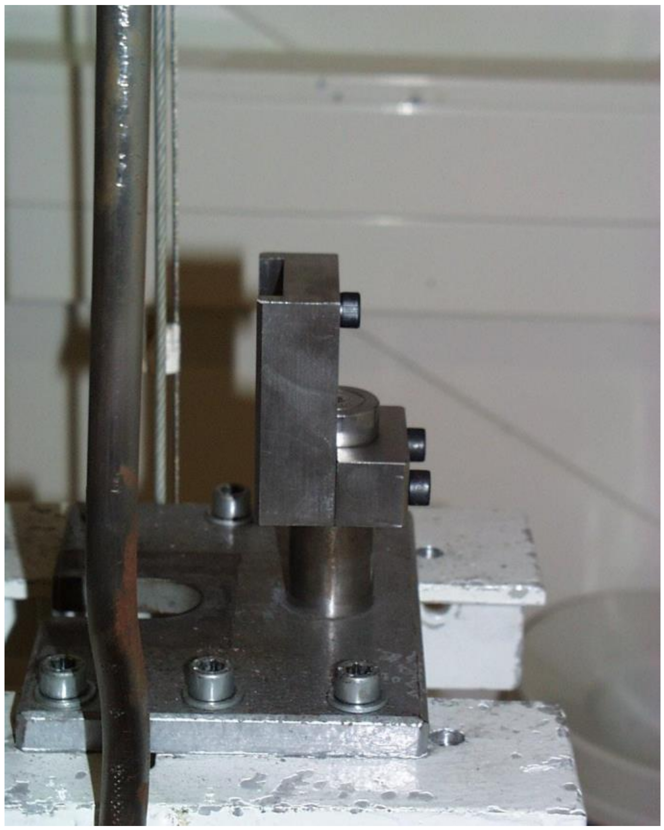


Figure 63: ES2 Rib support for Drop rig, H.AE

Tuning springs are necessary for tuning of the ribs. A set of tuning springs is included in the ES-2 toolbox.
Damper oil is required for servicing the dampers. Only use the damper oil provided in the toolbox.

5.3 Time interval between ES-2 certification tests

TEST ENVIRONMENT CONSIDERATIONS:
All testing done with ES-2 Crash Test Dummy should be performed in an enviroment at a temperature between 18.0 and 22.0 °C and a relative humidity of 10 to 70%.

When conducting certification tests or executing component testing a minimal time interval between two tests should be observed. The following table shows the required time intervals per test.

Table 6: ES-2 Time interval between testing

Component	Time interval
Head	30 min
Neck	30 min
Shoulder	30 min
Ribs	5 min/30 min*
Lumbar spine	30 min
Abdomen	30 min
Pelvis	30 min

* *Between rib tests in a test cycle (all impact velocities) the time interval is 5 minutes. Between two separate test cycles, the time interval is 30 minutes.*

5.4 Trigger levels and time shifts for ES-2 certifications

In some of the ES-2 certification procedures, a time requirement is specified. To apply the time requirement, it is necessary to define a 'time zero'. The following paragraphs indicate the required time shifts and 'time zero' definitions for the various ES-2 certification tests.

5.4.1 Neck and Lumbar spine pendulum tests

For the neck and lumbar spine pendulum tests, the following sequence is required to obtain the correct time shift for all signals:

- Pendulum acceleration should be processed using an ISO 6487 or SAE J211 Channel Filter Class 60;
- Determine the instant in time at which the pendulum acceleration response crosses the -10.0 g level (T_{10}) for the fist time;
- Calculate the time shift by T_{10}-T_m,

  (T_m = point in the middle of the pendulum acceleration corridor at the -10.0 g level);
- Shift all time responses by the above time shift.

Table 7: ES-2 Time shift, T_m, for neck and lumbar spine certification tests

Dummy Part	T_m (msec)
Neck	1.417
Spine	1.588

After filtering all individual data channels, the corrected time responses can be checked with respect to the required time corridors.

5.4.2 Full-body certifications

For all full-body certification tests (shoulder, abdomen and pelvis) of the ES-2 the following sequence should be followed to achieve the correct time shift and 'time zero' for all channels:

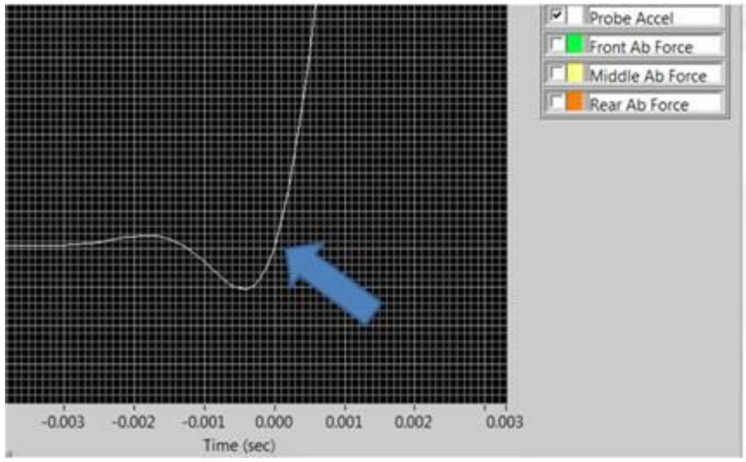
- Pendulum acceleration should be processed using an ISO 6487 or SAE J211 digital Channel Filter Class 180;
- Determine the instant in time at which the pendulum acceleration response crosses the 1.0 m/s^2 level for the first time (T_0), do this when the probe acceleration is positive. In case the probe acceleration is negative, the -1.0 m/s^2 must be used. Make sure that the T_0 that is searched for has the same polarity as the probe accelerometer (the arrow in the picture below is T_0).

- Calculate the time shift by T_0 - T_E,

  (T_E = time point of external trigger used in test);

- Shift all time responses by the above time shift.

The corrected data can be checked against the required time corridors.



5.5 Head

5.5.1 Introduction

The head should be visually inspected for damage to the skin or/and skull.

5.5.2 Test set-up

This test has to be conducted using the complete head assembly consisting of the head assembly and the upper neck load cell structural replacement. The head has to be instrumented with a tri-axial accelerometer located at its centre of gravity. Accelerations are to be filtered using ISO 6487 or SAE J211 Channel Filter Class 1000.

The head must be positioned with a 200 ± 0.25 mm spacing above a flat, rigid impact surface, as described in Part 572 subpart E (surface finish between 8 and 80 micro-inches). The impact surface must be horizontal and the head has to be oriented such that its mid-sagittal plane has an angle of 35° ± 1° with the impact surface and its anterior-posterior axis is horizontal ± 1° (see Figure 64)

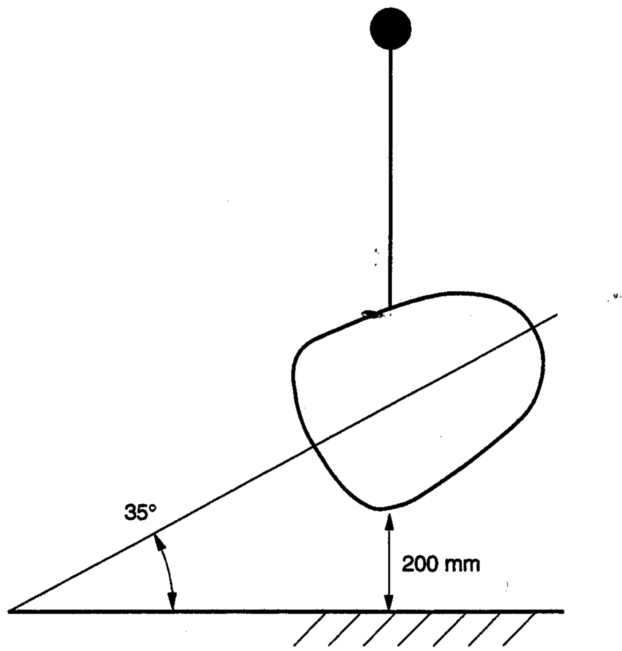


Figure 64: ES-2 head orientation definition in certification test

A 'quick release' mechanism is required to drop the head on the impact surface. The head drop support should be attached to the base of the upper neck load cell structural replacement with the mark “F” to the front of the head, see Figure65. For ease of assembly, it is advised to attach the head drop interface to the load cell replacement and then assemble both in the head and fasten the screws. Figure 66 shows the head drop for a left side impact. For a right side impact reverse the head drop support by unscrewing the plastic rod from the aluminium base and assemble the parts 180° turned.

5.5.3 Requirements

The head passes the test if the peak resultant head acceleration is between 100 g and 150 g. The head performance can be adjusted to meet the requirements by altering the friction characteristics of the skull-flesh interface (e.g. by lubricating the whole skull with PTFE spray or talcum powder). In case of failure of the test the skin should be replaced

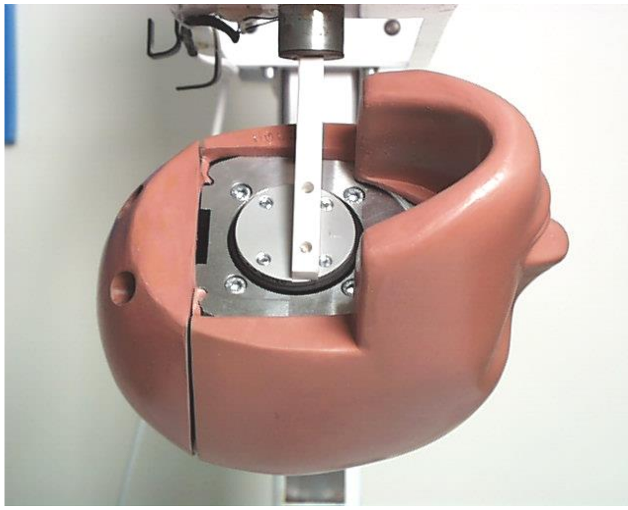


Figure 65: ES-2 head support bracket installed on the head (note the orientation)

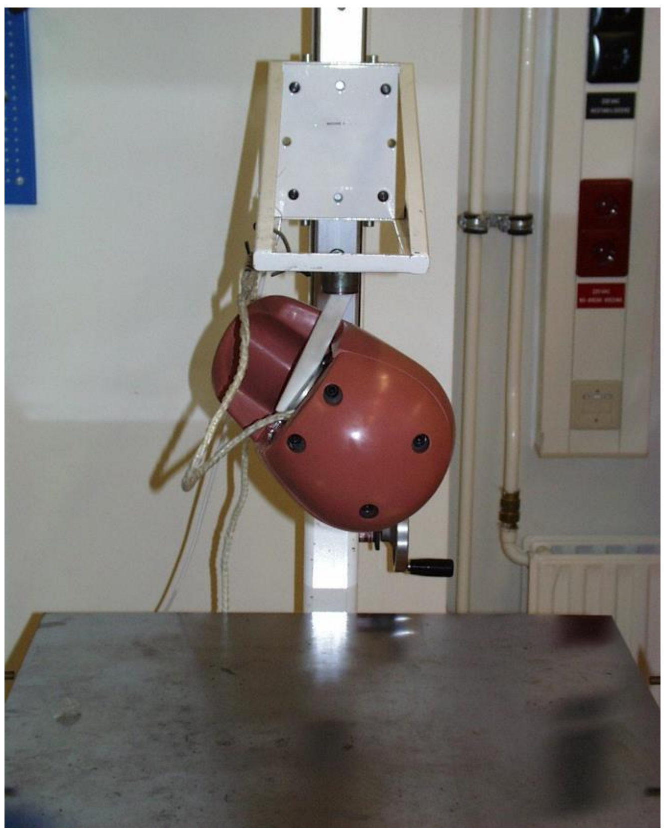


Figure 66: ES-2 head above a drop table

5.6 Neck

5.6.1 Introduction

The neck should be disassembled from the dummy (see Sections 4.4 and 4.5), be visually inspected. If the neck is permanently bent or twisted the circular section buffers and/or the central part must be exchanged (see Section 4.4). If the central rubber section is damaged (e.g. tears) it must be exchanged.

Grease the contact areas of the upper and lower half-spherical screws with appropriate grease (e.g. a high-pressure lubricant). The half-spherical screws are tightened using a torque of 10 Nm, applied using the special ES-2 neck, compression tool.

A dynamic calibration test using the Part 572 subpart E pendulum and the EUROSID-1 head form (see Appendix 3) should be performed as described in the following sections.

5.6.2 Test set-up

Attach the neck to the ES-2 head form interface plate with four M6x10 cap head screws.

Mount the head form is with its rotational potentiometers on the LHS (looking in the direction of impact).

CAUTION:

The length of the screws is different form the screws used in the dummy. Therefore, make sure that screws do not protrude into the neck rubber and the screw ends are flush with the face of the neck interface plate.

The head form interface can now be attached to the head form with four M6 cap heads. The base of the neck is attached to the pendulum interface with M6 screws. Again, make sure these screws do not protrude into the neck rubber since this will influence performance; adjust the length of the screws accordingly. A small amount of washers is supplied in the toolbox.

Attach the mounting base onto the pendulum, using four M6 screws.

Carefully slide the carbon fibre rods through the potentiometer housings on the pendulum. First, slide the pivot of the potentiometer closest to the pendulum over the central carbon fibre rod in the head form. Followed by a small spacer ring and finally the second pivot, which has to be carefully tightened with the two M4 set screws. Be careful do not damage the carbon fibre rod when tightening these screws. This is important to obtain correct results. See figure 67

The pendulum must be vertical when the impact speed is decelerated until zero m/s. To obtain this vertical position of the pendulum, the aluminium honeycomb (this is: 1.8 lbs./cu. ft.) should have a nominal height of 76.2 mm (= 3 inches). The pendulum has to be equipped with a uni-axial accelerometer. The sensitive axis of the accelerometer should be 1657.4 mm from the pendulum pivot in accordance with Standard Part 572 subpart E.

The neck should be kept in the test room for a period of at least four hours prior of a test at a temperature of 20 ± 2°C and humidity of 10 to 70 %. The period in which the pendulum is in pre-impact position (i.e. not the vertical position) should not exceed 5 minutes.

The head form rotations are measured with the three rotational potentiometers. Data-acquisition should be in accordance with ISO 6487 or SAE J211. The fore (A) and aft (B) pendulum base angles (see Figure) are directly measured during the certification test. The flexion angle of the head form must be determined using the following equation:

$$\beta = \Theta_A + \Theta_C - \pi/2$$

or

$$\beta = d\Theta_A + d\Theta_c$$

in which $d\Theta_A$ and $d\Theta_c$ are the deviations of the angles Θ_A and Θ_c (see Figure 67). After this calculation, all rotations are digitally filtered using ISO 6487 or SAE J211 CFC 180. The pendulum acceleration is also filtered digitally using ISO 6487 or SAE J211 CFC 60.

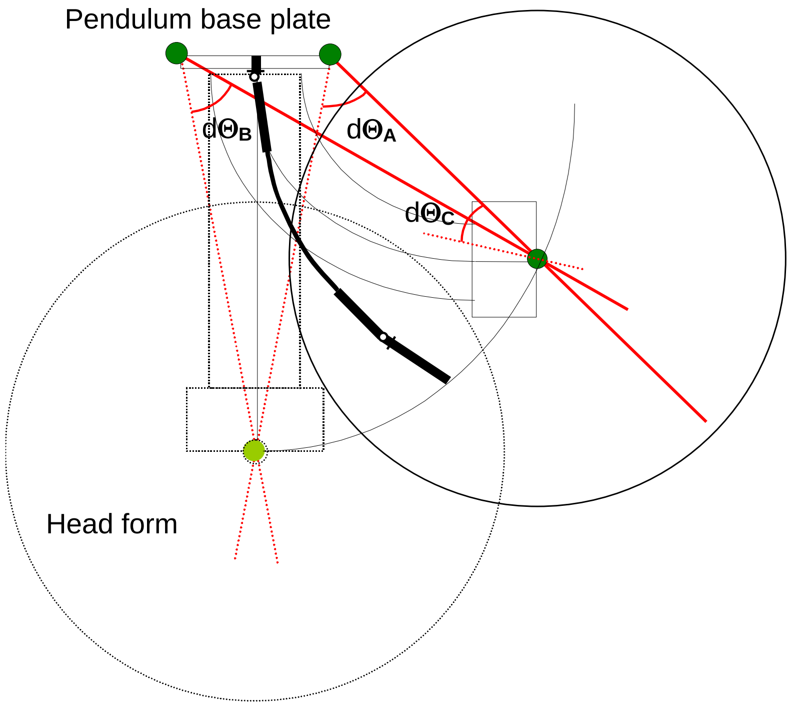


Figure 67: ES-2 neck certification: Angles measured with head form set-up

The pendulum is released and allowed to fall freely from a height chosen to achieve an impact velocity of 3.4 ± 0.1 m/s, measured at the centre of the accelerometer, 1657.4 mm from the pendulum axis. The velocity time-history of the pendulum should be inside the corridor specified in Figure 68.

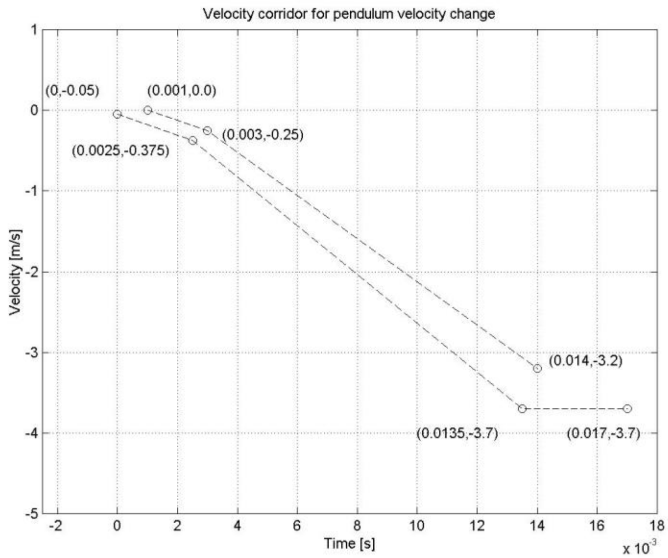


Figure 68: ES-2 neck certification pendulum velocity corridor

Table 8: ES-2 neck certification pendulum velocity corridor

Upper Boundary		**Lower Boundary**	
Time [s]	Velocity [m/s]	Time [s]	Velocity [m/s]
0.001	0.0	0	-0.05
0.003	-0.25	0.0025	-0.375
0.014	-3.2	0.0135	-3.7
		0.017	-3.7

5.6.3 Requirements

The neck passes this test if the following requirements are met:

- The maximum head flexion angle relative to the pendulum is 54.0 ± 5.0 degrees and should occur between 54 and 66msec.
- The maximum neck orientations at the fore (A) pendulum base angle is 34.5 ± 2.5 degrees. This maximum should occur between 53 and 63msec.
- The maximum neck orientations at the aft (B) pendulum base angle is 0.81*(A)+3.0 ± 1.25 degrees respectively. This maximum should occur between 54 and 64msec.

If the required values cannot be achieved, all eight circular section buffers can be replaced by buffers with a different hardness. Refer to Section 4.5 for assembly instructions of the buffers. A set of circular section buffers with a hardness of 60 (red), 70 (yellow) and 80 Shore A (blue) is supplied in the toolbox. If the given values cannot be achieved by using these buffers, the central part of the neck should be exchanged.

5.7 Arm

No dynamic certification procedure is defined for the arms. Testing of the arm flesh is part of the shoulder certification (see Section 5.8).
The mechanism of the joints and the construction of the arms should be visually inspected for damage.

5.8 Shoulder

5.8.1 Introduction

The construction of the shoulder (i.e. bearing, U-spring, elastic cords) and the condition of the arm flesh should be inspected for damage. The construction should be clean. The shoulder is checked statically as well as dynamically.

5.8.2 Static test

The elastic cord tension must be set prior to certification. The arm should be removed (see Section 4.8) and the M10x30 button head screw inserted in the shoulder cam. The force required to move the shoulder cam forward, when applied at 4 mm of the outer edge of the clavicle and applied in the same plane as the clavicle movement, should be between 27.5 N and 32.5 N. To set the elastic cord tension, the length of the elastic cord should be adjusted at elastic cord holder. Refer to Section 4.6 for instructions. After setting the elastic cord tension, check that the clavicles can travel the full range of motion and come to a stop on the cam stop blocks inside the shoulder box. If the shoulder range of motion is limited by the maximum extension of the elastic cord, the latter is worn and must be replaced. A dynamic test should then be performed as described in the following section.

5.8.3 Dynamic test set-up

The dummy (without suit and removed shoulder foam cap) is seated on a flat, horizontal, rigid surface without back support. Two sheets of 2 mm thick PTFE (Teflon) are placed between the dummy and the surface. The dummy legs should be horizontal, the distance between the ankles should be 100 ± 5 mm, and the thorax vertical, i.e. when the torso back plate is vertical ± 2 degrees (measured at torso back plate). The dummy should not be supported to maintain this position. The dummy should be positioned such that the anterior-posterior axis of the dummy is perpendicular to the direction of impact. The position of the centre line of the impactor and the centre pivot axis, i.e. the M10x25 pivot arm bolt of the upper arm, should be aligned ± 5 mm. The arms should be set at a position of 40 degrees forward with respect to the vertical, pointing downward. This is the middle pivot stop in the shoulder joint.

The impactor is the Standard Part 572 subpart E pendulum of 23.4 ± 0.02 0kg and 152.4 ± 0.25 mm diameter. The impactor must be suspended from rigid hinges by four wires, it is recommended that the centre line of the impactor at least 3.5 m below the rigid hinges, it is also recommended that the angle of the wires must not be more than 20 degrees (viewed along the axis of the impactor). The impactor should freely swing towards the shoulder of the dummy. The impact velocity of the impactor has to be 4.3m/s ± 0.1 m/s.

The impactor is equipped with an accelerometer sensitive in the direction of impact and located on the impactor axis. The acceleration signal should be filtered to ISO 6487 or SAE J211 Channel Filter Class180.

5.8.4 Shoulder requirements

The arm and shoulder pass the certification tests if the peak acceleration of the impactor is between 7.5 and 10.5 G. If the shoulder fails to meet the requirements the elastic chord adjustment must be checked. If the shoulder, in repeated tests, fails to meet these specifications, the arm should be replaced.

5.9 Thorax

5.9.1 Introduction

Two components of the rib unit determine the performance: the damper and the rib. If the rib unit fails the test, component inspection tests should be carried out. The certification tests of the ES-2 thorax as well as the component inspection tests can be performed on a drop test rig (see Appendix 4). The procedure for thorax certification is shown in Figure 69.

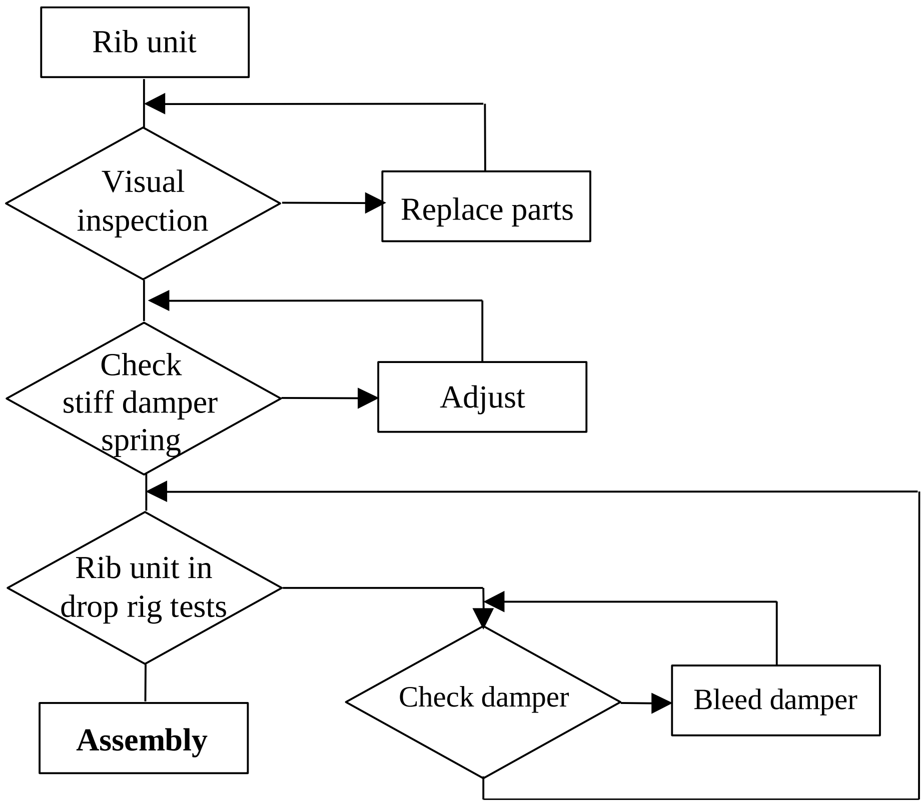


Figure 69: ES-2 thorax certification flow chart

Each full rib module is certified separately. A maximum displacement corridor for three impact velocities is specified for the rib module. First, the rib module must be visually checked.

Following the visual inspection, the adjustment of the stiff damper spring should be checked and if necessary adjusted (see Section 4.7). If the cup is screwed on too far, so that the damper is pre-compressed, the rib can fail although the individual components are in correct working order.

If the module fails to meet the certification corridor the damper must be removed and the presence's of air in the damper must be audibly checked, see Section 4.7.3. If there is air in the damper-oil, the damper should be bled, refitted in the rib and the full module should be tested again. If the rib module still fails to meet the requirements, some the damper performance must be checked (see Section 5.9.5).

5.9.2 Visual inspection rib unit

The full rib module should first be visually inspected for signs of damage, e.g. flesh damage, damaged piston, play in the linear bearing, non-symmetry in the rib, loss of oil from the damper. In addition, check that the rib easily expands back out to the bump stop without assistance. If the module appears satisfactory and the damper spring is correctly adjusted, so that no axial play exists (see Section 4.7) between rib and damper, the full rib module should be evaluated in the certification procedure described below. In the case of slightly damaged rib flesh, the rib bow may be turned so that the impacted side of the rib shows no sign of damage. If the rib flesh is severely damaged, the rib must be replaced. A repair service is available through your local Humanetics office.

5.9.3 Test set-up

The drop test rig with a falling weight is used for the complete rib module certification see figure 70. A free fall impactor with mass of 7.78 ± 0.01 kg free and with a flat face with 150.0 mm diameter is used for these tests. The rib unit is tested at three different impactor velocities. Displacement of the rib is measured with the rib unit's displacement transducer.

The rib module is mounted in the drop rig, impacted side up with the centre line of the mass, aligned with the centre line of the guide system piston. The ES-2 rib unit is mounted in the drop rig with a special bracket that makes use of the threads in the rib guidance bracket for rib to spine box attachment.

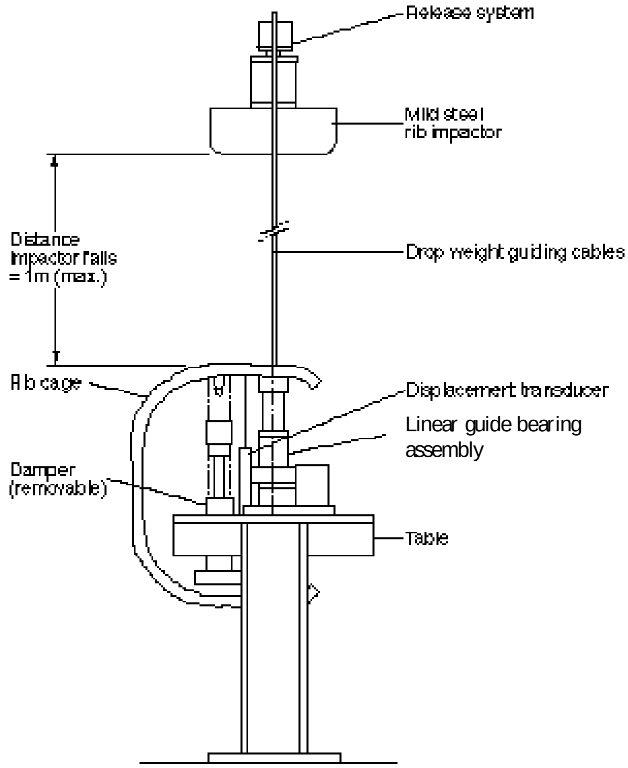


Figure 70: ES-2 rib unit certification test set up

5.9.4 Requirements for the full rib unit

The 7.78kg mass should fall freely onto the rib using impact velocities at approximately 2, 3 and 4 m/s. For each impact, the peak rib deflection should be recorded. The impact energies required are specified by the drop height of the impactor. Drop heights to be applied with an accuracy of ± 1% are measured between the impact point on the rib and the impactor face. The drop heights and the performance requirements are given in Table 9.

Table 9: ES-2 rib unit certification requirements

Test sequence	Drop height (accuracy 1%) (mm)	Minimum Displacement (mm)	Maximum Displacement (mm)
1	815	46.0	51.0
2	204	23.5	27.5
3	459	36.0	40.0

Testing of the rib module should be carried out using the following procedure. See also figure 69 for a flowchart of the rib module certification sequence:

- Attach the rib module to the drop test rig.
- Perform the drop test at the high impact velocity
- Use if necessary a stiffer or weaker tuning spring (for available tuning spring stiffness and the corresponding colors, see Table 5 on page 64)
- If the rib module fails to meet the requirements the following should be checked:
    1. The test can be repeated. To ensure that the first drop test was executed correctly.
    2. If the rib still fails to meet the requirements the rib unit should be removed from the test rig and the damper should be removed from the rib unit. The damper should be checked for the presence of air in the oil. If air is present the damper should be bled (Section 4.7.3) and the damper should be tested according Section 5.9.5. If the damper fails, to comply with the inspection test requirements after bleeding, the damper should be replaced.
    3. After reassemble of the damper, the rib unit should be tested again.
    4. If the module still fails, the rib bow itself should be checked carefully on its integrity. The rib bow must be replaced in case of permanent deformation. After replacement of any part, the module should be tested again.
- If the rib unit passes the high impact velocity test then complete the drop tests in the sequence as indicated (high – low – medium impact velocity).

5.9.5 Damper inspection test

The damper inspection tests can be performed to check functionality of the damper. The tests are only performed if the complete rib unit fails to comply with its certification requirement, see section 5.9.4.

The drop test rig can also be used for the damper inspection test, with the use of a different mounting plate. For the damper inspection test a specially shaped impactor with a mass of 1.0 ± 0.01 kg is used. The impact face of the impactor is recessed to accept the stiff damper spring and the centre of gravity of the impactor is below this face (see Appendix 4, item 20).

The damper is checked with the stiff damper spring incorporated. The pass/fail corridor is a damper piston displacement corridor (see Table 10). The damper is tested at different impact velocities. The impact velocities are between 3 and 10 m/s. For each impact, the peak damper deflection should be recorded. The displacement of the damper is measured at the piston rod by means of the rib transducer. The mass of the spring cup including

the moving parts of the displacement measuring system, mounted on the piston must be between 70 - 75 grams. The piston rod thread is not a standard M10 but a fine thread M10 x 1.25. Check that length of the damper return spring is set to 71 ± 1 mm for this test by screwing in or out the stiff damper spring cup.
The impact energies required are specified by the drop height of the impactor. Drop heights to be applied with an accuracy of ± 1% are measured between the impact point on the stiff damper spring and the impactor face. The drop heights and the performance requirements are given in Table 10.

The impactor should fall freely onto the end of the stiff damper spring. The axis of the mass should be aligned with the centre line of the spring. The mass should not fall sideways on impact. If it does or if the recorded displacement is not within the corridor, the test at that velocity should be repeated.

There is no time interval prescribed for the damper tests. The damper tests can be done directly after each other.

Table 10: ES-2 damper functional inspection requirements.

Test	Drop height (accuracy 1%) (mm)	Minimum Displacement (mm)	Maximum Displacement (mm)
1	459	11.70	14.50
2	815	14.75	18.45
3	1274	17.75	22.25
4	2153	21.75	27.25
5	3261	25.60	32.00
6	5096	29.60	37.00

Note: Dampers, delivered before January 2007, are tuned slightly softer. Their performance is in compliance with the functional requirements specified in the previous versions of this manual. Rib assemblies equipped with these dampers generally certify with application of the stiffest (blue 19.0 N/mm) tuning spring.

5.10 Abdomen

5.10.1 Introduction

The abdomen section should be disassembled for inspection (see Section 4.9). The construction should be visually inspected for damage, in particular the foam covering, the force transducers and the cables from the force transducers. The foam covering should be changed if significant tears are visible. If the cables of the force transducer are damaged, they should be repaired.

5.10.2 Test set-up

The tests are performed with the abdomen installed in the dummy (see Section 4.9). The dummy (without suit and shoulder foam cap) should be placed in an upright seated position on a flat, rigid, horizontal surface without back support. Two sheets of 2 mm thick PTFE (Teflon) are placed between the dummy and the surface. The dummy legs and arms should be horizontal, the distance between the ankles should be 100 ± 5 mm, and the thorax vertical ± 2 degrees (measured at torso back plate). The dummy should be positioned such that the anterior-posterior axis of the dummy is perpendicular to the direction of impact and the centre line of the impactor should be aligned with the centre of the middle force transducer ± 5mm.

The impactor is the Standard Part 572 subpart E pendulum of 23.36± 0.02 0kg and 152.4 ± 0.25 mm diameter. The pendulum is equipped with a horizontal 'armrest' impactor face of 1.0 ± 0.01kg. The 'rigid' armrest (70 mm high, 150 mm wide) should be allowed to penetrate at least 60 mm in the abdomen. The centre of the armrest is positioned on the longitudinal axis of the pendulum. The pendulum is suspended by eight long wires to allow a guided impact with the abdomen at velocity of 4.0 ± 0.1m/s.

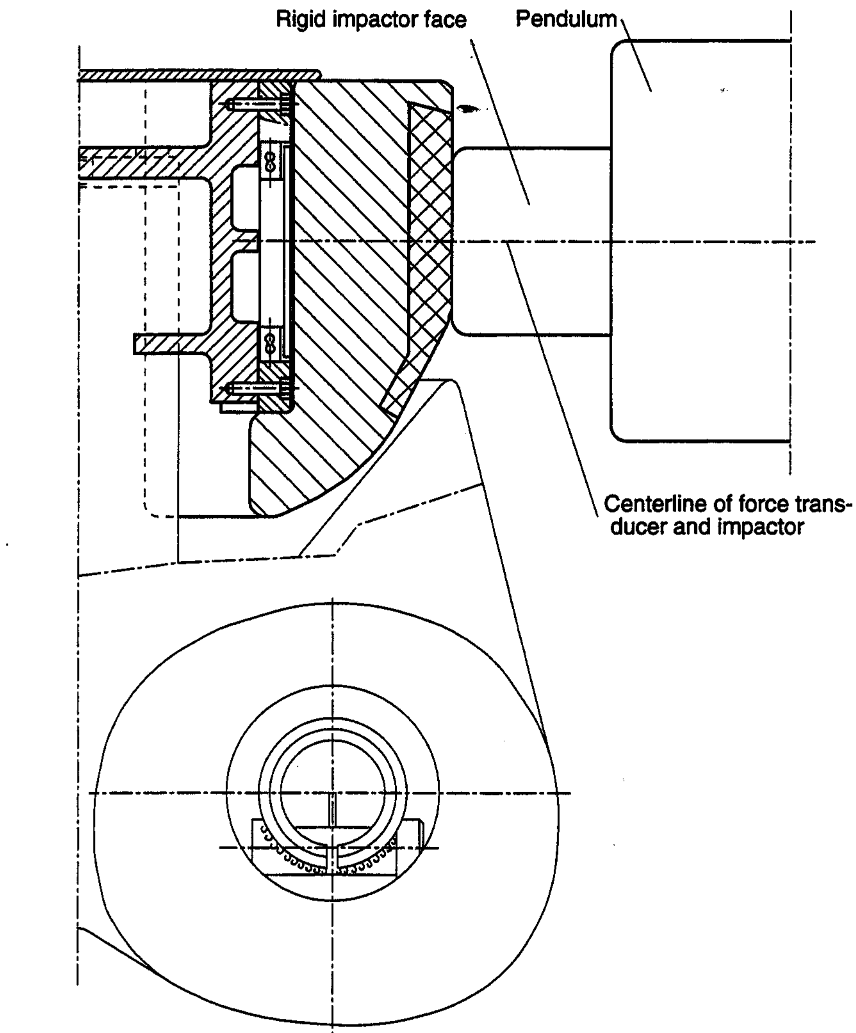


Figure 71: Abdomen test set-up

The pendulum should be equipped with an accelerometer located on the impactor axis and sensitive in the direction of impact. The accelerometer signals should be filtered to ISO 6487 or SAE J211 Channel Filter Class180 and the force transducer signals to ISO 6487 or SAE J211 Channel Filter Class 600.

5.10.3 Requirements

The force-time histories measured by the three abdominal force transducers must be summed and the peak force of this sum should be between 2.2 and 2.7 kN, and should occur between 10.0 and 12.3 msec. The maximum pendulum force (acceleration of the pendulum multiplied by the mass) should be between 4.0 and 4.8 kN, and occur between 10.6 and 13.0 msec.

If the abdomen, in repeated tests, fails to meet these specifications, the foam covering should be replaced.

5.11 Lumbar spine

5.11.1 Introduction

The lumbar spine should be removed from the dummy (see Section 4.10) and visually inspected. Prior to the first certification test, the nut should be tightened hand tight and further tightened with two complete turns of the nut (use a wrench, hold end with screw driver). Most lumbar spines are likely to fulfil the requirements when adjusted to this pretension. In further certification tests, the length of the spine should be close to that of the previous passed certification test. A dynamic calibration test using the Part 572 subpart E pendulum and the EUROSID-1 head form (see Appendix 3) should be performed as described in the following sections.

5.11.2 Test set-up

Attach the lumbar spine lower side to the ES-2 head form neck and spine interface (see figure 61) with four UNC ¼"-20x¾" cap head screws. Now attach the head form interface plate to the head form using four M6 screws. Ensure that the orientation of the lumbar spine is correct for the required impact direction. Attach the lumbar spine to the head form mounting base by four UNC ¼"-20x1" cap head screws. Attach the mounting base onto the pendulum, using four M6 screws.

Carefully slide the carbon fibre rods through the potentiometer housings on the pendulum. First, slide the pivot of the potentiometer closest to the pendulum over the central carbon fibre rod in the head form. Followed by a small spacer ring and finally the second pivot, which has to be carefully tightened with the two M4 set screws. Be careful do not damage the carbon fibre rod when tightening these screws.

CAUTION:
Make sure that potentiometer C that measures the angle of the head form, is connected to the rod of potentiometer A that measures the fore angle. This is important to obtain correct results. See Figure 72

The aluminium honeycomb (crush strength: 1.8 lbs./cu. ft.) should have a nominal length of 152.4 mm (= 6 inches). The pendulum is equipped with a uni-axial accelerometer. The sensitive axis of the accelerometer should be 1657.4 ± 0.25 mm from the pendulum axis in accordance with Standard Part 572 subpart E.

The lumbar spine should be kept in the test room for a period of at least four hours prior to a test at a temperature between 20 ± 2°C and humidity of 10 to 70 %. The period in which the pendulum is in pre-impact position (i.e. not the vertical position) should not exceed 5 minutes.

The head form rotations are measured with the three rotational potentiometers. Data-acquisition should be in accordance with ISO 6487 or SAE J211. The fore (A) and aft (B) pendulum base are directly measured during the certification test. The flexion angle of the head form must be determined using the following equation:

$$\beta = \Theta_A + \Theta_C - \pi/2$$

or

$$\beta = d\Theta_A + d\Theta_C$$

in which $d\Theta_A$ and $d\Theta_C$ are the deviations of the angles Θ_A and Θ_C (see Figure) After this calculation, all rotations are digitally filtered using ISO 6487 or SAE J211 CFC 180. The pendulum acceleration is filtered digitally using ISO 6487 or SAE J211 CFC 60.

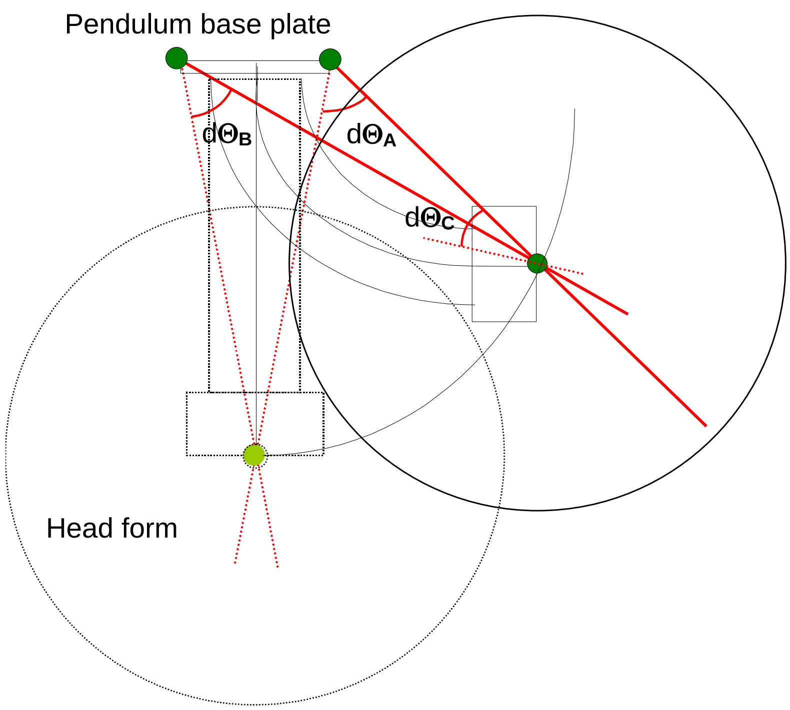


Figure72: ES-2 lumbar spin certification: Angles measured with head form set-up

The pendulum should be released and be allowed to fall freely from a height chosen to attain an impact velocity of 6.05 ± 0.1 m/s measured at the centre of the accelerometer, 1657.4 mm from the pendulum axis. The velocity time-history of the pendulum should be inside the corridor specified in figure 73.

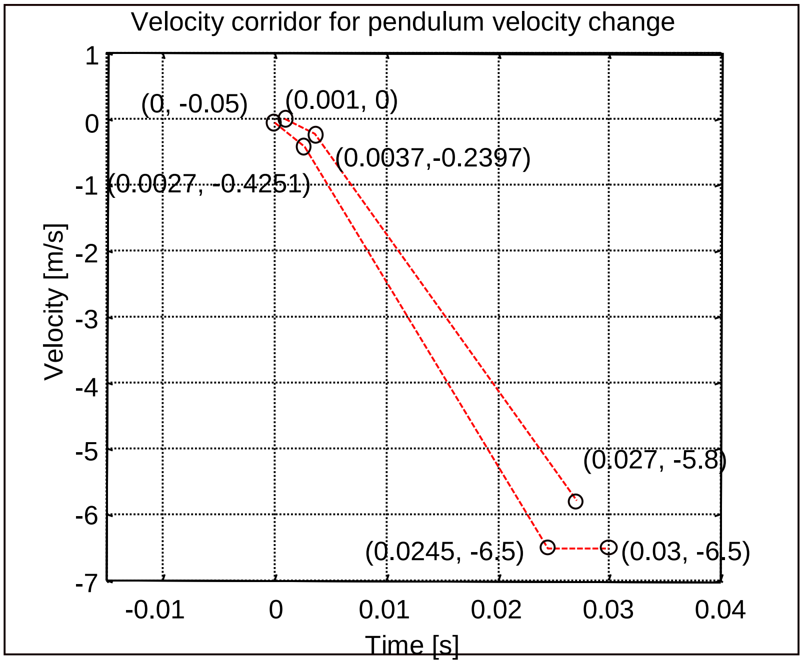


Figure 73: ES-2 lumbar spine certification pendulum velocity corridor

Table 11: ES-2 lumbar spine certification pendulum velocity corridor

Upper Boundary		Lower Boundary	
Time [s]	Velocity [m/s]	Time [s]	Velocity [m/s]
0.001	0.0	0	-0.05
0.0037	-0.2397	0.0027	-0.425
0.027	-5.8	0.0245	-6.5
		0.03	-6.5

5.11.3 Requirements

For the lumbar spine certification the following requirements are defined:

- The maximum head flexion angle relative to the pendulum should be 50.0 ± 5.0 degrees and should occur between 39 and 53 ms;
- The maximum spine orientations at the fore (A) pendulum base angle should be 33.0 ± 2.0 degrees. This maximum should occur between 44.0 and 52.0 ms.
- The maximum spine orientations at the aft (B) pendulum base angle should be 0.8*(A)+3.25 ± 1.25 degrees. This maximum should occur between 44.0 and 52.0 ms.

If the required values cannot be attained, the length of the lumbar spine should be changed. If the flexion angle and/or base angles are less than required increase the length of the lumbar spine by un-tightening the nut on top of the lumbar spine; if the values are more than required, decrease the length.

5.12 Pelvis

5.12.1 Introduction

The pelvis should be disassembled for inspection (see Section 4.11). Inspect the construction visually for damage. Damaged parts should be replaced. However, minor tears in the foam parts are acceptable, because these tears do not affect the pelvis performance.

5.12.2 Test set-up

The dynamic certification is performed with the whole dummy. The pubic symphysis load cell is placed in position. The dummy (without suit and shoulder foam cap) should be placed in an upright seated position on a flat, rigid, horizontal surface without back support. Two sheets of 2 mm thick PTFE (Teflon) are placed between the dummy and the surface. The dummy should have a free side motion on the sheets of about 500 mm. The dummy legs and arms should be horizontal, the distance between the ankles should be 100 ± 5 mm, and the thorax vertical ± 2 degrees. The dummy should be positioned such that the anterior-posterior axis of the dummy is perpendicular to the direction of impact and the axis of the impactor should be aligned with the centre of the H-point foam block ± 5 mm. This location is identical to the H-point back plate centre. The impactor is the Standard Part 572 subpart E pendulum of 23.4 ± 0.02kg and 152.4 ± 0.25 mm diameter. The pendulum is suspended by eight long wires to allow a guided impact with the pelvis at velocity of 4.3 m/s ± 0.1 m/s.

The pendulum should be equipped with an accelerometer sensitive in the direction of impact located on the impactor centre line. The acceleration signals of the pendulum should be filtered to ISO 6487 or SAE J211 Channel Filter Class 180. The pubic symphysis load-signal should be filtered to ISO 6487 or SAE J211 Channel Filter Class 600.

CAUTION:

As the dummy is hit at the pelvis in this test, it may fall towards the pendulum and its suspension cable, during the impact. A proper catch of the dummy immediately after the impact may be necessary.

This to prevent the occurrence of damage due to interference of the dummy with the pendulum suspension cables.

5.12.3 Requirements

The impactor force (acceleration of the pendulum multiplied by the mass of the pendulum) is required to be 4.9 ± 0.5kN and occur between 10.3 and 15.5 msec. The pubic symphysis load cell should indicate a load of 1.34 ± 0.30 kN and occur between 9.9 and 15.9 msec.

The parts of the pelvis should be checked again if these requirements are not met. The H-point foam blocks, iliac wings or pelvic foam should be renewed if repeated tests do not attain the required results.

5.13 Legs

No dynamical certification procedure is defined for the legs. The mechanism of the joints and the construction of the legs and feet should be visually inspected for damage.

6 Handling Procedures

6.1 Introduction

A few special handling procedures for the ES-2 will be presented in this chapter.

6.2 How to lift the dummy

The complete dummy should only be lifted by the eye bolt in the neck bracket (see Figure 74). The ES-2 dummy **cannot be lifted by the head**, because there is no cable incorporated in the neck. Further, to avoid tearing of the pelvis flesh of the leg skeleton, the legs should be well supported when the dummy is lifted.

Figure 74: ES-2 lifting device - eyebolt in the neck bracket

6.3 Neoprene suit

The rubber suit protects the 'open' thorax design and instrumentation against penetration of small particles (e.g. broken glass from vehicle window during impact), dust, etc. If the dummy is used without rubber suit, e.g. in a certification test, contact of the rib flesh with sharp objects should be avoided.

6.4 Storage of ES-2

When storing the ES-2 dummy between tests, or between a test and certification or vice versa it is advisable to support the dummy's rigid parts. The eye bolt at the neck bracket (see section 6.2) is suitable to support the dummy during storage. When doing so, do not forget to support the head in such a way that the neck is not under tension.

CAUTION:

Avoid supporting the dummy on its soft parts, i.e. ribs and pelvis.

To avoid accelerated ageing of dummy materials the dummy should be kept out of direct sunlight when storing. Storage temperature should be between 10 and 30 degrees Celsius. Further, it is advisable to make sure that the humidity of the storage environment does not exceed 70 %. To reduce the risk of corrosion, avoid direct contact between water and dummy parts.

7 Appendix 1: Setting-up Procedures

A1.1 Introduction

In this Appendix, a proposed set-up procedure for ES-2 in a vehicle is presented. The procedure described is an updated version of the procedure proposed for EUORSID-1 by the EEVC and conforms to the ECE Side Impact Test Procedure. Other procedures, however, are also possible. The position of the vehicle seats is not given, but left to the specific standard to which a test is carried out.

NOTE:

It should be noted that the hip joint of the ES-2 is located 21 mm more forward and 5 mm above the H-point of the H-point manikin (described in SAE J826). The H-point manikin is indicated with a M3 threaded holes in the H-point back plates of the dummy at each side. At these holes the indication "Hm" is applied. The "Hm" location is 21 mm aft of the hip joint. The vertical shift of 5 mm is not applied as it is assumed compensated by the pelvis foam compression.

A1.2 Dummy installation

1. Adjust the leg joints at knee and ankle so that they just support the leg when it is extended horizontally (1 to 2 g - adjustment).

2. Check if the dummy is adapted to the desired impact direction.

3. Clothe the dummy in form-fitting cotton stretch underwear with short sleeves and mid-calf length pants. Each foot is fitted with a shoe.

Recommendation:

The following clothes are recommended:

Shirt (if desired): Short Sleeve 78051-292; or E.IE, EuroSID T-shirt
Pant (if desired): Above Knee 78051-293 ; or E.IF, EuroSID mid calf-pant
Shoes (recommended): Men's Dress Oxford 11XW, MIL-S-13192P

4. Place the dummy in the outboard seat of the impacted side as described in the side impact test procedure specification.

5. The plane of symmetry of the dummy shall coincide with the vertical median plane of the specified seating position.

6. The pelvis of the dummy should be positioned such that a lateral line passing through the dummy H-point is perpendicular to the longitudinal centre plane of the seat. The line through the H-points should be horizontal with a maximum inclination of ± 2 degrees.

7. The correct position of the dummy pelvis can be checked relative to the H-point of the H-point Manikin by using the M3 holes in the H-point back plates at each side of the ES-2 pelvis. The M3 holes are indicated with "Hm". For the tolerance on the "Hm" position a circle with a radius of 10 mm is proposed.

8. The upper torso should be bent forward and then laid back firmly against the seat back. The shoulders of the dummy should be set fully rearward.

9. Irrespective of the seating position of the dummy, the angle between the upper arm and the torso arm reference line on each side should be 40 ± 5 degrees. The torso arm reference line is defined as the intersection of the plane tangential to the front surface of the ribs and the longitudinal vertical plane of the dummy containing the arm.

10. For the driver's seating position, without inducing pelvis or torso movement, place the right foot of the dummy on the not-depressed accelerator pedal with the heel resting as far forward as possible on the floor-pan. Set the left foot perpendicular to the lower leg with the heel resting on the floor-pan in the same lateral line as the right heel. Set the knees of the dummy such that there outside surfaces are 150 ± 10 mm from the plane of symmetry of the dummy. If possible within these constraints, place the thighs of the dummy in contact with the seat cushion.

11. For other seating positions, without inducing pelvis or torso movement, place the heels of the dummy as far forward as possible on the floor-pan without compressing the seat cushion more than the compression due to the weight of the leg. Set the knees of the dummy such that their outside surfaces are 150 ± 10 mm from the plane of symmetry of the dummy.

NOTE:

The ES-2 dummy is equipped with provisions to accept tilt sensors in the thorax and the pelvis. These sensors can be used to read the roll and pitch angle of the thorax and pelvis during positioning of the ES-2 dummy prior to a test. The use of these sensors can be helpful to obtain a reproducible dummy position in the car.

8 Appendix 2: Performance criteria limits for ES-2

A2.1 Introduction

The ES-2, as well as its predecessor EUROSID-1 is designed to assess potential injury risk to the head, thorax, abdomen and pelvis in a side impact test. The dummy is provided with instrumentation to record protection criteria corresponding to injury criteria for living human bodies (e.g. accelerations, deflection and force). The protection criteria as well as the levels for a standard crash configuration, called performance criteria limits, will be presented in this chapter.
These criteria are recommended by the EEVC for EUROSID-1 when used in the ECE Side Impact Test Procedure and it is anticipated that they will be maintained for ES-2.

A2.2 Head

The head protection criterion should be calculated for the total duration of head contact from the resultant head acceleration measured at the centre of gravity of the head, filtered at ISO 6487 Channel Filter Class 1000. The protection criterion should be compared with HPC (Head Performance Criterion) for the ES-2. The HPC is based on the HIC (Head Injury Criterion) used in frontal collisions. The same equation is used to calculate the HPC:

$$HIC = max\left[\frac{1}{t_2 - t_1}\int_{t1}^{t2} R(t)dt\right]^{2.5}(t_2 - t_1)$$

The HIC must be calculated in the domain between T_0 and T_{end} and t_1 is smaller than t_2.

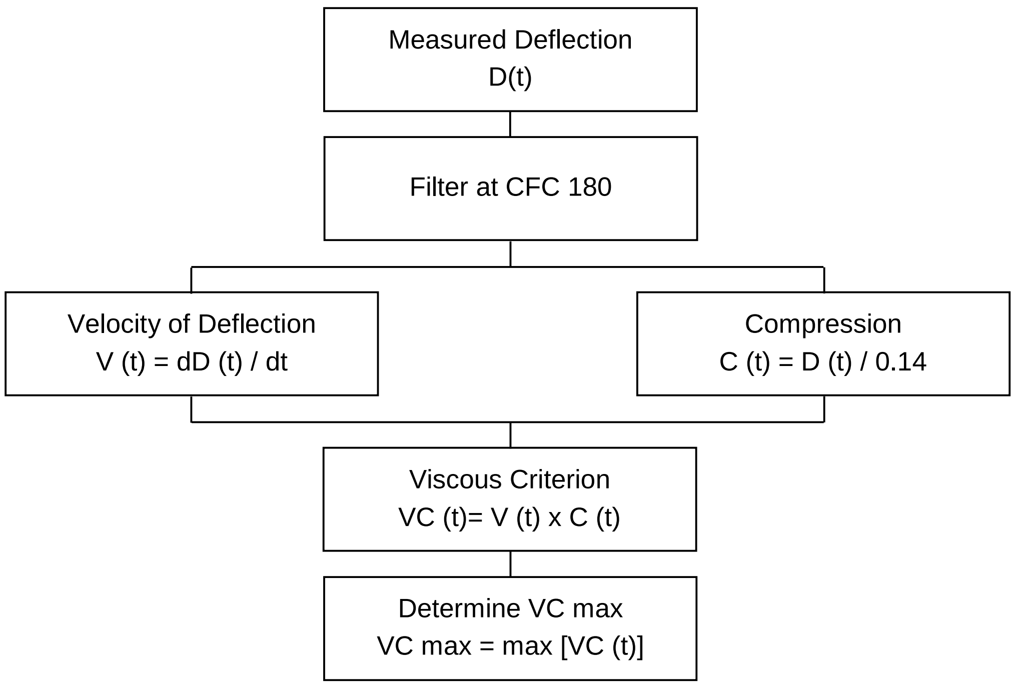
The performance criterion limit for the HPC is 1000.

Other parameters might be of interest, primarily for research purposes or for comparison of dummies and biomechanical reference data or between dummies. These parameters, which could be recorded without any criteria attached to them, are: peak head resultant acceleration and the level of resultant head acceleration lasting 3ms continuously.

A2.3 Thorax

The EUROSID-1 thorax is designed to measure rib deflections. The performance criterion limit is 42 mm for any of the three ribs, measured on the EUROSID-1 transducers and filtered at ISO 6487 Channel Filter Class 180. Furthermore, the viscous response should be calculated from the deflection responses [ref. 7]. The peak V*C response should be calculated using the following algorithm:

$$V(n) = [8 \times (D(n+1) - D(n-1)) - (D(n+2) - D(n-2))]/12dt$$



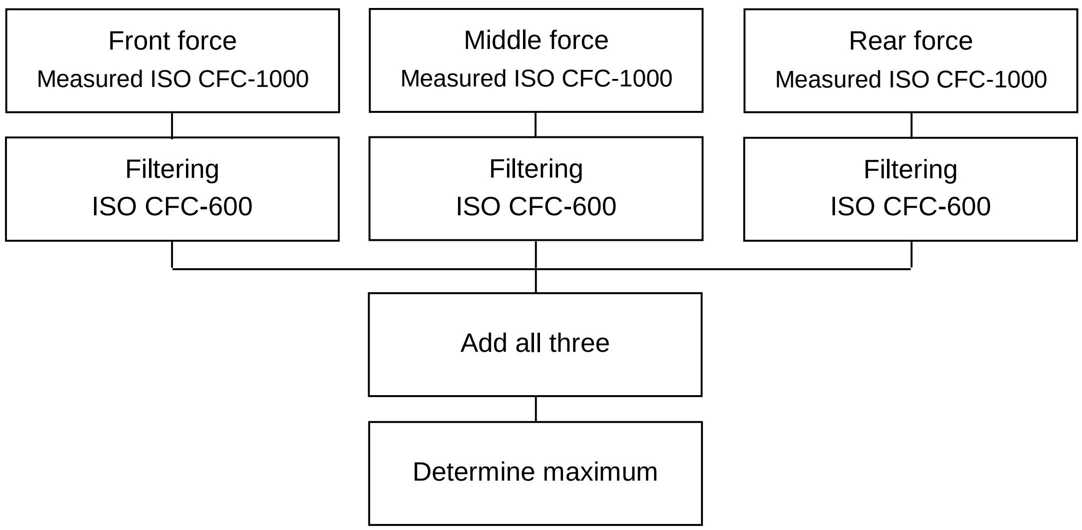
The performance criterion limit for the maximum V*C is 1.0 m/s for any of the three ribs.

For comparison purposes it is recommended to measure the lateral rib accelerations and lateral spine accelerations as well (see Section 3.6.2). Furthermore, the TTI criterion could be calculated from the rib and lower spine accelerations. A special 100-FIR filter should be used for the accelerations [ref. 8].

A2.4 Abdomen

The ES-2 abdomen is designed to detect exceedance of a force limit.

The performance criterion limit is a peak internal force of 2500 N measured as the sum of the instantaneous forces on the three abdomen force transducers, filtered at ISO 6487 Channel Filter Class 600.



A2.5 Pelvis

The ES-2 pelvis is designed to measure forces acting on the skeleton.

The performance criterion limit proposed by the EEVC is 6000 N for the peak pubic symphysis force, measured on the pubic symphysis force transducer and filtered at ISO 6487 Channel Filter Class 600.

For comparison purposes it is recommended to measure the peak lateral pelvis acceleration as well.

References

1. Hubbard, R.P. and D.G. McLeod: "Definition and Development of a Crash Dummy Head". SAE p 741193, Proceedings 18th Stapp Car Crash Conference, 1974.

2. USA Federal Regulations, Part 572 Anthropomorphic Test dummies, Subpart E 50th Percentile Male, issued August 1, 1973; Consolidation as CFR 49 dated October 1, 1991; Amended by Vol 56. No. 220 November 14, 1991 and Vol 57. No. 199 October 14, 1992.

3. USA Federal Regulations, Part 572 Anthropomorphic Test dummies, Subpart B 50th Percentile Male, Drawings SA 150 MO80 and MO81, issued August 1, 1973; Consolidation as CFR 49 dated October 1, 1991; Amended by Vol 56. No. 220 November 14, 1991 and Vol 57. No. 199 October 14, 1992.

4. USA Federal Regulations, Part 572 Anthropomorphic Test dummies, Subpart B 50th Percentile Male, Figure 2, issued August 1, 1973; Consolidation as CFR 49 dated October 1, 1991; Amended by Vol 56. No. 220 November 14, 1991 and Vol 57. No. 199 October 14, 1992.

5. USA Federal Regulations, Part 572 Anthropomorphic Test dummies, Subpart E 50th Percentile Male, Figure 22, issued August 1, 1973; Consolidation as CFR 49 dated October 1, 1991; Amended by Vol 56. No. 220 November 14, 1991 and Vol 57. No. 199 October 14, 1992.

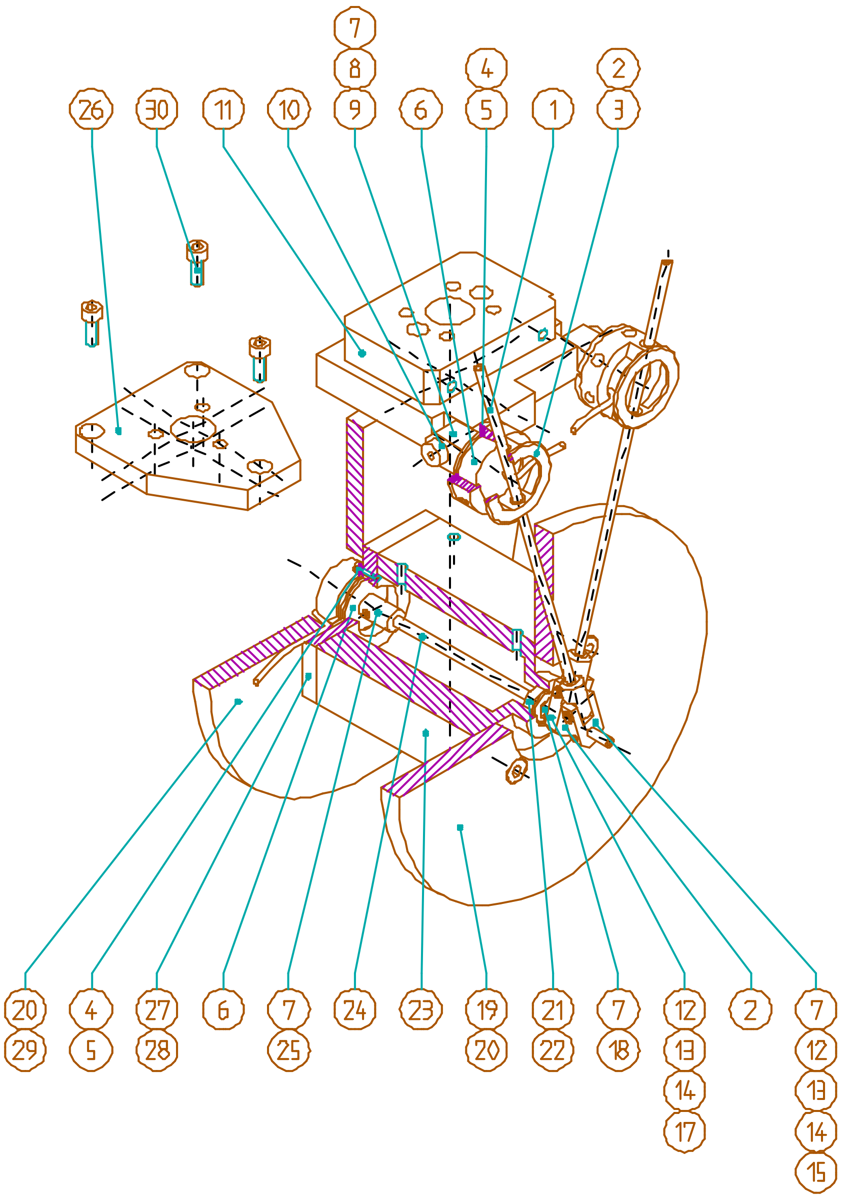
6. USA Federal Regulations, Part 572 Anthropomorphic Test dummies, Subpart B 50th Percentile Male, Paragraph 11, issued August 1, 1973; Consolidation as CFR 49 dated October 1, 1991; Amended by Vol 56. No. 220 November 14, 1991 and Vol 57. No. 199 October 14, 1992.

7. Lau, I.V. and D.C. Viano: "The Viscous Criterion – Bases and applications of an injury severity index for soft tissues". Proceedings 30th Stapp Car Crash Conference, October 1986, P–189, SAE p 861882.

8. Eppinger, R.H., J.H. Marcus and R.H. Morgan: "Development of Dummy and Injury Index for NHTSA's Thoracic Side Impact Protection Programme". SAE p 840885, 1984.

9 Appendix 3: Assembly drawings of the ES-2 Neck and Lumbar Spine Certification Equipment

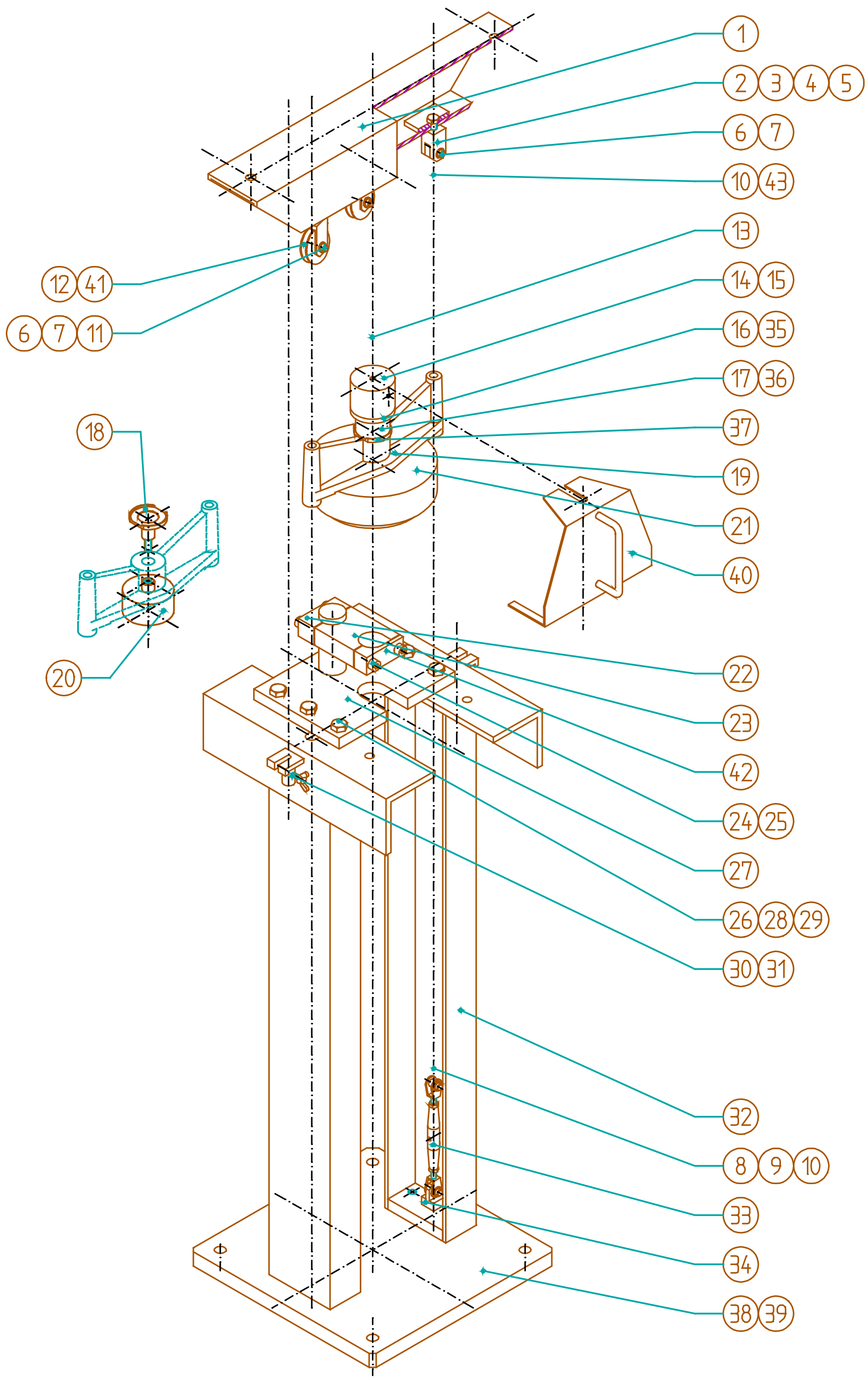
Exploded View Eurosid-1 Headform



PARTS LIST OF THE COMPLETE HEADFORM ASSEMBLY

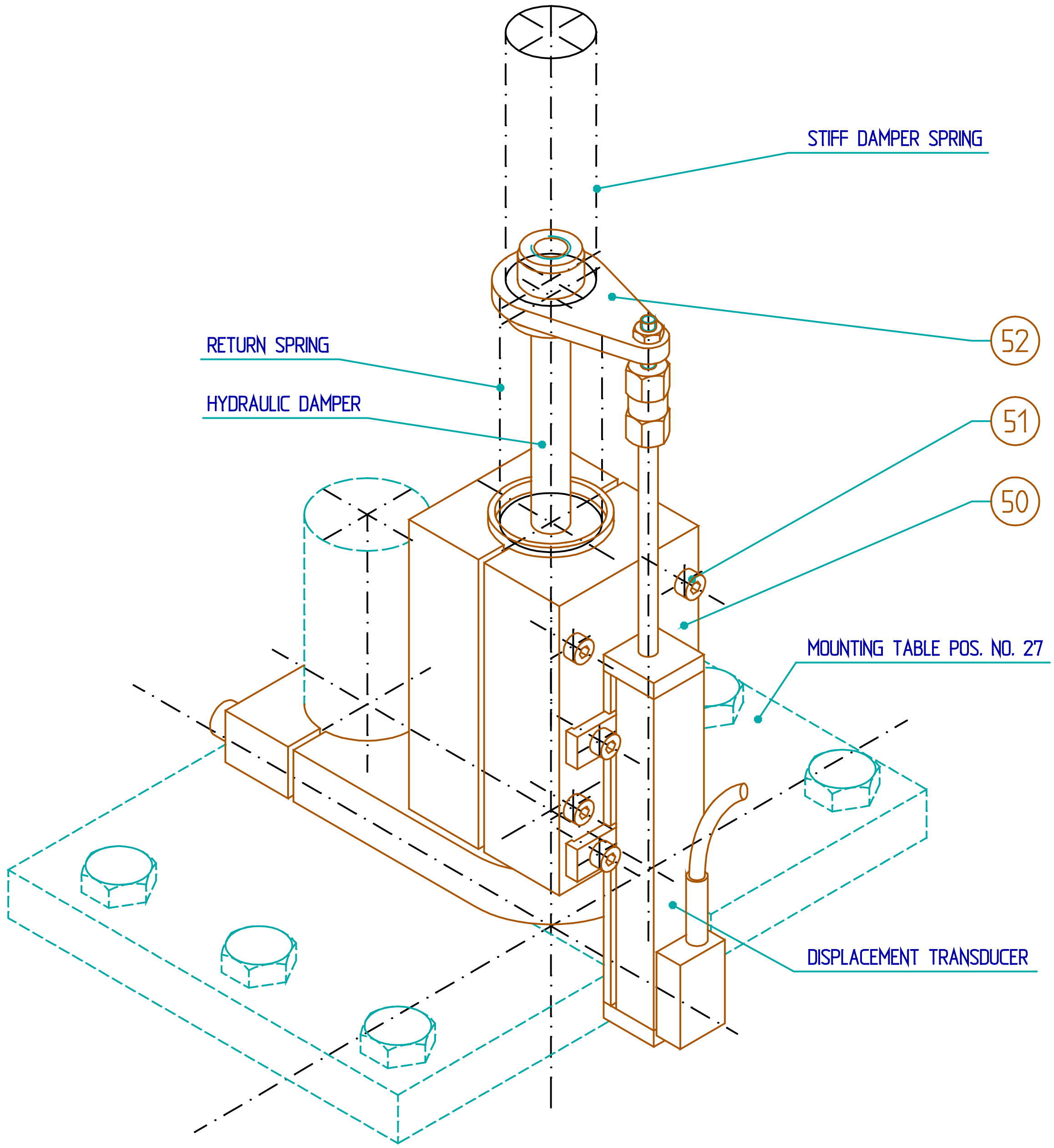
Pos.	Qty.	Description	
1	2	Shaft	
2	5	Bearing	
3	2	House	.
4	3	Clamp (set of 2)	.
5	18	Screw	M3 x 10
6	3	Potentiometer	
7	8	Screw	M4 x 5
8	2	Bearing	
9	2	Coupling	
10	2	Screw	$M6.8^{h8}$ x 16
11	1	Mounting base	
12	2	Pin	
13	4	Seeger. Ring	4 x 0.6 - ST
14	2	Coupling	
15	1	Pivot	
16	1	Spacer	
17	1	Pivot	
18	1	Lock spacer	
19	4	Screw	M8 x 20
20	2	Disc	
21	1	Seeger. ring	19 x 1 - ST
22	1	Ball bearing	
23	1	Central part	
24	1	Shaft	Carbon fibre
25	1	Coupling	
26	1	Mounting base (for lumbar spine attachment)	
27	1	Cover	
28	4	Dowel	ø3 x 20
29	4	Screw	M8 x 20
30	3	Screw	M8 x 16

10 Appendix 4: Drawings of the ES-2 Thorax Certification Equipment



PARTS LIST OF THE DROP RIG

Pos.	Qty.	Description	Material/Specifications
1	1	Mounting bar	
2	2	Bolt	M8 x 25
3	2	Washer	
4	2	Support plate	
5	2	Fork	
6	4	Shaft	
7	8	Retaining ring	
8	2	Cable eye	
9	6	Cable clamp	3 millimetres
10	2	Guide cable	
11	4	Washer	
12	2	Pulley wheel	
13	1	Magnet cable	
14	1	Grab screw	M5 x 10
15	1	Coupling	
16	1	Mounting plate	
17	1	Electro magnet	12V DC
18	1	Magnet holder, recessed	
19	1	Yoke	
20	1	Drop weight, (1.00 kilogram including Pos. 18 and19)	
21	1	Drop weight, (7.78 kilogram including Pos. 18 and19)	
22	2	Pole clamp	
23	1	Central clamp	
24	4	Bolt	M8 x 40
25	4	Washer	
26	6	Bolt	M10 x 40
27	1	Mounting table	
28	6	Washer	10.5
29	6	Nut	M10
30	2	Cable clamp	
31	2	Wing screw	M5 x 16
32	2	Leg	
33	2	Turnbuckles	Screw-thread M5
34	2	Fork	
35	4	Screw	M3 x 10
36	3	Screw	M4 x 10
37	1	Magnet holder, flat surface	
38	4	Screw	M10 x 35
39	1	Ground plate	
40	1	Support bracket	
41	4	Ball bearing	
42	1	Cylinder clamp	
43	2	Eye terminal	



OPTIONAL PARTS ASSEMBLY DRAWING.

Optional parts.

50	1	Clamp	
51	4	Screw	M4 x 35 - 8.8
52	1	Bracket	

11 Appendix 5: Tilt Sensor Installation

Two tilt sensors are installed in ES-2/ES-2re dummy. One is installed under the shoulder assembly to measure the thorax angles, and the second one is installed inside the sacrum block to measure the pelvis angles. MSC 260D/GP-M is a dual-axis tilt sensor, which has axis 1 and 2 corresponding to the dummy x-axis and y-axis, depending on how it is mounted inside the dummy. Some programming is needed to link the tilt sensor axis to the dummy axis (see tilt sensor user's instruction for details).

Thorax Tilt Sensor Installation

Tilt sensor in thorax is installed on the non-impact side of the dummy under the shoulder assembly as shown in Figure 1. The following parts are needed for the installation:

1. Mounting Bracket, 175-0013, Qty. 1
2. Screw, FHCS M4 x 10, 5000023, Qty.2
3. Screw, SHCS M4 x 8, 5000024, Qty.1
4. MSC 2-Axis Tilt Sensor, 6001805, Qty. 1

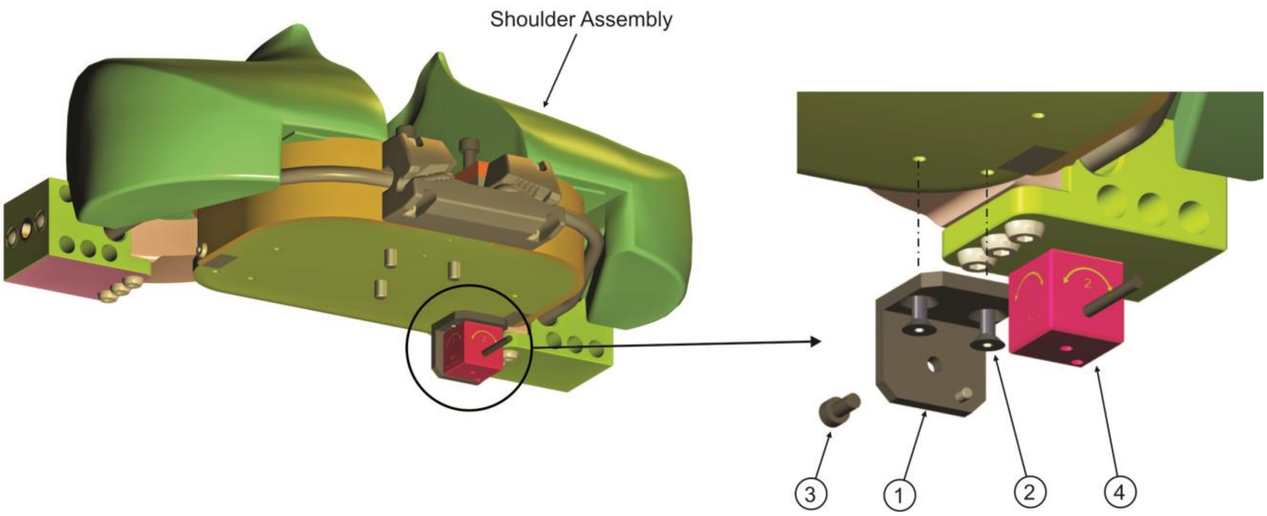


Figure 1: Thorax tilt sensor installation orientation

Tilt sensor axis 1 measures angle along dummy y-axis, axis 2 measure angle along dummy x-axis.

Pelvis Tilt Sensor Installation

The Tilt Sensor in the pelvis is installed inside the cavity of the sacrum. The following parts are needed for the installation:

1. Mounting Bracket, 175-0012, Qty. 1
2. Screw, SHCS, M3 x 8, 5000388, Qty. 2
3. Screw, FHCS M4 x 10, 5000023, Qty.1
4. MSC 2-Axis Tilt Sensor, 6001805, Qty. 1

First install the tilt sensor to the mount plate, PN 175-0012, as shown in Figure 2, using the FHCS (5000023).

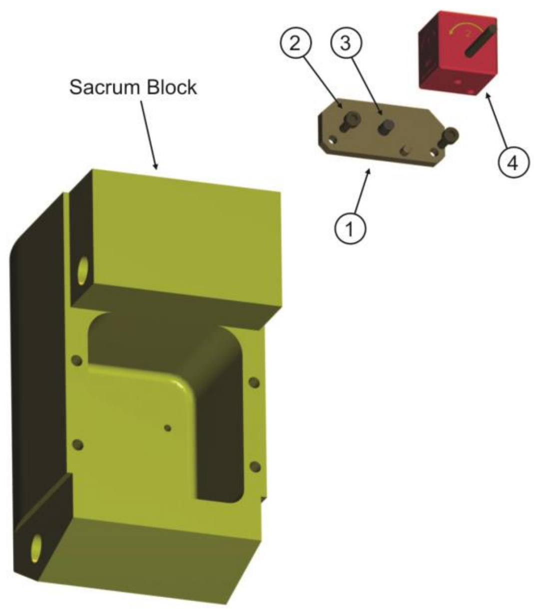


Figure 2: Pelvis tilt sensor and mounting bracket assembly

Secondly, use two SHCS, (5000388), to mount the assembly to the sacrum block as shown in Figure 3.

The pelvis tilt sensor axis 1 measures the angle along the dummy y axis, and tilt sensor axis 2 measures the angle along the dummy x axis.

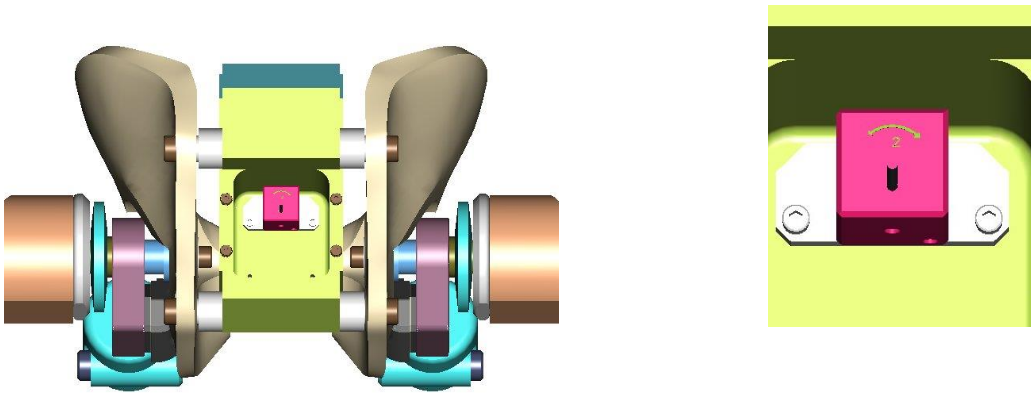


Figure 3: Pelvis tilt sensor installation

Manual Update Log

Rev. D, Feb. 2010

Page 65:

Added part numbers to Items 2-4 in lumbar parts list. Manual part number E2-9900 was 175-9900.

Rev. E, Feb. 2011

Added Appendix 5.

Rev. F, Mar. 2014

Upated paragraph on Pg. 86, stating; Recommanded not Required in impactor set up.

Rev. G, Dec. 2014

Page 91:

23.36 was 23.4 under 5.10.2 Test set-up

Rev. H, Jul 2015

Page 2:

Added lead material statement

Rev. I, May 2016

Page 25:

Updated Table 1, Toolbox list of Content; Removed Figure 15, ES-2 toolbox contents

Page 65:

Figure 44, added mising item 3 balloon

Updated part numbers, Humanetics IF-xxx was FTSS IF-xxx load cell